STATUS OF COMPASS UPGRADE CONSTRUCTION

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Abstract. COMPASS Upgrade (COMPASS-U) is a new medium-sized tokamak currently under construction at the Institute of Plasma Physics in Prague [1]. COMPASS-U is designed to address some of the challenges of next-step fusion devices. It features a unique hot metallic first wall (500 °C) and cryogenically cooled copper coils. This configuration enables a high magnetic field (Bt = 5 T) and plasma current (Ip = 2 MA), creating an ideal testbed for power exhaust, advanced confinement modes, and liquid metal divertor research. The project has entered a critical production phase. The site is ready, and the new power supply system is being commissioned. Production of the cryostat began in 2026 in Spain and installation of its base is expected in early 2027. This will be followed by the support structure (completed in 2026 in Italy) and the vacuum vessel (scheduled for completion in early 2027 in Italy). The PF coils production is underway in Slovakia, while the central solenoid and TF coils fabrication will follow. The production and installation of tungsten and Inconel 718 plasma facing components (PFC) are planned for 2026–2028. The first 1 MW triple-frequency gyrotron for the COMPASS-U ECRH system is under construction in Japan. Additionally, an internal program to develop 1 MW NBI units with 80 keV energy was launched in 2025. This contribution presents the status of production of individual tokamak systems and briefly describes the related support research and development essential for the COMPASS-U design and construction. This includes, for example, the development of high-temperature multilayer thermal insulation, sliding high-current electrical contacts for cryogenic and vacuum applications, development of high-conductivity CuCrZr alloys for cryogenically cooled coils, prototyping of additively manufactured PFCs, and tungsten coating on Inconel.

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MODERN REFLECTOMETRY MODELLING: FDTD AND INTEGRATED WORKFLOWS FOR SYNTHETIC DIAGNOSTICS AND BEYOND

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Abstract. Microwave reflectometry is a key diagnostic for present and future fusion devices, where reliable profile and position measurements are essential for operation and control. Its interpretation requires full-wave modelling due to complex plasma and vessel geometries. This talk introduces the fundamentals of FDTD simulation. It reviews the evolution of the REFMUL* codes, enabling synthetic diagnostics that integrate realistic CAD-based system geometry, plasma scenarios, and signal processing. Recent advances include 2D/3D benchmarking, engineering workflow integration, and the use of synthetic data to support emerging machine learning methods for improved reflectometry analysis in ITER, DEMO, DTT, and SPEKTRE (VOPOO).

THE NEGATIVE TRIANGULARITY LOW ASPECT RATIO TOKAMAK PATH TO COMPACT FUSION POWER PLANTS

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Abstract. Low aspect ratio tokamaks provide an attractive route to compact, high power density fusion devices due to improved stability, high achievable plasma pressure, and optimized plasma volume. These advantages, however, come with challenges in power exhaust and tight integration of magnets, shielding, and breeding blankets within a reduced central stack. Negative triangularity offers a compelling solution by increasing divertor wetted area, improving power exhaust, and providing additional inboard space for magnets and shielding. It can achieve H-mode-like confinement without a pedestal, avoiding ELMs and further alleviating exhaust constraints. These features are highly synergistic with high-temperature superconducting (HTS) magnets, enabling high magnetic fields in compact volumes and reactorrelevant operation. This architecture also enables compact volumetric neutron sources with high fluence and utilization, accelerating the qualification of breeding blankets, materials, and fuel cycle technologies under relevant conditions.

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ROBUST OPTICAL ELEMENTS BASED ON STRUCTURED PLASMA PHOTONIC DIELECTRIC MEDIA FOR USE IN HIGH POWER LASERS

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Abstract. High-power lasers have become huge because of the large diameter and relatively low damage threshold optical media required to manipulate their laser beams. Their large size is frustrating the development of next-generation, exawatt to zettawatt, short-pulse lasers and their beam delivery systems. Plasma is a very robust alternative dielectric medium for manipulating intense laser pulses because it is fully ionised and can withstand intensities up to the relativistic limit, which is more than four orders of magnitude higher than the damage threshold of conventional optical media, which means that the diameter of mirror can be reduced by a factor of 100, i.e. from meters to centimeters. We show how plasma-photonic Bragg structures, comprising layers of quasi-neutral plasma, are created when ions gain momentum from the space-charge fields of electron density modulations created by the ponderomotive force of the beat wave of counter-propagating "pump" laser pulses, which is balanced by the electrostatic force of displaced electrons. The space-charge fields impart phase-correlated momenta to ions, which then ballistically evolve to form a layered plasma photonic structure. This structure is an efficient scatterer of "probe" pulse. The two-step, inertial bunching mechanism can be used to create robust media for manipulate intense laser pulses. We present experiments that demonstrate several interesting properties of plasma photonic structures and compare observations with numerical simulations. We show that the plasma photonic structure is birefringent, and can act as a lens, a high efficiency mirror, compressor and an amplifier. We also show how machine learning can be used as a very effective tool for designing plasma photonic structures. High-power lasers have many applications, including production of medical radioisotopes using laser-plasma accelerator induced photo-nuclear reactions.

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SEEING THE INVISIBLE: A DECADE OF SMALL ANGLE X-RAY SCATTERING DIAGNOSTICS AT XFELS FOR HIGH-INTENSITY-LASER PLASMAS

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Abstract. Understanding how matter behaves under extreme conditions is a central challenge in plasma physics, with implications ranging from laboratory astrophysics to fusion energy research. Over the past decade, small- angle X-ray scattering (SAXS) at X-ray free-electron lasers (XFELs) has emerged as a powerful diagnostic for studying extreme states of matter created when intense laser pulses rapidly heat and compress solid materials into dense, transient plasma conditions. Unlike traditional diagnostics, SAXS provides direct access to nanometer-scale density structures and their ultrafast evolution, enabling researchers to observe processes that previously could only be inferred indirectly from simulations. Early experiments demonstrated that coherent X-ray scattering could reveal microscopic filamentary structures, return- current dynamics, and shock formation inside optically opaque targets. These observations have significantly advanced our understanding of energy transport in dense plasmas, especially the propagation and stability of energetic electron beams. Such processes are central to the fast ignition approach to inertial fusion, where efficient coupling of laser energy into the fuel depends critically on controlling electron transport and instability growth. SAXS measurements provide unique insight into the underlying density modulations and collective plasma behaviour that influence beam guiding, energy deposition, and compression symmetry. At large-scale facilities such as European XFEL and LCLS, the success of SAXS has helped shape integrated experimental platforms combining scattering, imaging, spectroscopy, and synchronized high-power laser drivers. These multi-modal environments enable simultaneous observation of structural evolution and plasma dynamics across multiple scales, strengthening the link between theory, simulation, and experiment. This plenary talk will present a ten-year perspective on SAXS as a plasma diagnostic, highlighting key discoveries, methodological advances, and interdisciplinary connections with photon science and condensed matter physics. The presentation will place these developments within the broader context of fusion research, illustrating how scattering-based diagnostics are contributing to the understanding of fast ignition physics and outlining future opportunities enabled by next-generation high-repetition-rate XFEL facilities.

PROGRESS IN HIGH SPATIOTEMPORAL RESOLUTION DIAGNOSTIC TECHNOLOGY FOR IMPLOSION STAGE IN LASER INERTIAL CONFINEMENT FUSION EXPERIMENTS

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Abstract. Abstract: In laser driven inertial confinement fusion (ICF) experiments, implosion symmetry and hybrid related diagnostic techniques are a direction that requires continuous development. During the implosion loading stage, factors such as the loading symmetry and wavefront flatness of shock waves have become the seeds that induce the development of compression asymmetry and promote the

growth of fluid instability. The research team has developed the wide angle velocity interferometer system for any reflector (Wide Angle VISAR) technology for characterizing the symmetry of multi angle shock wave driving. This technology can extend the symmetry diagnosis technology from the current dual axis VISAR technology and three-axis VISAR technology to the 120 degree wide-angle state, providing a new means for the analysis of symmetry throughout the entire time period. Developed two-dimensional VISAR (2D-VISAR) technology with a time resolution of 2ps for diagnosing the non-uniformity of wavefront velocity field. We are currently developing the Compressed Ultra Photograph VISAR (CUP-VISAR) technology based on compressive sensing technology. This technology can use commonly the optical streak cameras (OSC) as framing cameras (FC) and achieve a balance between high temporal and spatial resolution, making it a very promising technology. The research team has developed an ultra-high temporal spatial resolution X-ray microscopy imaging method that combines microscopy imaging with magnetic drift time broadening cameras. It is expected to achieve imaging analysis of high-order modes at hot spot. A new method for measuring spectra of curved crystals with variable cone surfaces has been designed, which achieves a sensitivity increase in the 1-10 keV energy range for X-ray spectra and enables high signal-to-noise ratio measurement of emission spectra of trace mixed elements. This technology is a very promising technique for quantitatively studying mixing mechanisms. Keywords: implosion compression and stagnation hot spot diagnosis; Shock wave velocity interference diagnosis; Spectral diagnosis of variable cone curved crystal;

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WATER-COOLED STEAM HEAT SHIELD UNDER STEADY EXTREME 80-160 MW M^{-2}

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Abstract. Divertor heat-flux handling beyond the ~10–20 MW/m^2 steady-state capability of state-of-the-art actively cooled plasma-facing components remains a key engineering challenge for practical fusion reactors. We present the STEAM heat shield concept for tokamak/stellarators combining high-speed water impingement, increased heat-transfer area and boiling- assisted heat removal. A TRL 3-4 prototype was tested on a plasma torch and analyzed using heat-transfer simulations, infrared thermography and calorimetry. STEAM sustained 80 MW/m^2 for 20 minutes, corresponding to 31 kW deposited on 4 cm^2. Heat removal seems far beyond the classical critical heat-flux limit. Thanks to an optimized injector, fast imaging captured an intense two-phase outlet and a peak load of 160 MW/m^2 for 1 minute, placing the experiment among the highest reported non-destructive steady-state test of a heat shield. Its vacuum-tight variant (ready for electron beam testing) will also be presented.

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PREDICTING PLASMA CURRENT REVERSALS IN ISTTOK USING DEEP LEARNING AND EXPLAINABLE AI

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Abstract. Tokamaks with alternating plasma current (AC) enable quasi-steady-state operation, but reliable current reversals are scenario-dependent and difficult to obtain. In ISTTOK, successful transitions are attained by trial and error. This work introduces a deep learning framework to predict current reversals and improve their success rates, while comparing recurrent and convolutional architectures. Using multiple diagnostics, the models were evaluated based on their ability to identify precursors. Results show that while recurrent networks struggle with generalization, an optimized convolutional model achieves a validation score of 0.95, effectively anticipating unsuccessful reversals. Additionally, explainable AI techniques enable the identification of a minimal set of signals, as well as weighting factors for each diagnostic. This approach provides a scalable methodology for enhancing the reliability of tokamak operations.

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PHYSICS-INFORMED MACHINE LEARNING: NEW HORIZONS TO THE SOLUTION OF INVERSE PROBLEMS IN TOKAMAKS

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Abstract. In tokamaks, inverse and ill-posed problems, such as magnetic equilibrium reconstruction and tomographic inversion, are essential for physics studies and plasma control. Conventional approaches are sometimes computationally demanding and limited in their ability to incorporate heterogeneous diagnostics. Physics-informed neural networks (PINNs) offer an alternative by embedding physical equations into neural networks, enabling the fusion of data and prior physical knowledge. This framework enhances the information content of sparse or incomplete measurements and promotes physically admissible solutions. We demonstrate the capabilities of PINNs by addressing key inverse problems, such as equilibrium reconstruction using magnetic, interferometric, and polarimetric data, as well as bolometric tomography with temporal coherence. Verification on synthetic data and application

to experimental measurements from JET highlight the potential of PINNs as a general and robust methodology.

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STUDIES OF OHMIC H-MODE ON MAST-U TOKAMAK

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Abstract. We present the studies of the purely Ohmic H-mode in MAST-U tokamak. The Ohmic H-mode plasma with significant type-III ELM bursts was achieved under the unique super-X divertor configuration in the first campaign of MAST-U tokamak. During the transition from L-mode to H-mode, the plasma went through a Limit Cycle Oscillation (LCO) phase, which was followed by the ELM H-mode. During the LCO phase, a strong turbulence propagating along the ion diamagnetic direction (in the lab frame) and a low- frequency zonal flow (LFZF) are found to exist around the top of pedestal. Meanwhile, the predator-prey (PP) oscillation between density fluctuation and

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EXTENDING THE BOUNDARIES OF FULLY NON-INDUCTIVE TOKAMAK OPERATION: NEW CURRENT RAMP UP SCENARIO ON TCV

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Abstract. A new plasma current ramp up scenario is developed on TCV to demonstrate for the first time the possibility to raise the plasma current fully non-inductively (NI) (with zero flux contribution from central solenoid (CS)) by applying Electron Cyclotron Current Drive (ECCD) right after the break-down. The operational domain is explored through scans in density, EC power and deposition. Reversed safety factor profile q forms at the start of ECCD and lasts throughout the discharge. Electron ITB is built with the formation of reversed q-profile. Core thermal electron confinement well above the L-mode Bohm-gyroBohm model prediction is achieved, with a Bohm-like transport being fully suppressed. Database assembled allows one to isolate the effect of negative magnetic shear from the ExB shear and fast ion turbulence stabilisation effects. Experiment and modelling presented here provide

a basis for the fusion reactor projects relying on strongly NI or even CS-free (spherical tokamaks) operation.

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IMPROVED NEUTRAL BEAM INJECTION SOURCE REGION MODELLING VIA SELF-CONSISTENT VIRTUAL CATHODE EVOLUTION

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Abstract. In negative ion neutral beam injection (NBI), H^-/D^- ions are produced in the source region via conversion of H atoms to H^-/D^- ions on a caesiated plasma grid (PG). To date, particle-in-cell (PIC) simulations have struggled to self-consistently reproduce the H^-/D^- ion density observed in the bulk plasma, typically underpredicting experimental values. This arises from the common assumption of a uniform background H atom density, leading to premature H^-/D^- emission and the formation of an artificially deep virtual cathode, suppressing ion transport into the bulk plasma. Here, two modifications were explored: (i) modelling emitted H^-/D^- ions with a truncated Maxwellian distribution, and (ii) introducing an artificial proton drift toward the PG to offset early ion emission. For a plasma density of 2 x 10^{17} m^{-3}, these approaches yield an H^- density of 4.3 x 10^{16} m^{-3} , representing an 89% increase relative to the baseline model (6 x 10^{16} m^{-3} experimentally).

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LASER-DRIVEN COMPACT MUON SOURCE: PRODUCTION AND OPTIMIZATION FOR VERSATILE APPLICATIONS

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Abstract. Muons, which play a crucial role in both fundamental and applied physics, have traditionally been generated through proton accelerators or from cosmic rays. In this work, we show the first proof of principle experiment for novel muon production with an ultra-short, high-intensity laser device. The results show that a significant yield of muons up to 0.01 μ/e- could be achieved. We further systematically investigate muon production mechanisms. Our analysis addresses critical requirements for both high-energy collimated muon beams and specialized applications such as muon spin rotation/resonance/relaxation research utilizing surface/decay muons. Our simulations derive optimized target configurations to specific application demands and characterize key performance parameters of the generated muon sources. These findings provide foundational guidance for establishing practical muon research capabilities within compact laser laboratories.

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IRON L-SHELL OPACITY MEASUREMENT AT TEMPERATURE REACHING 115 EV

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Abstract. We report spectrally resolved measurements of iron L-shell opacity in a high-energy-density plasma produced using a Z-pinch–driven dynamic hohlraum. An Fe/Al mixed sample is volumetrically heated by a ~6 ns long quasi-Planckian x-ray drive and backlighted by a ~2 ns long backlighter pulse during stagnation. Our spectrometer simultaneously captures Fe L-shell and Al K-shell transmission spectra, enabling direct opacity measurements and tracer-based diagnostics of plasma temperature and density. By comparing the measured transmission with calculations from the PrismSPECT code, we extract the iron opacity at an electron temperature of $T_e \approx 115eV$ and an electron density of $n_e \approx 1.4 \times 10^{22}\,\mathrm{cm}^{-3}$. These plasma conditions approach those in the solar convection zone but are characterized by lower values — approximately 1.6× and 6.5× lower in temperature and density, respectively, than at the radiation–convection boundary.

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EARLY-TIME DYNAMIC IN X-RAY DRIVEN FOILS EXPERIMENTS AT SG 100 KJ LASER FACILITY IN CHINA

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Abstract. Estimating the level of perturbation seeding and determining the onset of the acceleration phase is essential to find the path towards high-gain inertial confinement fusion and plays an important role in regulating the star-forming process in a galaxy. X-ray ablation dynamics of the planar foil with pre-imposed sinusoidal ripples is investigated at the SG laser facility, which is capable of an output energy of 100 kJ. First, a significant fraction of the second harmonics is observed and identified at the beginning of the ablative drive. Second, a period of secular growth is also observed. Our results can be applicable to various regions such as implosions in inertial confinement fusion and dynamics of molecular clouds in astrophysics.

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LASER DIAGNOSTICS ON THE PLASMA FOCUS FACILITY PFZ-200. DETERMINING THE ELECTRON DENSITY DISTRIBUTION AND DIRECTIONS OF THE ELECTRON DENSITY GRADIENTS.

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Abstract. In this contribution, we present the results of deuterium implosion experiments conducted using the PFZ-200 plasma focus facility. These experiments were conducted with an initial deuterium gas pressure of around 360 Pa and a charging voltage of 18 kV. This corresponds to an electrical energy of 3.2 kJ and a peak current of approximately 200 kA at maximum plasma compression.

We investigate the dynamics of the imploded plasma using a comprehensive diagnostic system that includes a four-frame XUV camera and laser-based imaging techniques (interferometry and Schlieren). A novel modification of the Schlieren diagnostic technique, based on redesigning the beam focal stop geometry, enables us to detect plasma regions with different density gradient orientations. These measurements are directly compared with interferometric data to provide complementary insight into the plasma structure and evolution.

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POINT-LIKE FUSION PROTON SOURCES IN COMPACT PULSED-POWER DEVICES

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Abstract. This study compares DD fusion proton emission in two compact devices: the PFZ-200 in a hybrid X-pinch configuration and the MPG (multipurpose generator). We aimed to maximize proton yield and minimize source dimensions for radiography. While PFZ-200 (~200 kA) used a hybrid geometry, the MPG (<100 kA) operated without cathode return bars, using the vacuum chamber as the cathode.

Proton diagnostics using CR-39 track detectors confirmed proton energies exceeding 3 MeV in both systems. Although PFZ-200 yields a higher flux (10^7 /shot), the MPG provides a more point-like source with a diameter below 1 mm. The results show that exceptional brightness can be achieved even at lower currents, making these configurations ideal for high-resolution imaging of dense plasma structures.

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NUMERICAL SIMULATION OF NEUTRON TRANSPORT IN THE MODERATOR OF THE SILVER ACTIVATION COUNTE

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Abstract. The next-generation Silver Activation Counter (SAC v3) is a fast-neutron detector designed for measurements of intense neutron bursts from short- lived fusion plasma sources. The SAC v3 detector is based on the activation of silver foils embedded in a polyethylene moderator.

The main motivation for developing neutron transport simulations was to determine the detector's response dependence on different neutron energies. This allows us to determine the correction coefficient between calibration with an AmBe neutron source and mono-energetic neutrons (2.45 MeV) corresponding to the average neutron energy from the D(d,n)3He fusion reaction. However, due to the kinematics of fusion processes, the energies of fusion neutrons may shift. Therefore, the detector response (number of pulses) as a function of neutron energy was also calculated. Another motivation was to achieve a better understanding of neutron moderation, material activation, and optimization of detector geometry.

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2D FLASH SIMULATIONS OF EXPLODING WIRES: INVESTIGATING THE EVOLUTION OF CURRENT DISTRIBUTION

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Abstract. Measuring the current density in the low density corona of exploding wires remains experimentally challenging. Therefore, this region is investigated using MHD simulations during the expansion phase.

The numerical results are validated using x-pinch driven proton radiographs obtained using the MAIZE and XP generators. The MAIZE facility delivered a peak current of 400 kA with a rise time of approximately 150 ns to the x-pinch. The XP generator was employed to produce a 500 kA current peaking at 70 ns. One quarter of the total current is estimated to couple to the exploding wire. Both facilities utilised 25 μm aluminium wire.

The analysis compares how the short (70 ns) and long (150 ns) driver timescales alter plasma evolution. Further study is dedicated to the processes shaping the coronal current. This computational approach yields insight into plasma regions inaccessible to standard diagnostics.

The simulations are performed using the FLASH code.

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CAVIPLASMA: MAPPING OF OH RADICALS PRODUCED BY ELECTRIC DISCHARGE IN HYDRODYNAMIC CAVITATION CLOUD

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Abstract. The CaviPlasma® technology is based on electric discharge in a cavitation cloud of fast-flowing liquids (1-5 m^3/h). It delivers treatment efficiency >12 g of H_2O_2/kWh and strong biocidal effects at short plasma-exposure (tens of ms). Understanding of the OH dynamics offers new insights into the excellent treatment efficiency.

The spatio-temporal mapping of OH radicals in CaviPlasma system was performed using the luminol chemiluminescent probe. The stability of luminol in a plasma-cavitation environment and its reported short luminescence lifetime enabled time-resolved optical emission study. The luminescence decay time was assessed with a fast-frame camera, and spatial mapping was performed using an ICCD camera with an optical filter. Strong emission was observed at the collapsing end of the cavitation cloud and within the cavitation cloud. The effective luminescence lifetime of 1.4 ms also enabled mapping of the stream dynamics in the wake flow after cavitation collapse.

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PULSED ELECTRON BEAM SUSTAINED ATMOSPHERIC PRESSURE DISCHARGE FOR CONVERSION OF CARBON DIOXIDE

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Abstract. In order to address limitations of self-sustained plasma sources, a novel reactor concept based on electron beam injection for gas conversion was developed. It comprises a toroidal electron generator which injects a radially converging area beam into a cylindrical reaction chamber. A uniform discharge is operated across the axial educt gas flow through the chamber. The beam electrons sustain ionization, thus the reduced electric field of the discharge (< 20 Td) controls the energy of the plasma electrons (0.1 – 1.0 eV). This is particularly suitable for vibrational excitation of gas molecules, facilitating a more energy-efficient dissociation pathway. The power deposition into

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FORMATION OF WATER MICRODROPLETS BY TRANSIENT SPARK DISCHARGE

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Abstract. Direct contact between electrical discharges and water forms plasma- activated water (PAW), a medium with numerous applications. Efficient reactive species transfer is enhanced by converting bulk water into microdroplets. Recently, transient spark (TS) discharges were shown to generate such microdroplets when water is introduced into the reactor. To optimize PAW production, we used ultrafast Schlieren imaging to visualize TS with and without a water inlet. Our observations reveal that microdroplets form via several mechanisms: primarily by ablation at the spark-water contact point, Coulomb fission of larger volumes, and the electrospray process. Schlieren imaging shows that even without external gas flow, TS induces a fast flow toward the grounded cathode. However, the resulting turbulent mixing does not significantly influence microdroplet formation.

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REARRANGEMENT OF CHEMICAL BONDS IN NITROGEN-CONTAINING PLASMA POLYMERS

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Abstract. Plasma polymerization yields materials with varied structures and properties, depending on the bulk plasma-chemical processes and conditions at the plasma-substrate interface. Moreover, the starting reactants can also significantly contribute to a unique thin film structure. Compared to other gas mixtures used for the deposition of amine plasma polymers in radio-frequency low-pressure discharges, the cyclopropylamine discharge tends to produce a significant amount of nitrile molecules as observed by optical emission spectroscopy, and these carbon-nitrogen unsaturated bonds are also detected in the films. We investigated the rearrangement of chemic

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PLASMA DIAGNOSTICS AND PARTICLE FLUX ANALYSIS IN INDUSTRIAL DUAL-MAGNETRON SPUTTERING

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Abstract. Dual magnetron sputtering is a particularly efficient PVD coating process, especially for optimized industrial processes. The Ar pressure dependence between 0.2 Pa and 3.3 Pa is being

investigated. Two magnetron cathodes with Ti targets in a closed-field configuration are used, and the total power of the two opposing targets is maintained at a constant 20 kW. The substrate bias voltage is -40 V. As the Ar gas pressure increases, the electron temperature decreases from 3.2 eV to 2.2 eV and the Debye length from 0.085 mm to 0.05 mm. At the same time, the electron and ion densities increase from 2.4×10^{10} cm^{-3} to 5.2×10^{10} cm^{-3}, the electron saturation current density from 120 mA/cm^2 to 180 mA/cm^2, and the ion saturation current density from 1.3 mA/cm^2 to 1.8 mA/cm^2. The results are explained by theoretical plasma considerations and demonstrate the effectiveness of dual magnetron sputtering.

TAILORING STOICHIOMETRY AND MORPHOLOGY OF FE_XN NANOPARTICLES VIA CYLINDRICAL MAGNETRON SPUTTERING.

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Abstract. Iron nitride nanoparticles (NPs) are promising noble metal-free electrocatalysts, with size and morphology being key factors that influence performance. we present a one-step, solvent free synthesis of iron nitride NPs using a gas-aggregation cluster source with a cylindrical magnetron. By varying the N_2 content in a reactive plasma, a phase transition from metallic Fe to Fe_4 N, Fe_3N and FeN was observed. TEM and SEM analysis confirm a morphological evolution from spherical to faceted or pyramidal NPs, while XPS, EDX and XRD confirm the shift in stoichiometry and crystallinity. These results show that controlled N_2 levels in an Ar/N_2 environment allow systematic tuning of NP morphology and phase composition.

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PLASMA-BASED SYNTHESIS OF CUBIC COPPER NITRIDE NANOCRYSTALS USING CYLINDRICAL POST MAGNETRON

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Abstract. Copper-based nanoparticles (NPs) are vital for catalytic applications where size and morphology dictate surface reactivity and selectivity. This study demonstrates a robust, one-step plasma-based synthesis of copper nitride (Cu_3N) NPs using a cylindrical post magnetron. By employing reactive sputtering of copper in nitrogen atmosphere, cubic Cu_3N NPs were synthesized. The NP size was observed to be correlated to the gas pressure during sputtering, and adjusting the pressure from 50 Pa to 150 Pa resulted in a controlled size evolution from 10 nm to 50 nm. SEM and TEM imaging confirmed the cubic structure, while XPS analysis verified the successful synthesis of the nitride phase. These results highlight a versatile sputter-based technique for synthesising NPs using plasma for potential applications as nanocatalysts.

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PLASMA JET–DRIVEN FORMATION OF ATMOSPHERIC PLASMOIDS AT THE LIQUID–AIR INTERFACE

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Abstract. The mechanism of plasmoid formation at atmospheric pressure during electrical discharges at the liquid-air interface is investigated. High- speed photography, electrical diagnostics, and optical emission spectroscopy were used to analyse the temporal evolution of the discharge. Plasmoid formation begins with the initiation of a spark and electrical breakdown inside a liquid-filled ceramic cathode, which leads to the formation of a shock wave that ejects vapour and droplets into the discharge region. After the breakdown, the arc transforms into a plasma jet that transports ionised matter upwards and supplies plasma to the developing plasmoid. Spectroscopic measurements show dominant Balmer hydrogen emission during the jet phase, while sodium and hydroxyl emission becomes more pronounced as the discharge current decreases. The application of an external magnetic field deflects the plasma jet and can suppress the formation of plasmoids by interrupted plasma supply.

MICROPLASMA-ASSISTED SYNTHESIS OF AUNPS/KERATIN NANOCOMPOSITES

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Abstract. Microplasma operates at room temperature and atmospheric pressure. It generates microplasma induced liquid chemistry (MiLC) which contains high reactive species that can enable nanomaterial synthesis. MiLC has been deployed to synthesize various nanomaterials such as chitosan/Au. Keratin protein is a sustainable polymer which can be extracted from Agri-waste resource (feathers). Although keratin has found applications (e.g., plastics), limited research has explored its combination with nanoscale materials like AuNPs for advanced applications. Furthermore, the use of MiLC for synthesizing protein-based composites remains largely unexplored. In this work, we present the first study on synthesizing AuNPs/keratin composites using MiLC. The resulting composites were characterized in detail using TEM&EDX, XPS, and UV-vis. Results show that the plasma has dual functions: modifies the keratin structures and induces the in-situ formation of uniformly dispersed spherical AuNPs.

FORMATION OF TUNGSTEN OXIDE NANOSTRUCTURES ABOVE THE WATER SURFACE MEDIATED BY THE PLASMA–WATER INTERFACE

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Abstract. Tungsten oxide nanoparticles (NPs) are of growing interest due to their electronic, catalytic, and optical properties. This work addresses how tungsten oxide nanoparticles can form through plasma-induced interfacial dynamics rather than traditional bulk oxidation pathways. The interaction of non-equilibrium plasma water enables the formation of tungsten oxide NPs above the water surface. Initially, water behaves as a polar dielectric, resulting in a low-current regime despite the plasma discharge. Plasma exposure increases the water's conductivity by the formation of long-lived species (e.g., H_2O_2). The rising discharge current causes a hot spot at the tip of the tungsten cathode and the release of tungsten species. These species undergo rapid oxidation by reactive water species above the water surface. Adding H_2O_2 reduces the induction stage by supporting the liquid phase transformation. These results provide insight into plasma-assisted synthesis routes for metal oxide NPs.

OPTIMIZATION OF POST-HEAT TREATMENT TEMPERATURE IN ATMOSPHERIC PLASMA SPRAYED LSCM-NIO/LDC/LSGM/SSC MULTILAYER METAL-SUPPORTED SOLID OXIDE FUEL CELLS

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Abstract. This study investigated the effect of post-heat-treatment temperature on multilayer metal-supported solid oxide fuel cells (MS-SOFCs) fabricated by Atmospheric Plasma Spraying (APS). The cell consisted of LSCM–NiO/LDC/LSGM/50%LSGM–50%SSC/SSC layers. Heat treatments at 825/850/875°C were evaluated by AC impedance and electrochemical tests.

The optimal temperature was 850 °C, where the maximum power density at 800°C increased from 0.688 to 0.830 W.cm^{-2}. Ohmic resistance decreased from 0.312 to 0.223 Ω.cm^{2}, with reduced polarization resistance.

The improvement was attributed to enhanced LSGM/SSC interfacial contact via hot pressing. Controlled sintering (3 h) suppressed cation interdiffusion and secondary phase formation, demonstrating that optimized thermal treatment improved performance and stability in APS-fabricated MS-SOFCs.

NANO- AND MICRO-PLASMA CHIPS FOR HIGH-EFFICIENCY CHEMICAL CONVERSION AND THZ GENERATION

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Abstract. We proposed low-voltage, fast-switching nano- and micro-plasma chips using field emission[1-3] for nonthermal plasma applications.

Microplasma chips (1–10 μm gap) self-generated nanosecond pulses for $CO_2 \rightarrow CO$ conversion. Low electron temperature (0.25 eV) allows efficient dissociation via ladder-climbing, with ~30% conversion and ~50% energy efficiency (2.5 sccm), surpassing many conventional plasma reactors with 2 orders of magnitude lower power. Application to dry reforming of methane was also demonstrated.

Nanoplasma chips (~100 nm gap) with ~1 ps switching time generated millimeter-wave and THz signals. Output at 0.4 THz with a power of ~2 W was measured, 2 orders of magnitude higher than solid-state THz devices.

These results demonstrate the promising potential of on-chip plasma technologies.

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Acknowledgement: *This research has been supported by the NCCR Catalysis (565280); European Union's Horizon 2020 research and innovation programme (945363); Swiss Office of Energy (810007679-Sl/502100-01); Chips Joint Undertaking (ALL2GaN-101111890); Innosuisse Swiss Innovation Agency; Swiss State Secretariat for Education, Research and Innovation.*

PLASMA-ASSISTED HETERO-AGGREGATION OF AL_2O_3-SIO_2 NANOPARTICLES FOR NANO-STRUCTURED OPTICAL PREFORM MATERIALS BE MODIFIED

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Abstract. Microwave atmospheric pressure plasma (MAPP) enables rapid synthesis of oxide nanoparticles under extreme thermal and reactive conditions. In this work, SiO_2-Al_2O_3 precursor suspensions were injected into an oxygen plasma (4.5-6 kW) using different injection strategies and solvent compositions. The influence of single and dual nozzle injection, as well as water and water-ethanol solvents, on plasma-droplet interaction and particle formation was investigated. Characterization by SEM, BET, XRD, and dilatometry reveals significant differences in morphology, crystallinity, and sintering behavior. The presence of ethanol enhanced droplet evaporation and altered plasma-droplet interaction, promoting particle coalescence and compaction, leading to reduced specific surface area (BET). These results provide insight into process-structure relationships and demonstrate the importance of precursor composition and injection strategy in tailoring nanoparticle properties.

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MECHANISTIC INSIGHTS INTO MICROBIAL INACTIVATION BY PLASMA NANOBUBBLE WATER IN FRESH PRODUCE WASHING

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Abstract. Ensuring microbial safety of fresh produce while maintaining sustainability remains a critical challenge, as conventional washing often fails to prevent cross-contamination. Here, we suggest that plasma nanobubble water (PNBW) is a promising approach for suppressing cross-contamination during washing. PNBW, which consists of nanobubbles containing plasma-modified air enriched with O_3 and N_2O_5 generated by a surface dielectric barrier discharge, achieved >5 log CFU/mL reduction of Salmonella within only 10s. Chemical scavenger tests identified OH radicals from O_3 as the dominant contributors to microbial inactivation, while fluorescence assays indicated that inactivation occurred via membrane permeabilization rather than complete cell lysis. When applied to inoculated cherry tomatoes, PNBW achieved >2 log CFU/g reduction after 60s, while Salmonella in the wash water fell below detection limit, suppressing cross-contamination and highlighting PNBW potential for fresh produce washing.

CONDENSATION OF FLUCONAZOLE AND ZINC UNDECYLENATE WITH LOW-PRESSURE RF PLASMA: AN INNOVATIVE ANTIFUNGAL COMBINATION APPROACH AGAINST RESISTANCE

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Abstract. This study aimed to combine fluconazole (FCZ) and zinc undecylenate (ZU) into a single structure using low-pressure radiofrequency plasma technology to address the growing problem of antifungal resistance. FCZ inhibits ergosterol synthesis, while ZU suppresses biofilm and hyphae growth. The two agents were superficially integrated while maintaining their chemical structures through a condensation process performed in an argon plasma environment. NMR, OES, and SEM analyses confirmed structural integration; zeta potential and particle size results showed statistically significant changes ($p<0.01$). A more negative zeta potential and increased particle size indicate successful surface modification. The developed new structure offers an innovative antifungal combination approach with the potential to reduce resistance development and increase treatment efficacy.

GALVANIC CORROSION OF COPPER INDUCED BY METAL NANOPARTICLES FOR CREATING ANTIVIRAL NANOCOMPOSITES

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Abstract. Antimicrobial coatings are an effective tool in the fight against bacteria and viruses that are transmitted via contaminated surfaces. Metallic materials, particularly copper-based ones, are highly effective at killing microbes due to the release of ions, and resistance to these mechanisms is very limited. However, they can be toxic at higher concentrations. The solution lies in using galvanic corrosion, which is commonly perceived as an undesirable phenomenon, at the nanoscale. The resulting silver–copper nanocomposite exhibits significantly higher activity against bacteria and viruses, including SARS-CoV-2, while reducing the amount of metal required. Furthermore, this technology can be transferred to textile materials for use in antimicrobial surfaces, as well as in protective and filtration devices.

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LASER METAL PRINTING FROM NANOPARTICLES PREPARED BY GAS AGGREGATION SOURCE

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Abstract. We present a vacuum-compatible approach to nanofabrication using laser and silver nanoparticles (NPs) prepared with a gas aggregation source (GAS), which enables deposition of homogeneous films of monodisperse NPs.

The SEM and ToF MS were used to investigate NP films/laser interaction as a function of laser power, irradiation time, and film thickness. Three distinct regimes were founded: (a) negligible modification at low power, (b) continuous metallic microstructures made by sintering, and (c) material removal by ablation.

We demonstrate that the combination of NPs sintering and ablation allows for micro-structure fabrication with a feature size of 0.8 mkm. This vacuum-based additive manufacturing could, therefore, facilitate electronics and sensor prototyping using a single device, possibly replacing multistep photolithography approaches.

RF PLASMA-POLYMERIZED NYLON (C:H:N:O) THIN FILMS AS TUNABLE RESERVOIRS FOR CONTROLLED MOLECULAR LOADING AND RELEASE IN INFECTION-MITIGATING IMPLANTS.

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Abstract. Implant-associated infections impose a major burden (≈20,416 PJI; ≈EUR 346 million in Europe). Localized antibiotic delivery can improve efficacy while reducing systemic exposure. RF magnetron–sputtered plasma-polymerized nylon (ppNylon) films were studied as reservoirs. RF power (20–60 W) and N_2 fraction (0–100%) govern matrix formation. Low power with 100% N_2 maximizes loading (~5× vs Ar) but reveals a durability threshold, where insufficient cross-linking causes hydration-induced cracking. Films at ≥40 W remain stable, defining a regime boundary.

A dye-based UV–Vis method maps loading and release. A hierarchy (azo > phenothiazine > triphenylmethane) indicates molecular sieving, while β-lactams show charge-selective transport. Optimized films deliver ≈1.5 mg/L ampicillin, exceeding MIC.

ELECTRON DENSITIES AND TEMPERATURES OF A MICROSECOND PULSED PLASMA IN WATER

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Abstract. Plasmas in liquids enable a wide range of applications, including plasma-assisted electrolysis. While ns pulsed plasmas typically generate higher yields of reactive species, μs pulsed plasmas offer the advantage of easier integration into electrolysis cells. To better understand the behavior of such plasmas prior to their use in an electrochemical system, key plasma characteristics must be determined.

Optical emission spectroscopy is applied to investigate the H-α and O 777 nm emission lines of a μs pulsed plasma in water. By fitting the measured line profiles with a model incorporating broadening mechanics, electron densities of up to 10^{22} m^{-3} and electron temperatures around 2500 K are obtained for different ignition voltages and frequencies. Additionally, the ignition behavior as a function of electrode distance is examined. Experimental ignition thresholds for varying electrode gaps and voltages are compared with a simulation.

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STUDY OF PLUME DEFLECTION IN AN ECR PLASMA THRUSTER: APPROACH TO MAGNETIC THRUST VECTORING

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Abstract. Plasma Thrusters offer extended operational life and lower system mass for space missions due to their electrodeless design. This study evaluates the performance and steering capabilities of an electrodeless Compact ECR Plasma Thruster (CEPT) developed at Plasma Lab, IIT Delhi. By utilizing a magnetic-field-based vectoring system with two transverse NdFeB ring magnets, the design eliminates mechanical gimbals, enhancing spacecraft reliability. Magnetic field simulations and experimental validation using Ar propellant confirmed plume deflection angles ranging from 0.5^0 at the source mouth ($z = 0$) to 8^0 at $z = 8$ cm. While the symmetric configuration of CEPT yielded a net axial thrust of 2.45 mN, the steered configuration successfully demonstrated active thrust vectoring via a non-zero radial force, albeit with reduced thrust. These findings provide a base for active thrust vectoring for next-generation electric propulsion.

STUDY OF TOXIC ELEMENTS BEHAVIOR DURING THE PHOSPHOGYPSUM TREATMENT USING THERMAL PLASMA

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Abstract. The production of phosphoric acid by treating natural phosphates with sulfuric acid generates a large amount of waste called phosphogypsum. This waste contains toxic substances in significant quantities and the main toxic substances present are heavy metal salts, and radioactive elements. The main objective of this work is to treat the waste using a system consisting of a plasma furnace. The treatment of this waste involves separating toxic elements from the other inert constituents of the waste. In this study, we investigated the influence of different parameters such as plasma current, and treatment time on the volatility of toxic elements present in the waste. The volatility of toxic elements is controlled both experimentally and through modelling using a computational code. With this code we determined the effects induced on the volatility of heavy metals and toxic elements by the plasma current, the liquid bath temperature, and the partial pressure of oxygen in the carrier gas.

CHARACTERIZING PLASMA IMPEDANCE AND RF CIRCUIT PARAMETERS WITH POWER SWEEPS IN LUPIN – A REDUCED SCALE ICP ION SOURCE

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Abstract. The Large Uniform Plasma for Ionizing Neutrals (LUPIN) ion source is a reduced-scale, inductively coupled plasma prototype designed to support design improvements for the DIII-D neutral beam auxiliary heating system. To help achieve this end, we designed a high-power impedance matching network (MN) and completed a comparison of experimentally measured plasma resistance and inductance against analytical circuit models. Further complicating the analytical modeling approach is the use of a Faraday shield (FS), which reduces discharge efficiency. This study presents a description of the LUPIN MN design methodology, along with RF circuit characterization up to 11 kW in hydrogen and helium gases with and without a FS. As power is increased beyond 2.4 kW, up to 11kW, plasma impedance is shown to plateau in both gases, corresponding to reduced change in discharge efficiency. Adding a FS caused shunt capacitance MN requirements to increase by a factor of 2 for the same discharge parameters.

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DESIGN, CALIBRATION, AND APPLICATION OF A RUNAWAY ELECTRON FLUX PROBE FOR STUDYING RUNAWAY ELECTRON DYNAMICS IN THE ADITYA-U TOKAMAK

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Abstract. Runaway electrons (REs) with energies from keV to several tens of MeV pose a significant threat to plasma-facing components during tokamak disruptions due to intense localized heat loads. A dedicated Runaway Electron Flux Probe has been designed, developed, and beam-calibrated for the ADITYA-U tokamak to obtain direct measurements of RE flux and energy. The in-vessel probe intercepts confined REs and operates as an energy-resolving detector to investigate RE transport, confinement, and MHD-driven loss dynamics. The design is based on machine parameters and guided by analytical modeling and PHITS Monte Carlo simulations to optimize shielding, filter stack, scintillator response, probe geometry, and heat-load tolerance. Calibration using 1–6 MeV electron beams established the quantitative relation between detector signal, incident RE flux, and energy, enabling energy-resolved measurements during instability-driven RE loss events.

Acknowledgement: *This research has been supported by the Department of Atomic Energy, INDIA.*

NEUTRAL BEAM OPTIMIZATION FOR A BEAM DRIVEN TOKAMAK

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Abstract. High fusion performance and long-pulse operation are critical design challenges for tokamak-based fusion neutron sources. Steady-state operation is sustained by non-inductive current driven by high-energy particle injection. Neutral Beam Injection (NBI) serves as an efficient tool for current profile and fusion intensity control, with beam-plasma interactions accounting for 60–99% of neutron yield.

This study evaluates NBI efficiency across various tokamak configurations and plasma geometries using the BTOR (Python) workflow. The methodology integrates high-accuracy beam models with efficient fast-ion tracking. By employing analytical processing for beam stopping and slowing down rather than individual particle tracing, the approach enables rapid large-scale simulations to establish NBI performance limits. BTOR has proven highly effective for the design optimization of beam-driven plasma devices.

LOADING OF THE COMPASS-U PLASMA-FACING COMPONENTS DURING DISRUPTIONS AND EDGE-LOCALIZED MODES

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Abstract. Components that are in direct contact with the plasma during tokamak operation are exposed to extreme conditions that place high demands on their design. The work presents a computational study of the most severe transients for the plasma-facing components (PFC) of the COMPASS-U tokamak, which is currently under construction in Prague. The largest electromagnetic loads on PFCs are foreseen during plasma disruptions, which, according to the developed 3D model, lead to a maximum force of up to 60 kN and a torque of about 4 kNm acting on a single representative PFC tile (150 x 170 mm) protecting the inner wall of the vacuum vessel. The highest power and particle load on the divertor plates is expected during the edge-localized modes (ELM) activity. Kinetic simulations of the initial phase of the ELM event using the BIT1 code for the low density H-mode scenario show that deuterium ions of temperature up to 300 eV (i.e. 52% of the top pedestal value) appear at the divertor targets.

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STRAY LIGHT-BASED LASER POWER COMPENSATION FOR A BURST-MODE LASER OF THOMSON SCATTERING DIAGNOSTICS ON VEST

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Abstract. Laser power compensation is essential for reliable electron density measurements in Thomson scattering (TS) diagnostic, as the signal intensity is directly proportional to the laser energy. Therefore, accurate monitoring and correction of pulse energy are required. In the Versatile Experiment Spherical Torus (VEST), measurement of the input laser pulse energy is difficult because the system operates in high repetition rate (burst-mode at 1 kHz), limiting pulse-resolved monitoring. To address this issue, we propose a compensation method based on stray light detected by the polychromator in use. Since the stray light is depends on the optical and structural configuration of the system, it provides a stable and reproducible indicator of the incident laser power in VEST. By correlating stray light with pulse energy, the power can be monitored without additional diagnostics. This method provides a simple calibration approach for burst-mode TS system and improves electron density accuracy.

Acknowledgement: *This research has been supported by the NRF grant funded by the Korean Government (MSIT) (RS-2024-00409564) and by KFE through government-funded programs EN2601 (High Performance Tokamak Plasma R&D) and EN2642 (Plasma Fundamental Technology Research).*

PARAMETRIC TURBULENCE AND ANOMALOUS ION HEATING IN THE TOKAMAK PEDESTAL DRIVEN BY HIGH-HARMONIC FAST WAVES

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Abstract. Steady-state tokamak operation requires efficient RF heating and non- inductive current drive. In MW-level high-harmonic fast-wave (HHFW) experiments, up to 50% of the launched power is lost in the near-antenna scrape-off layer (SOL), where linear theory becomes inadequate and nonlinear processes dominate. We investigate microscale turbulence driven by high-harmonic waves at 30 ion cyclotron frequencies as a mechanism of anomalous fast-wave power dissipation. For the first time, numerical analysis of high-harmonic ion cyclotron parametric instabilities is performed for pedestal

plasma conditions with gradients in the pre-knee region and radially inhomogeneous density and temperature profiles. The results demonstrate that high-harmonic parametric turbulence leads to anomalous ion heating and enhanced convective transport of hot pedestal plasma toward the SOL, providing a self-consistent mechanism for HHFW power losses.

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CONCEPTUAL DESIGN OF IMPURITY AND HYDROGEN SPECTROSCOPY IN VIS, NIR, AND NUV FOR COMPASS-U

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Abstract. This work presents the conceptual design of the impurity and hydrogen spectroscopy diagnostic for the COMPASS-U tokamak. It characterizes edge and Scrape-Off Layer (SOL) physics by monitoring radiation from hydrogenic species and impurities (e.g., tungsten, boron, oxygen, nitrogen) across the 250 − 1100 nm spectral range.

The design is driven by extreme environmental loads: high magnetic fields, elevated temperatures, spatial constraints and intense radiation flux. These conditions demand metal-coated pure fused silica fibers, radiation-hardened high-temperature optics, and non-magnetic, vacuum-compatible materials.

Crucially, radiation-induced detector degradation requires relocating detectors to a remote, shielded room. The resulting long optical fiber path, paired with inherently low emissivity of certain impurities, necessitates novel materials and high-throughput technologies to achieve a high quantum efficiency system.

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SYNTHETIC MACHINE LEARNING-BASED DENSITY FIELD RECONSTRUCTION FOR TOKAMAK PLASMA

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Abstract. In tokamak local electron density measurements will be critical for managing fuelling and divertor exhaust regimes. Machine Learning offers a promising solution; however, training robust models typically requires vast experimental datasets, which are unavailable for machines in the construction phase. We propose a synthetic ML-based approach for reconstructing the electron density field from interferometric measurements. The model is trained exclusively on synthetic datasets generated via physics-based simulations within the TOKALAB framework. This methodology yields a data-driven neural network capable of being deployed on new devices prior to their first plasma. We present the dataset generation pipeline, the neural network architecture, and preliminary reconstruction results. Furthermore, we analyse the impact of integrating complementary diagnostics, to improve reconstruction robustness. Finally, we propose a validation strategy to test this method on currently operating tokamaks.

PRELIMINARY STUDIES OF A PLASMA PINCH THRUSTER

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Abstract. The theta-pinch inductive pulsed plasma thrusters are a promising concept with larger energy density without the use of wearable electrodes, adding thermal compression over electrodynamic ejection for impulse. While these systems were planned for very large high-power missions, a conical model has been scaled down to the 900 W region, applicable to small satellites.

This work presents the first studies and construction of such a prototype for lower power levels. We describe the geometric magnetic design in Comsol, circuit modeling in PSPICE, and the initial manufacturing of the conical theta-pinch coil.

The magnetic field was simulated in 2D and 3D for comparison and error field estimation relative to the ideal symmetric case. The coil was manufactured over a molded 3D part. The simulated circuit includes a capacitor bank, thyristor, coil, a coupled plasma model; and agrees with experimental results. An RF argon plasma is used as a seed for the pinch discharge in a vacuum test chamber.

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CAPILLARY DISCHARGE FOR X-RAY LASER PUMPING, OPTICAL BEAM GUIDING, AND PARTICLE FOCUSING

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Abstract. The capillary discharge plasma has several interesting technical applications. We have participated in the research of several of them. Our method is based on the evaluation of plasma quantities of capillary discharge by MHD code NPINCH and by comparison of the results with relevant laboratory experiments. To get recombination EUV nitrogen laser pumping and to suppress ablation from the inner surface of the capillary, we have investigated capillary in a large-diameter capillary with long-lasting pre-ionization. To get lasing at wavelength 26.23 nm, we have studied a new laser-active medium formed by excited hydrogen- like boron ions. To increase plasma heating of the nitrogen laser active media we have analyzed hybrid pumping by capillary pinch and by subnanosecond infrared laser beam. To analyzed relativistic electron beam focusing by capillary discharge, we have evaluated electric and magnetic fields inside the capillary discharge and solved the relativistic electron motion equations.

VALENCE PHOTOABSORPTION SPECTROSCOPY OF ZR AND ZR+ FOR ASTROPHYSICAL APPLICATIONS

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Abstract. Accurate atomic datasets are essential to identify heavy elements synthesized by the rapid neutron capture process in kilonovae. Complete, accurate datasets currently do not exist for key elements, such as zirconium [1]. To address this, we present a novel supercontinuum photoabsorption spectroscopy experiment using laser-produced plasmas. A Nd:YAG laser was focused onto a zirconium target. The plasma was probed at a set delay using a SuperK supercontinuum laser (450–2400 nm). Spectra were recorded via a Czerny-Turner spectrometer with a CMOS camera. We analyzed a zirconium spectrum from 500–1100 nm at a time delay of δt = 11 μs [2]. Comparing these results with a high resolution Dual Comb Spectroscopy experiment demonstrates the complementary nature of both techniques. This work yielded 306 new spectral line identifications, significantly expanding the available atomic data.

References:

[1] Gillanders et al., MNRAS, 506 3560 (2021)

[2] Dowd et al., Exp. Astron. 60 7 (2025)

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RELATIVISTIC PONDEROMOTIVE EFFECTS ON STIMULATED RAMAN SCATTERING IN QUANTUM PLASMA

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Abstract. In this work, the combined effect of relativistic ponderomotive force (RP force) and stimulated Raman scattering of a high-power beam in quantum plasma is investigated. The dielectric function of the plasma becomes nonlinear due to the RP force. The density profile also modifies the three waves that are involved in the process. Based on these modifications, the second-order differential equations are obtained and studied for the beam width parameters of these 3 waves - the pump laser beam or the Input beam, the Electron Plasma Wave, and the back-scattered beam. Additionally, The RK4 method is used to perform numerical computation of nonlinear ordinary differential equations (ODEs) so that the effects of altering the laser plasma parameters, quantum contribution and combined action of RP force on the SRS back- reflectivity and beam widths of the different waves engaged in the process can be explored.

LASER ABLATION OF LEAD TARGETS: IMPULSE, CRATER VOLUME, AND PERMANENT MAGNETIC FIELD EFFECTS

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Abstract. A KrF laser with a wavelength of 248 nm, laser pulse 20 ns, and varying energy 150 → 450 mJ was used to ablate lead targets, a novel ablation fuel. Volumetric measurements of the created craters were acheived using a stylus profilometer. The laser ablative thrust was measured as a function of energy using a free-oscillating pendulum setup. Lastly, the effect of a permanent magnetic field is studied by placing neodymium magnets behind the lead targets of varying magnetic field strengths of 0.2 → 0.5 T.

THE INFLUENCE OF THE ELECTRODE MATERIAL ON RF PLASMA SHEATHS OBSERVED BY FORCE MEASUREMENTS ON OPTICALLY TRAPPED MICROPARTICLES

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Abstract. Using optically trapped microparticles, the sheath of a plasma can be probed in a non-invasive way. To investigate the effects of secondary electron emission from the surface of the electrode on the sheath of a capacitively coupled radio frequency plasma, the force upon single optically trapped microparticles was tracked along a path from the bulk of the plasma through the sheath towards the electrode. These measurements were carried out for electrodes made of stainless steel, aluminum, titanium and glass-ceramic, under a range of different argon gas pressures and rf voltages.

We observe significant changes in the electric field force onto the microparticle depending on the electrode material. We attribute the changes in the location of the sheath edge and the forces onto the particle to the emission of secondary electrons from the surface of the electrode, and resulting changes of the particle's charge.

MACHINE LEARNING-DRIVEN PREDICTION OF PLASMA PARAMETERS USING VI PROBE HARMONIC DATA IN AR AND N_2 PLASMAS

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Abstract. A machine-learning-driven framework is proposed for the prediction of plasma electron density and electron temperature in Inductively Coupled Plasma (ICP) using harmonic data from a voltage–current (VI) probe. By employing a systematic feature selection process via Lasso regression and Random Forest algorithms, this work identifies the most critical parameters from complex multi-harmonic datasets. Notably, the analysis reveals that high-precision predictions are achievable using only 1st harmonic data, which significantly reduces computational complexity. The models demonstrate exceptional accuracy and robustness across different chemistries, achieving a coefficient of determination exceeding 0.9 in both Argon and Nitrogen ICP sources. Ultimately, these findings highlight the

transformative potential of machine learning in streamlining plasma diagnostics, providing a versatile, efficient, and cost-effective solution for process monitoring in diverse industrial environments.

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INVESTIGATION OF ION ENERGY DISTRIBUTIONS AND PLASMA CHARACTERISTICS VIA TAILORED VOLTAGE WAVEFORMS IN INDUCTIVELY COUPLED PLASMA

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Abstract. As semiconductor manufacturing advances toward the atomic scale, precise plasma control is essential. Since process precision depends on ion- substrate interactions, achieving a narrow Ion Energy Distribution (IED) is critical to minimize substrate damage. Because IED is directly modulated by the substrate bias, sophisticated waveform control is indispensable. Recently, Tailored Voltage Waveforms (TVWs) have emerged as a key technology for achieving mono-energetic IEDs. In this study, various TVWs were applied in an ICP system. We experimentally characterized the resulting IEDs and analyzed the correlation between waveform modulation and ion energy evolution. Additionally, the impact of these waveforms on fundamental plasma parameters, such as electron density and temperature, was investigated. These results provide a foundational framework for designing customized pulse waveforms to optimize next-generation etching and deposition processes.

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GENERATION OF WHISTLER WAVE INSTABILITIES USING A SPIRALING ELECTRON BEAM IN A DUSTY PLASMA

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Abstract. The current manuscript presents a novel conceptual approach to investigate the phenomenon of whistler wave excitation using a spiraling electron beam in plasma. Using first order perturbation theory, the growth rate and unstable wave frequencies are expressed. Only cyclotron resonance happened for whistler waves that were propagating parallel to the applied magnetic field, whereas both cyclotron and Cerenkov resonance happened for whistler waves that were propagating at an angle to the applied magnetic field. It is discovered that as wave number and beam density increase, so do the numerical values of unstable wave frequencies and growth rate. Additionally, it has been shown that the growth rate increases even as the electron beam's velocity increases.

DATA-DRIVEN PREDICTION OF PLASMA PARAMETERS IN MICROWAVE ATMOSPHERIC PLASMA JETS USING INTERPRETABLE AND UNCERTAINTY-AWARE MACHINE LEARNING

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Abstract. Microwave atmospheric-pressure plasma jets (MW-APPJs) are widely used for applications such as hydrogen production, CO_2 conversion, water treatment, material processing, and waste remediation due to their stable atmospheric operation and ability to generate highly reactive species. In this work, an interpretable and uncertainty-aware multi- output machine learning framework is developed to predict eight plasma parameters, including electron excitation temperature, electron density, emission intensities (OH, N_2, H_α, O), gas temperature, and plume length. A dataset of 441 experiments was generated by varying the microwave power, the sliding short position, and the argon flow rate. Among the six models tested, gradient boosting achieved the best performance (MAPE $<$ 3%, $R^2 > 0.97$). Bootstrap uncertainty and SHAP analysis provided reliable prediction intervals and identified microwave power as the dominant control parameter.

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ELECTROSTATIC SURFACE PLASMONS AT A QUANTUM-CLASSICAL PLASMA INTERFACE WITH LANDAU DIAMAGNETISM AND THERMAL EFFECTS

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Abstract. Abstract: Electrostatic surface plasmons at the interface between a quantum plasma and a classical warm plasma are investigated using the quantum hydrodynamic (QHD) framework. The quantum region includes Fermi pressure, Bohm potential, and Landau diamagnetism, while the classical plasma is modeled with finite electron temperature effects. By solving the linearized governing equations with appropriate boundary conditions, a generalized dispersion relation for surface modes is derived.

CHARACTERISTICS OF ION ENERGY DISTRIBUTIONS IN ICP PLASMAS UNDER PULSED OPERATING CONDITIONS

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Abstract. In plasma processing, the ion energy distribution (IED) incident on the substrate is a critical factor for etch selectivity, profile control, and thin-film properties. Conventional continuous biasing methods (DC or CW-RF) control the average ion energy but are limited in shaping the IED.

Pulsed biasing techniques have been explored to manipulate plasma sheath dynamics and thereby control the IED. In this study, a negative pulsed bias voltage was applied to the substrate in an ICP plasma chamber, and IED variations were measured under different operating conditions (frequency, duty cycle, negative voltage, and slope voltage). The results revealed shifts in ion energy magnitude and changes in IED shape driven by ion flux variations during the pulse ON-time. These results provide insights into ion energy control strategies for low-damage etching, advanced semiconductor fabrication, and next-generation display technologies.

VLASOV SIMULATIONS OF DRIFT-DRIVEN ELECTRON-ACOUSTIC WAVES IN MULTI-COMPONENT PLASMAS

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Abstract. We present a theoretical and numerical investigation of electron- acoustic waves in a collisionless plasma consisting of hot and cold electrons with stationary ions. Using both fluid analysis and Vlasov-Poisson simulations, we examine the influence of drift velocities on wave stability and nonlinear evolution. In the absence of drift, the system remains stable and no phase-space structures develop. When hot electrons drift, instability arises at relatively low velocities due to kinetic resonances, leading to energy transfer from particles to waves, growth of electrostatic fields and formation of phase-space vortices. In contrast, cold-electron drift requires significantly higher threshold velocities to excite instability because of their narrow velocity distribution, resulting in a more fluid-like response. As drift increases, a transition from kinetic to fluid instability is observed.

MODELING OF MULTICOMPONENT LIQUID EVAPORATION RELEVANT TO PLASMA–LIQUID INTERACTIONS

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Abstract. Plasma–liquid interaction is an emerging field with unresolved challenges in interfacial transport. When plasma contacts a liquid, evaporation, surface deformation, and droplet formation may occur. Understanding evaporation and species transport is therefore important for accurate plasma–liquid modeling.

This work presents an OpenFOAM model based on the Volume of Fluid (VOF) method for multicomponent liquid evaporation. It solves coupled equations for mass, momentum, energy, and species transport. Species-dependent evaporation produces composition gradients at the liquid surface, which drive Marangoni flows.

The results show that multicomponent evaporation affects interfacial flow and species redistribution. The framework provides a basis for studying evaporation-driven transport in plasma–liquid systems and can be extended to include plasma dynamics.

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AN ANALYTIC MODEL OF EVAPORATING CATHODIC ARC MICRODROPLETS USING PLASMA SYSTEMS WITH FAST ELECTRONS

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Abstract. Cathodic arc deposition is a versatile thin film fabrication process which is attractive due to its high deposition rate and the formation of dense films. A common drawback of the method is the production and deposition of microdroplets that are the result of the cathode explosive processes. Modern filters and methods for removing these microdroplets lead to significant loss of material in the plasma flow and in the productivity of the ion-plasma coating deposition process, which motivates the quest for alternative methods for microdroplet removal. In this paper, we explore the possibility of using fast electrons self-consistently generated in a plasmadynamic system to evaporate micrometer-sized droplets. Using analytical modeling, we demonstrate, using materials such as copper, titanium, and aluminum, that a microdroplet with a radius of $\leq 1\ \mu$m can be completely evaporated during its passage through such a plasma system.

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APPLICATION AND VALIDATION OF THE RESONANCE METHOD IN ONE-DIMENSIONAL AXISYMMETRIC GEOMETRY

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Abstract. This paper presents the application of the resonance method for the evaluation of the inception voltage U0 for non-self-sustained discharges in dry air within a 1D axisymmetric geometry using the commercial software COMSOL Multiphysics. The model is first validated against a reference configuration from previous work. A parametric study is performed to assess the influence of electrode polarity, gas pressure, and electrode geometry on U0. The results confirm the expected trends. Furthermore, the use of a local kinetics model for negative ions reveals the reduction in the model complexity while introducing only minor deviations in U0, demonstrating its suitability for efficient calculations. In contrast, the omission of photoionization leads to expected strongly polarity-dependent effects. These findings show the applicability of the resonance method as a robust tool for U0 evaluation and highlight the critical role of selected physical processes in discharge modeling.

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COMPREHENSIVE ANALYSIS OF POWER VARIATION IN RF MAGNETRON SPUTTERING USING FEM, LANGMUIR PROBE, AND OPTICAL EMISSION SPECTROSCOPY

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Abstract. A comprehensive study of low-pressure Ar plasma generated by RF magnetron sputtering was conducted using FEM, Langmuir probes, and OES. Key plasma parameters—ion density (ni), electron density (ne), and electron temperature (Te)—were investigated. FEM provided precise plasma modeling, Langmuir probes measured density, Te, plasma potential, and EEDF, while OES characterized plasma composition and emission intensities. RF power varied from 20–90 W. FEM results showed ni and ne up to $1.24 \times 10^{16} m^{-3}$, Te 4.09 eV; Langmuir probes: ne $1.17 \times 10^{16} m^{-3}$, ni $1.67 \times 10^{16} m^{-3}$, Te 2.72 eV; EEDF: Te 3.42 eV. OES with Al target gave Te 2.99 eV.

DUST ION-ACOUSTIC DOUBLE LAYERS AND SUPERSOLITONS IN DUSTY PLASMAS WITH TWO-TEMPERATURE ELECTRONS

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Abstract. The present study investigates the dust acoustic supersolitary waves and double layers in an dusty plasma composed of warm positive ions, cold mobile negatively charged dust grains, and two-temperature electrons obeying Maxwellian and Cairns distributions. Using the Sagdeev pseudopotential method, the energy balance equation is derived under the boundary conditions required for the formation of double layers, and supersolitons. Supersolitons are shown to exhibit distinctive characteristics compared to regular solitons, particularly in their electric field profiles, which deviate from the typical bipolar shape, and in their phase-space trajectories, which differ from standard homoclinic orbits. The study reveals that plasma parameters play a decisive role in shaping the existence domains and properties of these nonlinear structures. These results are directly applicable to dusty plasma encountered in space, offering deeper insights into the dynamics of nonlinear wave phenomena.

MACHINE LEARNING BASED ELEMENTAL RECOGNITION IN DISCHARGE LAMP SPECTRA FOR LOW-TEMPERATURE PLASMA DIAGNOSTICS

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Abstract. High-frequency electrodeless lamps (HFEDLs) are efficient narrowband radiation sources widely used in atomic absorption spectroscopy, plasma diagnostics, and environmental monitoring. Their emission spectra often contain numerous closely spaced and partially overlapping lines originating from the filling elements, which complicates manual spectral interpretation. In this study, a machine-learning approach based on the Random Forest algorithm is proposed for automated recognition of elemental composition in HFEDL emission spectra. Synthetic datasets were generated for the target elements and used for model training and evaluation. A feature-engineering strategy was employed to construct line-wise input vectors from physically meaningful features, including wavelength, relative intensity, local prominence, normalized distances to adjacent peaks, and centroid-relative wavelength. The obtained results demonstrate good recognition performance for both synthetic and experimental spectra.

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ASSESSMENT OF DEAL.II FEM LIBRARY FOR MULTIPHYSICS SIMULATION OF PLASMA–LIQUID INTERACTION

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Abstract. We present an assessment of the deal.II finite-element library for multiphysics simulations of plasma-liquid interactions, with a focus on streamer propagation along a gas-water interface. The model combines electrostatic field computation with transport equations for charged species, accounting for strong permittivity and conductivity gradients across the interface. Special attention is given to numerical treatment of the Poisson equation on adapted meshes and to stability issues arising from surface charge accumulation and discontinuous material properties. Tests are performed for discharge inception and propagation parallel to the interface, highlighting the influence of dielectric contrast and mesh resolution. The results demonstrate the capabilities and current limitations of deal.II for resolving coupled plasma-liquid dynamics and provide guidelines for robust implementation in future studies.

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EFFECT OF TARGET GEOMETRY ON MAGNETIC FIELD GENERATION AND AMPLIFICATION IN HIGH-INTENSITY LASER–PLASMA INTERACTION USING 2D PIC SIMULATION

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Abstract. The effect of target geometry on magnetic-field amplification in relativistic laser–plasma interaction is investigated using 2D PIC simulations with the EPOCH code. Double-cone and curved-foil targets are compared under identical laser and plasma conditions. The results show that the curved-foil target generates a stronger and more stable magnetic field due to improved electron confinement, enhanced axial current density, and reduced radial electron divergence. These findings demonstrate the important role of target geometry in optimizing magnetic-field generation in high-intensity laser–plasma interactions.

DISCHARGE DYNAMICS, NON-EQUILIBRIUM KINETICS AND DUST PARTICLE NUCLEATION IN HYDROCARBON CONTAINING PLASMAS

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Abstract. Non-equilibrium plasmas generated by electrical discharges in hydrocarbon containing gases are of interest for a variety of applications. The development of optimal hydrocarbon plasma processes requires however better understanding of their governing physical phenomena. Hydrocarbon containing plasmas are highly reactive and involve molecular growth processes that result in the formation of large species and end up with the nucleation of dust particles. The composition of the plasma strongly

differs from the feed gas one and the discharge dynamics strongly depend on the evolution of its chemical composition and on the characteristics of the dust particle cloud. In this contribution, we present a one-dimensional plasma model that self consistently describes (i) the discharge dynamics, (ii) the molecular growth kinetics, and (iii) the aerosol dynamics of the dust particles in a capacitively coupled RF discharge in argon acetylene mixture. The discharge dynamics is described using a fluid approach where the charged species transport is described with a drift-diffusion model[1]. Convective fluxes associated with the gas flow are also taken into account, in both neutral and charged species equations, using a stagnation line model. The species source terms are derived from a chemical kinetic model that takes into account primary electron impact processes, such as dissociation ionization and attachment that result in the formation of small reactive radicals and positive or negative ions[1]. The chemical model also takes into account the formation of large neutral and ions through molecular growth processes. The rate constants of electron-impact processes are calculated as a function of the electron average energy assuming that the electron energy distribution function is solution of the two-term expansion Boltzmann equation. The electron average energy is determined by solving an electron energy balance equation that takes into account electron energy transport by drift-diffusion, electron heating and electron energy dissipation in the plasma. The self consistent electric field in the discharge is determined by solving Poisson's equation taking into account all the species and the dust particles contributing to the space charge. Due to the highly reactive nature of the plasma and the need for a highly conservative model in terms of mass conservation and element abundance boundary conditions on electrodes were treated with a special care taking into account diffusive fluxes, convective fluxes and surface reactions at the electrodes. The formation of large species is described using a reactive flow model that takes into account both the molecular chemistry and species transport by convection and diffusion. The chemical model used in this study takes into account three molecular growth routes involving either neutral, positive or negative ions[2]. The molecular growth is driven by acetylene and its radical, i.e., C_2H_2 and C_2H, proceeds by the addition of two carbon atoms and involves polyyne molecules, i.e., C_2nH_2. The growth is assumed to take place up to a largest molecular edifice, the growth of which results in a nucleation process. In the present model the largest molecular edifices is taken to be C60Hy, the growth of which is assumed to result in the production of a dust particle nucleus (the smallest solid particles). The evolution of the produced dust particle is described by an aerosol dynamics model that, beside the nucleation process, and takes into account particle coagulation and dust particle growth by surface deposition of molecules and ions. In order to keep the numerical solution of the model equations tractable, we assume a bimodal particle size distribution with a nucleation mode and a core, or growth, mode [3]. The dust particle charging is described using the orbit-motion- limited (OML) theory. The charge fluctuation is also taken into account for the nucleation mode that may involve a fraction of positively charged and neutral particles which strongly enhance the coagulation kinetics[3]. The physical model described above results in a large set of differential equations that describe the time-space evolution of the plasma species, the electron average energy and the dust particle bimodal size distribution. This system is characterized by a very strong stiffness. It cannot be solved directly and a special procedure has to be used[4]. In this procedure, we first focus on plasma dynamics, e.g., electron dynamics, that are typically faster that the RF period. We consider that the dust particle cloud is stationary and time-integrate the self-consistent plasma electrodynamics equations until a periodic regime is obtained. This enables the determination of the time-averaged electron density, electron temperature, electric field, electron impact rate constants for a given configuration of the dust cloud. These are then used in a second module (LTC module) where we concentrate on the system evolution over time scales that are much larger than the RF period without resolving the RF period time-scale. In this module, we time-average the heavy species continuity equations and derive the time dependent continuity and aerosol dynamics equations [4]. These equations are integrated over typically 0.1 s time scale. The obtained new heavy species densities are relaxed and used along with the calculated particle size distributions as new inputs for the discharge dynamics module. The discharge dynamics equations can be further integrated taking into account the updates discharge composition. The procedure is iterated several times, which enables simulating the plasma evolution over up to few minutes time scale[4]. Using this methodology we investigated argon-acetylene in capacitively coupled RF discharges. As for the discharge dynamics, the results confirm the key-role of argon metastables, which always strongly contribute to the ionization and primary dissociation kinetics. The results also show the major impact of the flowrate on the discharge behaviour. Depending on this parameter, argon-acetylene discharges may (i) be dominated by either hydrocarbon or argon ionization kinetics, (ii) exhibit or not a strong electronegative character, (iii) show different mode of molecular growth. Basically a short residence time (large flowrate) results in a significant concentration of acetylene in the plasma. The discharge is dominated by HC ionization and attachment kinetics that result in a narrow strongly electronegative plasma bulk and a significant population of large neutral and ions. For large residence-time values, although the acetylene is strongly depleted in the plasma and the discharge is dominated by argon-ion, the contribution of acetylene to the overall ionization kinetics remains significant. The depletion of acetylene results however in the decrease of large positive and neutral HC densities. The negative ion concentrations remain significant. It also appears that an accurate description of the boundary conditions is essential in order to achieve a satisfactory mass balance without any normalization/correction procedure that would introduce a large error on the plasma composition in these highly reactive plasmas. As far as molecular growth and nucleation are concerned, two situations were identified. A first one corresponds to discharge conditions where acetylene conversion is high and lead to low C_2H_2 concentration in the gap. In this case, the molecular growth is driven by neutral species. The large neutral molecules are much more populated than the corresponding positive and negative ions. Nevertheless, the size distribution of neutrals show very strong decrease for large polyyne molecules which prevent nucleation through neutral species. The second situation corresponds to limited acetylene conversion yield and a large acetylene concentration in the gap. In this case, the molecular growth process is driven by positive ions. The size distributions of large molecular hydrocarbons show very slight decrease for neutrals and positively charged ions and an almost no variation for negative ions. The molecular growth model used in this work can fully explain the gas phase dust particle nucleation under high acetylene concentration in the feed gas, i.e., C_2H_2% greater than 20%. Although, the negative ions are not directly involved in the growth processes, the discharge electronegativity is essential; its role is to decrease the diffusion and loss rate of positive ions at the electrodes As for the dust cloud characteristics, we showed the existence of three distinct regimes in Ar/C_2H_2 dusty plasmas depending on acetylene concentration: (i) dust-in-plasma regime at low nucleation rates where dust particles do not contribute to the space charge balance of the discharge, (ii) locally-coupled dusty plasma regime at moderate rates where dust particles experience a significant growth and substantially contribute to the space charge of the discharge, and (iii) self-sustained enhanced nucleation and limited growth regime where particles enhance their own production which leads to a high density small size dust particle cloud. Surprisingly, the contribution of the particles to the space charge remains fairly limited.

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KINETIC MODELING OF COLD MOLECULAR PLASMAS

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Abstract. This talk presents a personal perspective on the progress achieved in the computer simulation of cold, molecular ionized gases over the past 30 years. While a personal viewpoint is inherently a limitation, it helps to keep a consistent account and reduces the risk of misinterpreting facts or perspectives within such a broad field. Consequently, some important topics will necessarily be omitted. It is hoped that what is presented will nevertheless be significant and act as a source of inspiration. Successive attempts to model increasingly complex phenomena have led to a “standard scheme” of molecular plasma modeling. This consists of two sets of equations. The first set of equations applies kinetic theory to particles such as ions, electrons, and hot atoms. The second group of equations represents the time- dependent statistical physics of evolving populations of various molecular and

atomic states [1]. An important aspect of the standard scheme is that it is based on probability distributions that cannot be replaced by a restricted set of moments. Therefore, the modelling of cold molecular plasma requires a kinetic/functional approach rather than a purely macroscopic one. After initial tests on nitrogen [2], since the 1990s this scheme has been applied extensively to hydrogen, driven by its importance in materials science, fusion energy, and astrophysics [3,4]. Later, the focus on the circular economy, specifically regarding energy and chemical sustainability, has catalyzed research into CO_2 [5] and back to nitrogen [6]. Prebiotic chemistry has proven to be a rich source of molecular plasma phenomena linked to lightning in early planetary atmospheres [7]. The complexity of molecular plasmas fostered innovative modeling techniques which, although tested in previous decades, only recently proven their full feasibility thanks to the availability of the standard model as a benchmark [8,9].

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VALIDATION OF SIMULATIONS OF LOW-PRESSURE LOW-TEMPERATURE MAGNETIZED PLASMAS FOR ELECTRIC PROPULSION APPLICATIONS

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Abstract. Currently, Hall thrusters are widely used for the electric propulsion of satellites. These thrusters are developed since 1960s but some aspects of their operation remain poorly understood [1-2]. It is important to note that thrusters have to operate reliably for thousands of hours, necessitating extensive qualification testing in high-vacuum space simulation chambers. These tests are both costly and time-consuming, underscoring the importance of accurate models and simulations to design new thrusters. Hall thrusters use an E×B configuration in an annular channel to ionize neutral gas and propel the resulting ions outward, generating thrust. Electrons required for ionization are typically emitted by a cathode located near the channel exit. The E×B configuration causes the electrons to drift azimuthally in the channel, leading to the emergence of various instabilities, mostly in the 100s kHz and MHz range. While numerous studies have focused on understanding and addressing these instabilities, the most significant instability in Hall thrusters is not directly linked to the E×B electron drift. Instead, it is a long-period ionization instability, known as the breathing mode, lasting tens

of microseconds. This mode is often likened to a predator-prey type instability, where the neutral gas injected in the thruster acts as the "prey" and plasma as the "predator," resulting in significant fluctuations in discharge current and plasma properties. These fluctuations notably impact overall thruster performance by increasing wall erosion and modulating power absorption. Over the last few decades, a large number of different multi-dimensional simulations have been developed to help predict Hall thruster operation. These include plasma simulations where both ions and electrons are treated using a fluid description, hybrid simulations using fluid electrons and a kinetic description for ions, and fully-kinetic particle-in-cell (PIC) simulations. Usually, the neutral gas flow is simulated using a fluid description. In this talk, we will first present a review of recent numerical results obtained on the impact of several instabilities, including the breathing mode on the plasma characteristics [3-6]. In a second step, we benchmark three different numerical codes by simulating an SPT-100 Hall thruster under identical operating conditions [7]. The codes include one-dimensional stationary and non-stationary fluid models describing the axial thruster direction, as well as a two-dimensional axial–azimuthal Particle-In-Cell/Monte Carlo Collision (PIC/MCC) model. A partial validation is performed with available experimental measurements of the discharge current, thrust, and anode specific impulse, showing good agreement. Overall, the fluid and PIC/MCC models compare favorably with each other, and several fluid approximations are found to be acceptable.

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NUCLEAR ASTROPHYSICS AND APPLICATIONS USING LASERS

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Abstract. In this talk I will discuss experiments performed at the PW laser facilities at Vega3 located in SalamancaSpain, ELI-beamlines in Prague, SGII-Shanghai, the PW laser at the University of Texas in Austin and the ABC-ENEA laser in Frascati. First, I will show how we can measure fusion cross sections and temperatures (@UT) in plasmas at 'air' densities and temperatures of tens of KeV (CD2+3He targets). Using many lasers (@SGII) we can compress the targets to much higher densities than solid but very low temperatures (<1KeV). Energetic ions maybe produced using short pulse lasers with the so-called Target Normal Sheath Acceleration (TNSA). To understand and better control the TNSA method we have performed experiments at Vega3 and ELI-beamlines using a PW laser for p+11B fusion reactions (third generation fusion power plant). We show that highly non equilibrated and non-neutral plasmas are responsible for the acceleration of ions to tens of MeV which may be directed on a target. These energetic ions can also be used for other applications such as radioisotope production for medicine or other purposes. Measuring the yield of produced ions give an insight to the plasma time evolution and its deviation from neutrality (Solitons?).

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CURRENTS FROM RELATIVISTIC LASER-PLASMA INTERACTION AS A NOVEL METROLOGY FOR THE SYSTEM STABILITY OF HIGH-REPETITION-RATE LASER SECONDARY SOURCES

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The Extreme Light Infrastructure

Abstract. High repetition rate operation of secondary sources driven by high-power lasers requires development of non-invasive metrology schemes. We show experimentally the close relation between kA-scale return currents from relativistic laser-driven target polarization and the quality of the relativistic laser plasma interaction for laser driven secondary sources. The precise measurement of such currents is demonstrated following an inductive scheme that does allow for an operation at high repetition rates. We demonstrate that return currents can be used as a metrological online tool for stability monitoring, using the example of ion acceleration by Target Normal Sheath Acceleration.

Acknowledgement: *This research has been supported by the IMPULSE Project.*

CALIBRATION OF RATIOS OF CROSS-SECTIONS FOR TALIF (O/XE AND H/KR) USING PULSED NANOSECOND DISCHARGE AS A SOURCE OF KNOWN DENSITY OF ATOMS

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Abstract. O and H atoms are key reactive species in non-thermal plasmas and play a central role across a wide range of scientific and technological fields as materials processing, plasma-assisted combustion, biomedical and agricultural applications. Two-photon absorption laser-induced fluorescence (TALIF) is widely used to measure absolute atomic densities. Quantitative calibration relies on noble-gas referencing (H, N/Kr, O/Xe) derived for nanosecond TALIF. In collision-dominated environments such as high-pressure plasmas and flames, the use of ultrashort (picosecond or femtosecond) laser pulses can be advantageous. The talk will include a discussion of the possibility of calibrating two-photon absorption cross-sections for experiments employing short-pulsed lasers. Experimental data on the measured cross-section ratio for O/Xe will be presented for both nanosecond and picosecond TALIF, using a pulsed capillary nanosecond discharge as a source of a known density of O-atoms.

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RESEARCH ON HIGH-ENERGY-DENSITY TURBULENT MIXING UNDER CYLINDRICAL IMPLOSION CONDITIONS

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Abstract. Turbulent mixing in high-energy-density environments plays a critical role across numerous fields, such as astrophysics and inertial confinement fusion. This study investigates turbulent mixing driven by fluid instabilities in light-heavy media during cylindrical implosions under indirect drive. Results reveal dual-scaling behavior in the azimuthal turbulent kinetic energy spectrum during shock convergence-rebound or deceleration phases: and , consistent with classical two-dimensional turbulence theory. By evaluating viscous and thermal diffusion coefficients of high-temperature plasma alongside

flow field distributions, ionization states, and temperature profiles of heavy media, key turbulent parameters during the compression phase were quantified. Additionally, temporal evolution characteristics of key turbulent quantities were analyzed.

ELECTRON, ION AND EMP EMISSION AT THE KILOJOULE LASER SYSTEM PALS

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Abstract. We present results from study of electron, ion, and electromagnetic (EMP) emission at the laser system PALS (1315 nm, 0.3 ns, 700). Charged- particle emission was investigated using a comprehensive set of diagnostics, including magnetic spectrometers and differential absorption spectrometers at various angles. EMP was measured using an array of broadband B-dot and D-dot probes and antennas with a bandwidth up to 18 GHz. The signals were recorded by a 33GHz/100GSps oscilloscope via ultra-low-loss cables. The experiments were performed using both metallic foil targets and low-density foams. With a help of novel focusing and target positioning system, the focal effective area was minimized and nearly relativistic on-target laser intensities were reached. In result, we observed target polarization currents of up to 10 kA, escaped electrons with energies exceeding 9 MeV, proton energies up to 5 MeV, and EMP spectral components extending to 18 GHz at an on- target laser power of 2 TW.

Acknowledgement: *This research has been supported by the GAČR – Project No. GM23-05027M, MŠMT – Project No. LM2023068, EUROfusion Grant Agreement No. 101052200, and Research Project AWP24-ENR-IFE.02.CEA-01 'Magnetized ICF'.*

THE IMPACT OF ION MIXING AND VISCOSITY ON THE EVOLUTION OF RICHTMYER–MESHKOV INSTABILITY

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Abstract. Hybrid fluid-PIC simulations aimed at a better understanding of the effect of ion diffusion and viscosity on the evolution of Richtmyer–Meshkov instability (RMI) under high pressure conditions

are described. The use of the hybrid fluid-PIC method, which treats ions as the traditional particle-in-cell method and electrons as a massless fluid, is motivated by the difficulty of handling material mixing in the context of commonly used fluid simulations. The super-diffusive behavior observed at the plasma interface is primarily attributed to the kinetic effect, which exerts a considerable influence on the evolution of the RMI. Applying time-varying viscosity and diffusion corrections to the analytical model of Carles and Popinet results in a high degree of alignment between the simulation outcomes and the theoretical predictions. These discussions contribute to a more detailed understanding of the physics of ion mixing and its effect on the evolution of RMI in ICF implosion.

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LABORATORIAL RADIATIVE SHOCKS WITH MULTIPLE PARAMETERS AND VERIFICATIONS TO CORE-COLLAPSE SUPERNOVAE

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Abstract. A radiative shock (RS) is one in which the density and temperature structures are affected by radiation from the shock-heated matter. In most astrophysical shocks, the temperature and density conditions lead to strong emission, with radiation thus playing a major role therein. In particular, RS exists in the blast waves of core-collapse supernovae (CCSNe), where the radiation pressure in matter is larger than the thermal one.

Here, we present experiments to reproduce the characteristics of CCSNe with different stellar masses and initial explosion energies in a laboratory. In these experiments, shocks are driven on the SGIII prototype laser facility. We get the necessary parameters for the first time to scale with CCSNe cases using relevant scaling laws. Furthermore, the rescaled theoretical values are similar to three CCSNe cases. Based on the laboratory conditions, the driving mechanism of the supernova explosions could be investigated and unified by multiple cases.

STUDIES ON TURBULENT MIXING AND ION-ELECTRON NON-EQUILIBRIUM IN HIGH ENERGY DENSITY

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Abstract. Turbulent mixing and ion-electron non-equilibrium are important phenomena in the relevance of inertial confinement fusion, astrophysics, laser-driven plasmas, etc. It has been revealed that the Rayleigh-Taylor instability induced turbulent mixing is greatly affected by a premixed layer or electron conduction effect at the interface, and a transition model is proposed to include the effect of the premixed layer. It has been proposed that an ion-electron non-equilibrium would greatly enlarge the central-hot sport ignition conditions, and the temperature relaxation between the ions and electrons of pure hydrogen plasmas or hydrogen-helium mixtures is studied with both molecular dynamics (MD) simulations and binary scattering theories, and new analytical models for the ion-electron temperature relaxation are proposed, and these models are validated with both MD simulations and laser-driven experiments.

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EXPERIMENTAL AND SIMULATION STUDIES OF 3D PERTURBATION IMPLOSION AT HIGH ENERGY DENSITIES

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Abstract. Convergent hydrodynamic instability represents an important mechanism driving mixling in laser fusion and astrophysical research. We developed an experimental platform on a 100-kJ-class laser facility to diagnose implosion hydrodynamic instabilities and mixing. Implosion performance degradation was systematically examined using targets with varying numbers of surface defects, yielding measurements of neutron yield, ion temperature, and hot-spot images. Analysis of the degradation mechanism was conduceded through two-dimensional isolated defect simulations. Three-dimensional simulations of the implosion process were performed using an Eulerian radiation hydrodynamics code with adaptive mesh refinement radiation diffusion modeling. These simulations qualitatively account for some discrepancies between certain two-dimensional simulation results and experimental data. Our findings advance the understanding of performance degradation patterns in implosions influenced by multiple defects.

THERMAL PLASMA FOR EMERGING NANOALLOYS: SCALABLE SYNTHESIS OF HIGH-ENTROPY ALLOY NANOPARTICLES

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Abstract. High-entropy alloy nanoparticles (HEA NPs), composed of five or more elements in near-equimolar ratios, offer unique properties from their compositional diversity and nanoscale effects. Despite growing applications in catalysis, energy, sensors, and biomedicine, scalable synthesis with atomic-level homogeneity remains challenging. We present a thermal plasma process enabling continuous production of uniform, highly crystalline HEA NPs (~50 nm) directly from elemental metal powders at rates up to 35 g/h, supporting kilogram-scale fabrication. The method allows facile control of nucleation temperature and cooling rate (10^3–10^8 K/s) via reactor pressure, plasma composition, and nozzle design. Nucleation and growth under varied conditions are analyzed using in-situ optical emission spectroscopy and CFD simulations to guide process optimization for large-scale HEA NP synthesis.

REferences:

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A FIRST-PRINCIPLES FRAMEWORK FOR PLASMA TRANSPORT AND THERMODYNAMIC PROPERTIES BASED ON QUANTUM COLLISION MODELLING

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Abstract. Plasma transport and thermodynamic properties are commonly evaluated using collision integrals derived from empirical cross-section models, limiting predictive reliability beyond calibrated conditions. In this work, a unified first-principles framework is developed for argon plasma, where collision integrals are constructed from energy-resolved quantum mechanical scattering calculations for electron–neutral, ion– neutral, and ion–ion interactions. Cross sections obtained from direct solutions of the Schrödinger equation are incorporated into the Chapman–Enskog formalism to compute electrical conductivity, viscosity, diffusion, and thermodynamic properties. Comparison with empirical models reveals measurable deviations in key transport coefficients, highlighting the influence of microscopic collision physics on macroscopic plasma behaviour and enabling scalable, physics-based plasma property evaluation.

CONTROL PARAMETER ANALYSIS OF ELECTRODE SPOT MOVEMENT FOR IMPROVED ELECTRODE LIFETIME ON A 300KW PLASMA TORCH

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Abstract. SINTEF is currently developing and optimizing a new plasma torch concept, whose main characteristic is that the electric arc is burning in front of the torch. This results in efficient heat transfer, high thermal efficiency, and very low demand for plasma gas per kWh generated heat. The 300kW torch uses water cooled copper electrodes that slowly suffer wear during operation. This wear should be minimal. The main wear mechanisms are electrode material melting or being evaporated at the anode/cathode spots. A key strategy to ensure the maximum electrode lifetime is to continuously move the electrode spots across the electrode surfaces using a DC magnetic field. Through direct observation of the plasma torchin operando in a dedicated water-cooled plasma test reactor, continuous electrode spot movement was successfully maintained, and sticking in specific locations was avoided, reducing local heating, and thus ensuring that wear is spread evenly with minimal amount of lost material.

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OPTICAL INVESTIGATIONS OF HYDOGEN PLASMA SMELTING REDUCTION FOR ENVIRONMENTALLY FRIENDLY STEEL PRODUCTION

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Abstract. Following the strong demand for reduction of carbon dioxide emission, hydrogen and plasma-based technologies offer process interesting options to avoid fossil fuel use in pyrometallurgy. A lab-scale hydrogen plasma smelting reduction was applied where hydrogen was used as environmentally friendly alternative to carbon as a reducing agent and an electric arc of 150 A transferred the necessary energy into the slag. Beside electric measurements of voltage and current, overview spectra with low temporal and spectral resolution and colour camera were used to analyse the general evolution of the reduction process. Spatially resolved optical emission spectroscopy of atomic iron and the hydrogen beta lines were applied for determination of plasma temperature and electron density, respectively. High-speed imaging was performed in parallel to track the arc position, 2D distribution, and arc length throughout the experiment.

Acknowledgement: *This research has been supported by the COMET (Competence Center for Excellent Technologies), the Austrian program for competence centers.*

INTEGRATED ASPEN PLUS MODELING AND EXPERIMENTAL INVESTIGATION OF GRAPHITE ELECTRODE-BASED AR-CO_2 THERMAL PLASMA GASIFICATION OF PLASTIC WASTE

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Abstract. This study investigates Ar-CO_2 thermal plasma gasification of low-density polyethylene for H_2-rich syngas production. An integrated process model was developed in ASPEN Plus v14.0. The model was validated using an in-house lab-scale reactor. Thermodynamic analysis showed that optimized gasification conditions produced high-purity syngas (95.6 vol%), mainly composed of 52.0 vol% H_2 and 43.6 vol% CO, while CO_2 formation remained limited to 1.18 vol%. The system achieved a specific syngas yield of 4.30 Nm^3/kg plastic and a cold gas efficiency of 74.8%. Energy analysis indicated a specific energy consumption of 4.04 kWh/Nm^3 of H_2 at the laboratory scale, reducing to 1.35 kWh/Nm^3 of H_2, when scaled to a 10 kg/h pilot system. Integration of carbon capture and utilization further reduced emissions, achieving a net carbon footprint of 0.06 kg CO_2/kg plastic, representing an 88% reduction compared with conventional incineration.

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PLASMARC4GREEN: INTEGRATED MODELLING AND IN-SITU DIAGNOSTICS FOR PLASMA-BASED GREEN METALLURGY

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Abstract. PlasmArc4Green (PA4G) aims to develop a unified modelling and diagnostics framework for electric arc and plasma-based green metallurgy. Across its six coordinated projects, PA4G develops first-principles plasma property databases, multifluid and LTE/NLTE arc models, and detailed near-electrode descriptions, complemented by experiments on plasma-solid and plasma-liquid interactions.

Experimental progress includes lab- and pilot-scale hydrogen plasma smelting reduction studies using high-speed imaging, optical emission spectroscopy, gas analysis, and microwave-plasma torch trials. PhD students and partner institutes contribute simulation tools, optical diagnostic methods, and metallurgical expertise, enabling cross-validation between models and measurements. This contribution provides an overview of PA4G's objectives, presents key modelling and experimental achievements and outlines how these results support the development of future carbon-neutral plasma-based reduction processes.

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CYLINDRICAL MAGNETRON SPUTTERING AND GAS AGGREGATION FOR THE PREPARATION OF METAL NITRIDE NANOPARTICLES

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Abstract. Cylindrical magnetron sputtering combined with the gas aggregation has been used for the preparation of metal nitride nanoparticles (NPs) such as Cu_xN and Fe_xN. Different mixtures of Ar and N_2 have been used to tune the chemical composition, size and shape of resulting NPs. In case of sputtering of Cu in N_2, cubic, stoichiometric and hollow Cu_3N NPs have been deposited They are thermally stable until 200°C under the ambient atmosphere, transforming to CuO at higher temperatures. The catalytic and sensing applications of these NPs are envisaged. Sputtering Fe target in different Ar/N_2 mixtures produces different nitride stoichiometries. The morphology of NPs can be tuned between spherical and tetragonal depending on the experimental conditions. Further perspectives of gas-aggregated Cu_xN and FeN NPs are outlined.

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MAGNETRON-SPUTTERED GRAPHENE OXIDE-TIO_2/ZNO HETEROJUNCTIONS FOR PHOTOACTIVE ENERGY CONVERSION AND SENSING

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Abstract. Magnetron sputtering enables precise control over the growth of oxide thin films for advanced devices. In this work, graphene oxide (GO)-TiO_2 and ZnO heterojunctions were fabricated by reactive DC magnetron sputtering under controlled oxygen partial pressure, enabling tuning of defect density and microstructure. The integration of GO with metal oxides promotes interfacial charge transfer and modulates electronic transport. Under UV illumination, the heterostructures exhibit enhanced photoresponse due to improved separation of photogenerated carriers at the GO/oxide interface. This leads to increased sensitivity and faster recovery in gas sensing, together with improved photoactive behaviour for energy conversion. The role of oxygen vacancies and surface states is discussed. These

results demonstrate that plasma-assisted fabrication provides an effective route for multifunctional sensing and energy devices.

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MODEL-BASED INVESTIGATION OF A PLASMA-ASSISTED GLASS MELTING PROCESS

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Abstract. This study presents a comprehensive CFD modeling approach to investigate fluid flow and heat transfer in a novel hybrid glass-melting furnace operated with microwaves and microwave plasma. The three-dimensional model solves the conservation equations of mass, momentum, and energy, including turbulence as well as species transport with chemical reactions. Electromagnetic effects are neglected, and the microwave plasma is represented by a volumetric heat source with a defined energy distribution. Initial simulations and validation were conducted for air as plasma gas. The model predicts temperature and velocity fields and enables the identification of hot spots as well as the optimization of flow conditions to improve heat transfer into the glass melt. Overall, the model provides a useful numerical framework for the investigation of plasma integration in high-temperature processes and supports the evaluation and optimization of operating conditions.

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ROTATING ELECTRIC AND MAGNETIC FIELDS FOR MASS SEPARATION.

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Abstract. Rotating electric and magnetic fields generate a ponderomotive force on ions along an axial magnetic field. The direction of the force depends on whether the ion cyclotron frequency is larger or smaller than the fields rotation frequency. Thus, ions of different mass could be pushed in opposite directions. This process could be used for the important process of mass separation.[1] For example, Li^6, crucial for generating tritium for fusion, has to be separated from Li^7, the majority isotope. We have recently studied this process under standing waves.[2]. However, exciting such waves in a plasma is difficult. In this talk we examine configurations that generate vacuum rotating electric and magnetic fields. We examine how, despite the gradients in the fields, the ion separation process is valid.

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ENGINEERING AND AGING OF RADICAL-RICH AMINE PLASMA POLYMERS FOR BIOAPPLICATIONS

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Abstract. Engineering a successful bioactive plasma polymer (PP) surface relies on key chemical features: amino groups and unsaturated bonds, which drive excellent reactivity towards antibodies in immunosensors, and free radicals, employed to covalently bind complex molecules to surfaces exposed to energetic ion bombardment. PP prepared from cyclopropylamine (CPA) exhibits high radical density, which is not induced by energetic ions but rather follows from the CPA monomer's unique structure. We investigated the decay kinetics, accounting for diffusion and recombination of free radicals. Fitting the data revealed the presence of two types of radicals that differ in their diffusion coefficient. Similarly, the EPR spectra were better fitted when considering two radicals that differ chemically in their g-factors. Additionally, we investigated how temperature and immersion in liquids affect film stability and radical lifetime, as these are critical requirements for bioapplications.

BACTERIAL PHYSIOLOGICAL RESPONSE TO PLASMA- ACTIVATED WATER UNDER NUTRIENT-RICH CONDITIONS

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Abstract. Plasma-activated water (PAW) is an emerging antimicrobial agent due to plasma-generated reactive oxygen and nitrogen species. While its bactericidal properties are well established, its effects under realistic, nutrient-rich conditions remain less understood. In this work, the response of Escherichia coli to PAW diluted in Lysogeny Broth was investigated over a range of concentrations. Bacterial activity was quantified using colony-forming unit (CFU) counting and nanomotion sensing based on atomic force microscope cantilevers. CFU results confirmed complete inactivation at high PAW concentrations, while intermediate concentrations led to increased bacterial proliferation relative to controls. Nanomotion measurements revealed enhanced activity at sub-lethal concentrations followed by suppression beyond the inhibitory threshold. These results indicate a biphasic response consistent with hormesis, highlighting the importance of controlling PAW concentration in antimicrobial applications.

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PLASMA SYNTHESIS OF NANOPARTICLES IN GAS AGGREGATION SOURCES: REFLECTION DURING DEPOSITION

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Abstract. A versatile physical method for nanoparticle (NP) synthesis is provided by gas aggregation sources (GAS). An important yet often overlooked effect during NP deposition via GAS, is NP reflection from the substrate, which is especially crucial when precisely controlled sub-monolayer coatings are required. The reflection phenomenon has previously been observed and described for plasma polymer (pp) NPs. In this work, we demonstrate that NP reflection is a universal feature of NP film growth, independent of the material system. Experiments on pp, metal and metal@pp core@shell NPs are compared with numerical simulations of NP deposition that accounts for reflection. The model employs three phenomenological parameters and two scaling factors, and successfully captures the experimentally observed behavior of NPs across different material systems. Together, these results establish a unified framework for understanding NP reflection, enabling precise control of surface coverage.

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ACTIVE AIRFLOW CONTROL USING PLASMA-ON-A-CHIP

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Abstract. Ionic wind has emerged as a promising method for silent, rapid airflow control in microfluidic and aerodynamic applications. However, high voltage requirements and poor electric-to-wind conversion efficiency remain significant challenges.

To overcome these limitations, we propose a micro-electromagnetic device that generates stable ionic wind at significantly reduced voltages while improving conversion efficiency through Lorentz-force-driven charge transport. By injecting initiation carriers and inducing periodic plasma movements, stable atmospheric plasma is achieved at one-tenth the voltage required for two-electrode discharges. These Lorentz-force-driven movements are highly effective for ionic wind generation, with plasma movement speeds reaching nearly 5 m/s. The induced airflow was characterized using particle image velocimetry, revealing an airflow propagation profile and a maximum velocity of 0.4 m/s at 1 W of plasma power.

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ANALYSING THE PERFORMANCE OF A NOVEL PLASMA DEPOSITION TECHNOLOGY USING PLASMA DIAGNOSTICS

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Abstract. Plasma coating technologies such as PVD and PECVD are widely applied to produce high-quality functional and protective thin films with superior mechanical, electrical and optical properties. While parameters e.g. substrate temperature, bias and pressure influence film growth, plasma characteristics such as electron density and temperature fundamentally control ionization efficiency. Conventional DC magnetron sputtering often exhibits low metal ionization, leading to porous and columnar microstructures. To improve coating density and mechanical properties Bosch Coating Technology developed a microwave source assisting magnetron sputtering to enhance plasma density. Langmuir-probe measurements and OES confirm an increase in electron density, electron temperature and ion flux. Ti films deposited using microwave assisted magnetron sputtering showed higher hardness and reduced roughness, indicating improved densification and coating performance. XRD revealed the growth of metastable fcc-Ti.

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GAS FLOW AND MIXING EFFECT ON MICROWAVE PLASMA METHANE DRY REFORMING PRODUCT

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Abstract. In this work, a 2.45 GHz atmospheric-pressure microwave plasma system was used to process CH_4 and CO_2. The gases were supplied under different conditions, including premixed feeding and separate injections, with tangential and axial configurations, to study their effects on the process. The experiments were carried out at a plasma input power of 6 kW. The flow rates ranged from 21 to 65 slm for CO_2 and from 5 to 25 slm for CH_4, tested across various mixing and feeding arrangements.

The best performance was achieved with 16 slm CO_2 and 21 slm CH_4 fed tangentially, along with an additional 5 slm CO_2 supplied axially. Under these conditions, the output gas composition contained 34 vol.% hydrogen and 34 vol.% carbon monoxide (CO). The remaining components included 15 vol.% CO_2 and 14 vol.% CH_4. Interestingly, 3 vol.% acetylene was detected, indicating that the reforming process proceeds through a hybrid mechanism of pyrolysis and gasification.

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EFFECT OF CURRENT-PATH GEOMETRY ON PLASMA FLOW SELF-ORGANIZATION

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Abstract. Self-organization is a fundamental feature of current-driven motion in resistive plasmas where generated magnetic fields interact with imposed current distributions. In this work, we present numerical simulations of electro-vortex type flows in a current carrying plasma confined within a cylindrical geometry. A one-fluid magnetohydrodynamics model is employed, solving for the magnetic vector potential in a regime where the magnetic Reynolds number is of order unity. The effect of electrode area asymmetry is examined by varying the cathode to anode area ratio – this modifies current constriction and the resulting Lorentz force distribution. The three-dimensional simulations show that changes in current path geometry has an observable influence on the emergence and structure of coherent rotating flow patterns. These results highlight the role of boundary geometry in controlling self-organization in current-driven plasma flow.

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ELASTIC CROSS SECTIONS AND CHARGE TRANSFER CROSS SECTIONS IN H^+-NE AND H^+-N COLLISIONS AND ISOTOPE EFFECT OF HYDROGEN.

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Abstract. The integrated, and transport cross sections are calculated for the H^+-Ne(1S), H(2S)-Ne^+(2P), and H^+-N(4S) collisions. The energy range of 10^{-4} - 55 hartree ($2{,}7.10^{-3}$ - 1500eV) has been covered.

The charge transfer in a nonadiabatic spin–orbit induced process N(4S) + $H^+ \rightarrow N^+$(3P) + H(2S) is also investigated. The cross section and the rate constant are reported and compared with other calculations, correcting the previous values based on approximate potentials. Novel methodology based on two-dimensional nonadiabatic wavepacket dynamics will be mentioned.

The calculation is extended to collisions involving deuterium and tritium, which are relevant for the transport codes (such as SOLPS-ITER) used in the modeling of fusion plasma, in particular the possibility of scaling is important. The energy range also allows for the treatment of low-temperature plasmas.

NUMERICAL INVESTIGATION OF HYBRID STABILIZED ARC BEHAVIOR IN A DIRECT CURRENT (DC) NON-TRANSFERRED ARC (NTA) THERMAL PLASMA SYSTEM

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Abstract. In DC-NTA thermal plasma system, an electric arc established between the cathode and anode heats the incoming gas to generate thermal plasma. Using air as the plasma forming gas erodes the hot cathodes. Injecting air tangentially to form vortex and involve in the plasma formation, while feeding argon coaxial to the hot cathode as the shielding gas is an operational strategy to mitigate erosion. In this case, the arc is stabilized by both axial and tangential gas flows, termed as hybrid stabilization. Also, there is a significant variation in the plasma properties due to the inhomogeneous mixing of argon and air. To investigate this complex multi-physics phenomenon, a Local Thermodynamic Equilibrium (LTE) based plasma model has been developed using OpenFOAM. The influence of operating parameters like plasma current, argon gas mass flow rate, axial-swirl gas mass flow rate ratio and different vortex generation techniques on the arc behavior are discussed for ideal operation.

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PHYSICS-INFORMED SIMUALTION OF THE HALL EFFECT MODE OF A MULTIMODE PLASMA THRUSTER

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Abstract. State-of-the-art multimode propulsion systems provide adaptable mission capabilities by utilizing distinct operational modes. In efforts to create a versatile and agile design, we have identified three modes of ion acceleration: a pulsed plasma thruster for Lagrange point transfer, a Hall effect thruster (HET) for orbit maneuvering, and a rarified gas electrojet thruster for fine control. Here, we solely focus research efforts on the dynamics of the HET mode that is investigated numerically with a Physics-Informed Neural Network (PINN). The one dimensional simulation results will demonstrate the influence of boundary conditions on both solution stability and the resulting plasma solution. The efficacy of PINNs will also be explored as a future design tool for efficiently simulating the complex thrust dynamics of a multimode thruster.

IMPACT OF AIR IMPURITY QUENCHING ON THE DETERMINATION OF ELECTRON TEMPERATURE AND DENSITY IN ATMOSPHERIC-PRESSURE HELIUM PLASMA JETS

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Abstract. This study investigates electron temperature (T_e) and density (n_e) in atmospheric-pressure plasma jets by considering quenching between metastable helium and nitrogen/oxygen molecules in the air.

Optical emission spectroscopy was performed in the plasma plume region. Based on the framework by Lin et al. (2023), the collisional-radiative model was extended to include Penning ionization. Parameters (T_e, n_e, metastable densities, and He/air ratio) were optimized via grid search by minimizing the discrepancy between measured and calculated population densities of helium excited states.

The He+Air model yielded $T_e = 1.21$ eV and $n_e = 3.9 \times 10^{11}$ cm^{-3}. In contrast, the Pure He model gave an unrealistic 0.23 eV. Metastable densities dropped by ~6 orders of magnitude in the He+Air model due to quenching. Although the He+Air model had a higher fitting error, its results are physically consistent with active streamer discharges. The He+Air model provides the physically correct solution.

INVESTIGATION OF SURFACE STREAMERS IN SURFACE DIELECTRIC BARRIER DISCHARGES UNDER NS EXCITATION

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Abstract. Nanosecond-pulsed surface dielectric barrier discharges (sDBDs) have emerged as promising tools for the energy-efficient conversion of airborne pollutants such as volatile organic compounds (VOCs) and nitrogen oxides. Streamers play a central role in their performance and determine discharge evolution. Using the 2D fluid plasma simulation code nonPDPSIM, the effects of adjusting the voltage pulse, discharge pressure, and dielectric material, e.g. due to catalytic coating of the surface, on surface charge dynamics are investigated to analyze changes in streamer propagation. The results show that these parameters significantly influence streamer length, propagation velocity, and direction. Qualitative agreement with time-resolved optical emission spectroscopy measurements highlights the value of the simulations for understanding streamer physics and improving plasma driven pollutant conversion.

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PLASMA IN LIQUID-GAS-LIQUID SYSTEMS: CONDUCTIVITY- AND COMPOSITION-DEPENDENT CHARACTERISTICS

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Abstract. Plasma discharges at gas-liquid interfaces have been widely studied for applications such as water treatment and biomedical processes. While the gas-liquid interface is a key region for reactions and mass transfer, the influence of liquid properties on discharge behavior remains unclear.

This study examined plasma discharges in a liquid-gas-liquid system, where the applied and grounded electrodes are immersed in liquids, confining the discharge to the gas-liquid interfaces under atmospheric pressure. We used phosphate-buffered saline (PBS) and ultrapure water (UPW) in four configurations.

Electrical, optical and chemical analyses revealed that discharge behavior and interfacial reactions depend on liquid conductivity and configuration. Spark and glow discharges occured in PBS-PBS, whereas dielectric-barrier discharges occured in UPW-UPW.

These results demonstrate that liquids act as active components governing discharge modes and interfacial reactions in gas-liquid plasma systems.

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THE EFFECT OF ELECTRODES MATERIALS ON THE EMISSION OF ELECTROMAGNETIC WAVES.

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Abstract. We investigated the effect of electrode materials on the spectra of electromagnetic waves emitted by a volume dielectric barrier discharge in air over a frequency range up to 500 MHz. The electrode system of this discharge consists of a driven electrode, a grounded electrode, and a dielectric barrier. For the same electrode configuration, we measured the discharge electrical parameters and the electrical component of the emitted waves when both driven and grounded electrodes were made of the same material: either copper or aluminum. We found that, for the same discharge voltage, the energy delivered to the discharge is approximately the same for both materials. However, the emitted spectra are more complex. For frequencies below 48 MHz, the frequency distributions are the same, with the peak of power level at frequency 38 MHz. For frequencies above 48 MHz, there are significant differences in the emitted spectra regarding the power levels of individual frequency peaks.

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INVESTIGATION OF ELECTRON BEAM FLUX AND ENERGY IN WEAKLY MAGNETIZED PLASMAS WITH A GRID SYSTEM

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Abstract. In this study, we investigated the effects of a non-uniform magnetic field on the radial distributions of electron-beam flux and energy in an ICP with a grid system. Electron beams were extracted using varying acceleration voltages and controlled via electromagnetic coil currents, with experimental results validated through COMSOL Multiphysics trajectory simulations. The results demonstrate that while zero or weak magnetic fields maintain radial uniformity, increasing magnetic field strength enhances electron beam flux and induces a center-high, edge-low distribution profile. The observed profile evolution is primarily attributed to the large radial magnetic-field component near the chamber edge, which preferentially steers electron motion toward the center. Consequently, these results and associated physical mechanisms provide significant insights into the precise control of electron beam characteristics.

ADVANCED CURLING PROBE FOR ELECTRON DENSITY MEASUREMENT

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Abstract. The Curling probe is a conductive spiral on a dielectric substrate whose resonant frequency shift with surrounding permittivity, enabling local plasma density measurement. Its small size allows non-intrusive integration into chamber walls for process monitoring and control. However, detectable density ranges are limited by the probe's design frequency. This study introduces the Curling probe (CP) and characterizes it experimentally in a hot tungsten cathode DC plasma system at low-pressure argon. We compare electron densities measured by this probe, and Langmuir probe (LP) under identical conditions, focusing on low-pressure regimes, probe behaviour near dielectrics, and non-reactive plasmas.The results show CP densities (n_e) closely matching LP(n_e) values across discharge currents, confirming its reliability and validate CP for robust, non-intrusive n_e monitoring in plasma discharges, with implications for plasma process optimization.

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OPTO-ELECTRICAL CHARACTERISATION OF NANOSECOND DIELECTRIC BARRIER DISCHARGE ON A SINGLE STRIP ELECTRODE: EFFECTS OF PULSE WIDTH, POLARITY AND FREQUENCY

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Abstract. Nanosecond pulsed surface dielectric barrier discharge with a single- strip geometry offers a unique platform for fundamental study of discharge physics. In contrast to multi-strip electrode

configurations, it is free of complicating interactions with neighboring plasma channels. This contribution presents a systematic opto-electrical study of ns-SDBD sustained on a single-strip Ti thin-film electrode in dry synthetic air at atmospheric pressure. The pulse widths of 200, 300, 400, and 500 ns, both positive or negative polarities, and several repetition frequencies were investigated over a wide range of applied voltages. The results demonstrate that pulse width exerts a pronounced influence on both the temporal evolution and the spatial distribution of the discharge emission. Voltage polarity affects discharge morphology, and increasing the pulse repetition frequency introduces measurable thermal accumulation between successive pulses.

ATOMIC LAYER ETCHING OF TWO-DIMENSIONAL MATERIALS AND SURFACE FLATTENING OF SIO^2 VIA PLASMA-ENHANCED ELECTRON ETCHING (PE^2)

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Abstract. Atomic-scale precision etching of dielectric materials remains challenging due to surface roughening and plasma-induced damage in conventional fluorine-based processes. Here, we present a plasma electron-enhanced etching (PE^2) technique that minimizes chemical reactions and ion bombardment. In an inert helium plasma environment, energetic electrons are selectively accelerated toward the surface, depositing energy in the near-surface region and weakening atomic bonds to enable controlled layer-by-layer removal. The PE^2 process is demonstrated for Silicon dioxide, Silicon nitride, and the two-dimensional material Hexagonal boron nitride, achieving atomic-layer etching with excellent surface uniformity. These results highlight PE^2 as a low-damage, high-precision etching platform for dielectric and layered materials.

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RECOMBINATION OF HCO$^+$ IONS WITH ELECTRONS IN THE TEMPERATURE RANGE OF 80–200 K

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Abstract. Dissociative recombination of HCO$^+$ with electrons is a key process in cold interstellar chemistry, yet published low-temperature data remain inconsistent. We present measurements performed in the 80–200 K range using a stationary afterglow apparatus combining cavity ring-down spectroscopy with microwave diagnostics. The main advantage of this approach is in situ monitoring of both HCO$^+$ and electron densities, enabling a more reliable determination of the recombination rate coefficient even when additional ions are present in the afterglow. The measured temperature dependence is $\alpha(HCO^+) = (1.32 \pm 0.14) \times 10^{-7}(300/T)^{(0.52\pm0.14)}cm^3s^{-1}$. We also determined pressure broadening of the P(4) transition of the $20^00 \leftarrow 00^00$ band of HCO$^+$ and upper estimates for helium-assisted HCO$^+$.CO cluster formation. The results are relevant for modelling of cold interstellar clouds.

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STUDY OF TRANSIENT SPARK USING SCHLIEREN IMAGING

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Abstract. Transient spark (TS) is an atmospheric-pressure self-pulsing discharge characterized by a streamer-to-spark transition, producing short (10–100 ns) high-current (~10 A) pulses at repetition rates of 1–10 kHz. TS is an efficient source of reactive nitrogen species (RNS) and is widely used for plasma-activated water generation.

This study investigates gas dynamics induced by TS discharge in an open reactor under various airflow conditions using high-speed Z-type schlieren imaging.

Three gas-dynamic phases are identified. The pre-breakdown phase involves ionic wind and initial gas heating within a narrow streamer channel. The breakdown phase includes rapid spark channel formation and generation of a radially expanding shock wave. During the post-discharge phase, the shock wave propagates further while the conductive plasma channel decays.

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CHYHIN COMPLEX PULSES OF NEGATIVE CORONA: PHYSICAL MECHANISMS, EXPERIMENTAL AND MATHEMATICAL JUSTIFICATION. TRICHEL PULSES AS A PARTICULAR CASE

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Abstract. A unified physical model of complex current pulses in negative corona discharge (1988–2014) is presented. It is shown that classical Trichel pulses are a special case occurring only at high electronegative impurity concentrations, where the main pulse disappears, leaving only the precursor. In electropositive gases (Ar, N_2) and mixtures with 10^{-3-21}% electronegative additives (O_2, the full pulse structure was first observed and justified: a stepped leading front, the main pulse, and superimposed HF-oscillations. Numerical modeling (e/i fluxes, Poisson eq.) revealed that the front step results from local field enhancement in the cathode layer, while HF-oscillations stem from relaxation processes in the same region. The model describes also transitions to breakdown and glow discharge. Unlike simplified interpretations, the "Chyhin complex pulse" concept accounts for diverse experimental conditions and realistic cathode geometry.

INVESTIGATION OF PLASMA-INDUCED SYNTHESIS OF COMPLEX ORGANIC COMPOUNDS IN CARBON MOXIDE-BASED GASEOUS MIXTURES

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Abstract. Electric discharges in gases can be used under laboratory conditions to study chemical processes in prebiotic and planetary atmospheres.

This work investigates the discharge-initiated synthesis of molecular life precursors in CObased gas mixtures (CO, CO/H_2, CO/N_2, and $CO/H_2/N_2$). The influence of mixture composition on the type

and yield of plasma-generated products was analyzed. The plasma was characterized via high-resolution optical emission spectroscopy, while gaseous products were monitored in situ using proton transfer reaction mass spectrometry.

OES identified H, C, O atoms, C_2 molecules, and CN radicals as key reactive species. Mass spectrometry confirmed the formation of diverse hydrocarbons, nitriles, amines, aldehydes, and alcohols. The highest chemical complexity were achieved in the $CO/H_2/N_2$ mixture.

These results provide a fundamental basis for understanding molecular evolution in the Earth's early atmosphere, interstellar matter, and exoplanetary environments.

HOW SPACE CHARGE INJECTED BY A POSITIVE LEADER OF A LONG SPARK AND LIGHTNING CAN GENERATE A RETURN STREAMER CORONA AND AN IONIZATION WAVE

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Abstract. Currently, a phenomenon known as the "recoil leader" has been reliably established experimentally. Recoil leaders manifest as luminosity waves that propagate toward the channel of a previously existing, bright lightning or long spark leader channel. They frequently retrace the pre-existing branches of the main leader channel [4]. On the other hand, radio interferometry has revealed a phenomenon within thunderstorms where radio emission sources move toward what is presumably a positive leader channel. This phenomenon has been termed "needles" [2]. We propose a hypothesis that explains recoil leaders and "needles" based on the phenomena of return streamer corona, which has been observed during laboratory experiments with ultra-long sparks.

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TIME-DEPENDENT NUMERICAL ANALYSIS OF REACTIVE SPECIES TRANSPORT IN A 10 MHZ ATMOSPHERIC PRESSURE PLASMA JET USING COMSOL MULTIPHYSICS.

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Abstract. Cold atmospheric pressure plasma (CAPP) is an effective source of reactive species for biomedical applications. In this work, a time-dependent COMSOL Multiphysics model was developed to analyse reactive species transport in a Tesla coil-based CAPP jet operated at 10 MHz[1]. The device was characterized by OES, UV-visible absorption, fluorescence spectroscopy, confirming O, OH, O3 and H2O2 formation. A two-dimensional axisymmetric model coupled Laminar Flow and Transport of Diluted Species interfaces was used. Argon (Ar) was introduced at 8 Lpm, corresponding to an inlet velocity of 1.4 m/s. The Ar-air flow was solved using incompressible Navier-Stokes and continuity equations with convection-diffusion transport. Dirichlet inlet, no-slip wall, no-flux species and open outflow boundary conditions were applied. The model evaluates axial propagation, radial spreading, dilution and decay of reactive species from the plasma outlet.

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SPECTROSCOPIC DIAGNOSTICS OF ARC DISCHARGE PLASMA BETWEEN COMPOSITE MO-CU ELECTRODES WITH OXIDE IMPURITIES

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Abstract. This work presents the results of the spectroscopy investigation of the arc discharge plasma parameters at a current of 3.5 A in an argon flow. In particular, the discharges between electrodes manufactured of a composite Mo-Cu material with the addition of oxide impurities, namely 2% Y_2O_3 , 5% Y_2O_3 and 2% Al_2O_3, were investigated.

The Boltzmann plot technique based on the absolute emission intensities of the Cu I and Mo I spectral lines was used to determine the key plasma parameters: temperature and number density of metal atoms in the discharge gap.

Special attention is paid to assessment of local thermodynamic equilibrium realization in the plasma under study. A comparative analysis of the obtained temperature values determined by different components of the composite (Mo and Cu atoms) was carried out. The influence of the number density and nature of oxide admixtures (Y_2O_3 and Al_2O_3) on the realization of local thermodynamic equilibrium in plasma was studied.

PLASMA-ASSISTED METHANE PYROLYSIS IN A DC THERMAL PLASMA TORCH: EXPERIMENTAL INVESTIGATION AND THERMODYNAMIC–KINETIC MODELING

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Abstract. Methane pyrolysis in thermal plasma reactors offers a promising approach to producing low-carbon (turquoise) hydrogen. This study examines the decomposition of methane in a DC nitrogen thermal plasma torch with post-discharge methane injection. Experiments were conducted using a tornado-type torch with a reforming chamber and rapid quenching. The results were interpreted using thermodynamic equilibrium calculations based on Gibbs free-energy minimisation and gas-phase kinetic simulations employing a simplified mechanism. The temporal and spatial evolution of species was analysed at temperatures estimated from the energy balance. High methane conversion and hydrogen mole fractions of 20–30 vol% were obtained, which is consistent with the experimental results. This combined analysis demonstrates the advantages of post- discharge methane injection for achieving stable plasma operation, while also clarifying the key mechanisms that govern methane pyrolysis in thermal plasma jets.

COMBINED DIFFUSION COEFFICIENTS IN AR–CU AND HE–CU BINARY PLASMAS AT ATMOSPHERIC PRESSURE

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Abstract. This study examines diffusion phenomena in binary argon-copper and helium-copper thermal plasmas over a wide temperature range (300–30,000 K) at atmospheric pressure for various concentrations of copper vapor, composition, temperature, pressure gradients, and electric fields. The results reveal three regimes: a low-temperature binary diffusion regime, an intermediate region dominated by ionization with peak values, and a high-temperature regime governed by Coulombic interactions. process optimization and product quality.

NUMERICAL INVESTIGATION OF THERMAL PLASMA FLOW CHARACTERISTICS IN STEP AND HORN NON-TRANSFERRED DC PLASMA TORCHES

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Abstract. This study presents a numerical approach for simulating axisymmetric thermal plasma flows in a rod-type, non-transferred DC plasma torch operating with nitrogen. The continuity, momentum, and energy equations with the k–ϵ turbulence model are solved using the finite volume method. The electric current is calculated from Ampere's law, and the magnetic field from Ohm's law. A SIMPLE algorithm with a SIP solver is used to solve the governing equations. Two torch designs, Step and Horn, are analyzed at currents of 40–90 A and flow rates of 25–95 SLM. The torch lengths are 46 mm and 51.8 mm for two designs, respectively, with an inlet width of 4.5 mm. The Step design produces higher outlet axial velocities (100–200 m/s) than the Horn design (20–100 m/s). The outlet temperature ranges from 2800–5200 K for Step and 2400–4600 K for Horn.

STUDY ON THE PRODUCTION CHARACTERISTICS OF TURQUOISE HYDROGEN AND CARBON MATERIALS USING MICROWAVE PLASMA TORCHES

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Abstract. This study explores turquoise hydrogen production via methane pyrolysis using microwave plasma torches. This technology excels by eliminating electrode contamination and enabling continuous operation within a high- temperature environment ($> 7,000$ K).The results demonstrate the successful simultaneous production of high-purity hydrogen and valuable carbon byproducts, specifically carbon black and multi-layer graphene (MLG). By integrating clean energy generation with the synthesis of industrial-grade nanomaterials, this process proves its economic feasibility and industrial value. These findings highlight a sustainable, scalable approach to carbon-neutral energy solutions.

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COMPARATIVE STUDY OF MECHANICAL PROPERTIES OBTAINED BY PLASMA IMMERSION ION IMPLANTATION AND PLASMA NITRIDING IN TOOLOX 44 STEEL

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Abstract. Sheet metal forming and cutting processes in the metal-mechanical industry require continuous improvements in alloy steel dies to enhance durability under high and repetitive working pressures that accelerate tool wear. Traditionally, steels used in these operations relied mainly on chromium-based alloying to increase mechanical strength. Advances in surface engineering introduced coatings that extend tool life and reduce friction due to low surface roughness. However, under high contact pressures these coatings may fail, since the thin layers can be removed during operation. In such conditions, thermochemical treatments based on nitrogen diffusion, such as plasma nitriding, become more effective because they promote deeper surface hardening. This study evaluates Plasma Immersion Ion Implantation (3IP) applied to Toolox 44 steel and compares it with conventional plasma nitriding. Results show that 3IP improves resistance to adhesive and abrasive wear under high-pressure conditions.

THERMAL PLASMA TECHNOLOGY AS A VERSATILE TOOL FOR MATERIAL PROCESSING AND ENERGY APPLICATIONS

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Abstract. Thermal plasma technology provides a versatile platform for material processing, enabling thermochemical transformations under extreme temperature and reactive conditions. Its flexibility arises from high energy density and variability of plasma generation methods and media, influencing plasma properties and process behaviour. At the Institute of Plasma Physics of the Czech Academy of Sciences, plasma sources cover a broad power range, from low-power units (3–5 kW) to systems exceeding 100 kW. These include commercial devices and self-developed torches, such as the hybrid H_2O–Ar stabilised DC arc torch (up to 160 kW), microwave torches (up to 100 kW), and low-power comercially available torches. Plasma properties depend on power and plasma-forming media (e.g. water vapour, argon, air, or water–alcohol mixtures). Applications include waste treatment, material synthesis and surface modification, with conversion of feedstocks into syngas (H_2, CO) and solid products.

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INACTIVATION OF CRYPTOSPORIDIUM USING PLASMA NANO-MIST TECHNOLOGY

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Abstract. *Cryptosporidium parvum* (*C. parvum*) is an apicomplexan protozoan parasite that infects mammals and causes severe gastrointestinal disease. Its oocysts possess multilayered structures and acid-resistant lipid membranes, making them highly resistant to conventional disinfectants. This study aims to establish a simple and efficient inactivation method using novel plasma nano-mist technology. Plasma generates reactive oxygen species in the mist, unlike chemical agents, these species do not persist long-term, thereby reducing environmental impact. It also produces nanometer-scale mist for uniform coverage in livestock housing. To evaluate efficacy, plasma-treated phosphate-buffered saline was applied to *C. parvum*, and inactivation was assessed by excystation and cellular infection assays. The results suggest that plasma inhibits the parasite infection process and suppresses cellular infection, highlighting potential as a hygiene management technology for livestock facilities.

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POST-PLASMA CATALYSIS SCHEMES IN AMMONIA SYNTHESIS

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Abstract. Current research in plasma catalysis focuses on in-plasma catalysis, where the plasma is operated directly in front of the catalyst surface. This approach poses significant scientific challenges, as the plasma- catalyst interaction may lead to synergisms or anti-synergisms when aiming at maximizing species conversion or species selectivity. We use a kHz DBD plasma jet array to study the role of plasma-generated species in ammonia synthesis. The discharge initiates guided streamers that impinge on the catalyst surface. Plasma-catalyst contact occurs only for about 2% of the pulse duration. This separates the plasma dynamics from the surface chemistry. The jet array consists of two sets of three individual jets. Each set of electrodes is powered independently and fed with different gases. We investigate the impact of species injection and discharge timing on the ammonia yield by measuring the product density via molecular beam mass spectrometry.

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ENHANCED IGNITION IN RF ION THRUSTERS VIA FERRITE-CORE ASSISTED PRE-IONIZATION

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Abstract. Plasma thrusters are increasingly used in earth orbiting satellites. Among these, Radio Frequency (RF) ion thrusters provide very high specific impulse. However, their widespread application is limited by the high power requirement for the transition of the system from the Capacitively Coupled Plasma (CCP) to the Inductively Coupled Plasma (ICP) mode.

This study proposes pre-ionizing the propellant within the feeding tube, before entering the primary ionization chamber, eliminating reliance on high-intensity ignition bursts. Additional system includes a toroidal ferrite core, encircled by an auxiliary RF coil that induces a high intensity electromagnetic field within a small volume, achieving highly efficient propellant ionization. This localized field triggers ionization of the propellant resulting in reduced power threshold, and a reduced ignition delay of the main discharge, thus eliminating the need for bulky power processing units and preventing propellant waste during ignition.

SURFACE CHARACTERIZATION OF $TI_{25}TA_{25}NB_3SN$ ALLOY TREATED BY PLASMA ELECTROLYTIC OXIDATION

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Abstract. The Ti25Ta25Nb3Sn alloy is a promising metallic biomaterial due to its high biocompatibility, corrosion resistance and mechanical stability. This study investigated the surface modifications induced by plasma electrolytic oxidation (PEO). The treatment was conducted under direct current at 350, 450 and 550 V for 6 minutes in an electrolyte containing calcium glycerophosphate, calcium acetate and sodium phosphate. The resulting coating was structurally, mechanically and morphologically characterized by contact angle measurements, eddy current testing, Fourier transform infrared spectroscopy (FTIR), Vickers microhardness and scanning electron microscopy. Preliminary results revealed increased oxide layer thickness, chemical surface changes and voltage-dependent variations in wettability and hardness, demonstrating the strong influence of processing parameters on the functional performance of the alloy.

ANALYSIS OF THE SURFACE MODIFICATION OF THE AZ31 MAGNESIUM ALLOY BY ELECTROLYTIC PLASMA OXIDATION

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Abstract. Applications AZ31 magnesium alloy is a promising biomaterial due to it's biodegradability and mechanical strength; however, it's high corrosion rate limits clinical applications. This study investigated the surface modification of AZ31 alloy via Plasma Electrolytic Oxidation (PEO). Treatment was performed using a calcium glycerophosphate electrolyte 0.07 g/L at voltages of 260 V, 320 V, and 440 V for 3 minutes. Samples were characterized by MEV, EDS, FTIR, polarized light microscopy, contact angle, and Vickers microhardness. Corrosion resistance was evaluated through mass loss testing. Results indicated the formation of a porous, reactive oxide film, primarily composed of magnesium oxide, which imparted a super-hydrophilic character to the samples. Higher voltages resulted in superior surface coverage and increased hardness, promoting biocompatibility and corrosion control of the alloy for implants.

UNIMOLECULAR DECOMPOSITION KINETICS OF C3F6 AS A LOW-GWP ALTERNATIVE TO C-C4F8 FOR SEMICONDUCTOR PLASMA ETCHING

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Abstract. Hexafluoropropene(CF_2=CF-CF_3) is a candidate low-GWP alternative to c-C_4F_8 for fluorocarbon plasma etching. We examine its unimolecular decomposition and compare it with 1,3-C_4F_6, a related perfluoroolefin containing both C-C and C=C bonds. A reaction network (primary/secondary channels, transition states, and key fluorocarbon radical intermediates) was built using DFT(ωB97X-D/aug-cc-pVTZ). Stationary points were verified by frequency analysis and IRC calculations. Temperature-dependent rate coefficients and channel competition were evaluated using canonical variational transition state theory(CVT) over a broad temperature range. The kinetic set was assembled into an overall decomposition scheme to identify dominant bond-cleavage and radical-forming pathways under plasma-etch conditions, highlighting contrasts with 1,3-C_4F_6. These parameters support plasma-chemistry models, byproduct prediction, and process optimization toward more sustainable semiconductor etching.

PLASMA-ASSISTED VACUUM THERMAL EVAPORATION OF QUATERTHIOPHENE: NEW ROUTE FOR SYNTHESIS OF NANOSTRUCTURED POLYMER/ PLASMONIC METAL SERS-ACTIVE PLATFORMS

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Abstract. Thiophene-based thin films constitute an important class of materials with a wide range of applications. Among these, their use as novel platforms for Surface-Enhanced Raman Scattering (SERS) spectroscopy is of high interest. However, to maximise the SERS performance of thiophene-based films, they must be nanostructured and often combined with plasmonic metal. This study explores the deposition of nanostructured quaterthiophene (4T) thin films, selected as a model system, using plasma-assisted vacuum thermal evaporation. In this process, evaporated 4T passes through an RF plasma. We demonstrate that the RF plasma induces significant changes not only in the chemical structure of 4T films but also in their morphology, inducing the formation of well-developed nanostructures. These nanostructures were proven to be critical for SERS sensing, and when decorated with Ag, enabling

SERS enhancement beyond purely Ag sputter-deposited nanostructures or Ag-decorated evaporated 4T films.

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MICROWAVE–ASSISTED GASIFICATION OF PYROLYSIS OIL

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Abstract. A newly developed reactor equipped with a microwave plasma torch operating at a frequency of 2450 MHz and a maximum power of 6000 W, employing a working gas mixture of nitrogen and/or argon, was used for the gasification of liquid fuels (e.g. pyrolysis oil). Different layouts of the fuel feeding were tested, as well as the influence of the gas flows and torch power on the process performance. The composition of the gaseous products was analyzed by means of mass spectrometry and IR spectroscopy, revealing the formation of hydrogen together with acetylene, significantly diluted by the plasma-forming gases. The overall process efficiency was subsequently evaluated.

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A DOCTOR-MIMICKING ROBOT ARM PLASMA TREATMENT SYSTEM: WOUND SEGMENTATION, AREA MEASUREMENT, AND USER INTERFACE DESIGN AND EVALUATION

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Abstract. Plasma therapy is used to treat chronic wounds. Clinically, the dosage is determined based on the wound size to ensure uniform plasma coverage of complex surfaces. Manually executing precise isometric scanning paths is extremely difficult, easily leading to uneven plasma dosage and untreated micro-areas, thus requiring automated and precise solutions. A plasma therapy system simulating physician operation integrates AI and automation technologies: an AI-driven wound recognition model, depth camera-based 3D scanning, and a six-axis robotic arm, achieving a streamlined automated process. This system uses a U-Net model for image segmentation and a point cloud algorithm for area measurement; the robotic arm, equipped with a plasma device and a depth camera, can locate the wound and automatically perform treatment based on the segmentation results, demonstrating powerful functionality and real-time response capabilities.

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DEVELOPMENT OF SURFACE STREAMERS AND INDUCED GAS FLOW DYNAMICS UNDER NS–μS EXCITATION

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Abstract. Industrial exhaust streams often contain harmful gases, especially volatile organic compounds (VOCs). Since VOCs can damage the environment and affect human health, it is important to find efficient ways to remove them. Usually, this is done by thermal oxidation at high temperatures, which can provide high conversion but requires a large energy input. A promising alternative is the use of non-thermal plasmas, which produce reactive species that break down VOCs while keeping the gas temperature low. Many types of plasma reactors have been studied for this purpose, such as packed-bed reactors, corona discharges, gliding arcs, glow discharges, and surface dielectric barrier discharges (SDBDs). In particular, SDBDs are easy to scale and show high conversion efficiency. However, this efficiency cannot be explained only by plasma induced chemistry near the electrode surface. SDBD reactors also generate complex plasma-induced gas flow, which enhances mixing and increases the effective treatment volume. In addition, catalytic coatings can further improve the efficiency and enable control of the product spectrum, for example, by enhancing overall selectivity, but may also influence streamer behavior and, consequently, the gas flow dynamics. Here, we use a twin-SDBD configuration with two identical mesh electrodes placed on both sides of a dielectric plate and aligned with each other. In this geometry, the electric field is strongly localized near the electrodes and can be described as dipole-like, so the surface potential is mainly controlled by the local discharge and deposited charge. Using fast nanosecond excitation, we observe reproducible streamer dynamics from pulse to pulse (via phase-resolved optical emission spectroscopy), which allows direct comparison with simulations using the 2D plasma fluid code, nonPDPSIM, provided by Prof. M. Kushner (University of Michigan). In contrast, under microsecond excitation, the discharge becomes more stochastic, and the streamers appear more random in space and time. The polarity of the applied voltage determines whether mainly positive (photoionization-driven) or negative (electron- drift-driven) streamers are generated near the surface. The two polarities exhibit different electric field structures in the streamer heads, leading to differences in electron temperature and, consequently, influencing the plasma chemistry. Streamer propagation is also strongly affected by the gas composition and the dielectric properties of the surface. In particular, the permittivity of the dielectric and of catalytic coatings has a noticeable influence on the local electric field and, consequently, on the streamer dynamics. This shows that both the excitation waveform and material properties play a key role in controlling the discharge behavior. Beyond the plasma region itself, SDBDs are characterized by their ability to actively modify the surrounding gas flow. Through momentum transfer from charged to neutral species, a so-called electrohydrodynamic force is generated, which induces macroscopic flow structures on timescales orders of magnitude longer than the discharge development. The flow structures are strongly influenced by whether the SDBD is driven by nanosecond or microsecond excitation due to the different streamer dynamics described above. While plasma processes evolve on ns–μs timescales, the flow field develops on millisecond timescales, whereas steady-state conditions are reached only after several tens of seconds due to thermal effects. Experimental investigations using particle image velocimetry reveal the formation of pronounced vortex structures above the electrode surface, with characteristic velocities that can exceed the externally imposed gas flow. These vortices extend far beyond the active plasma region and are capable of transporting gas species between the bulk flow and the near- surface discharge zone. Overall, the results show that SDBD systems should be described as plasma–fluid systems, where the interaction between streamer dynamics, dielectric and catalyst properties, excitation waveform, and induced flow structures determines the macroscopic performance. While ns–μs excitation governs the fundamental discharge physics and reactive species generation, the resulting ms- scale flow dynamics control transport and mixing, ultimately enabling high conversion efficiencies. These results provide a basis for controlling discharge modes and transport processes, enabling improved reactor design and optimization of plasma-catalytic performance.

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PLASMA-WATER INTERACTION: THE INFLUENCE OF THE WATER TARGET ON GAS-PHASE PLASMA PROPERTIES

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Abstract. The interaction of non-thermal atmospheric pressure plasmas and water is important for applications related to the environment, medicine and agriculture. This work presents how the presence of a water target, common in medicine and agriculture, affects gas-phase plasma properties including electron density, gas temperature and NO production by plasma. Specifically for NO, the enhancement of its production correlates with increased OH radical production and elevated energy deposition at the interface, which promotes NO formation via OH + N pathways. The persistence of OH throughout the discharge cycle further amplifies its role in NO generation in the presence of water. These results underscore the critical role of water vapor and liquid surfaces in governing plasma–gas chemistry in atmospheric pressure plasma jets.

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ABOUT PHYSICS AND CHEMISTRY IN DIELECTRIC BARRIER DISCHARGES

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Abstract. Despite its wide application in industry (e.g. ozone generation, surface activation, air cleaning, plasma medicine, analytics) and its current study for gas conversion (e.g. carbon dioxide splitting), flow control and others, there are still many open scientific questions on dielectric barrier discharges (DBDs). The lecture will give a short overview about the historical development of the field, in particular the diagnostics of these nonthermal, atmospheric pressure plasma sources. Special focus is on the electrical characterization, determination of active species and generation of discharge regimes (i.e. filamentary and diffuse modes). Furthermore, it is evaluated how the splitting of carbon dioxide to carbon monoxide can be enhanced by the operation parameters and the electrode geometry. Therefore, planar and coaxial volume barrier discharges as well as packed bed reactors are examined. The scaling with different parameters, namely the specific input energy (a microscopically and macroscopically defined parameter governing the energy transfer by the electric field to the molecules via inelastic collisions) and the total number of charges being transferred through the discharge during the residence time of the gas are discussed.

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NON-EQUILIBRIUM ELECTRON KINETICS IN NANOSECOND PULSED PLASMAS: FROM LASER-PRODUCED PLASMAS TO ELECTRICAL DISCHARGES

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Abstract. This talk compares non-equilibrium electron kinetics in two setups: (1) laser-produced sparks in Ar/H_2O and (2) nanosecond pin-pin discharges in helium. We use optical diagnostics to resolve the spatiotemporal evolution of electron density (n_e) and temperature (T_e).

For laser sparks, we benchmark Thomson scattering against OES. Using 1064 nm drive and 532 nm probe beams, we track plasma decay from 500 ns to 20 μs. OES (H-atom Stark broadening) matches TS data, showing n_e decay from 10^{17} to 10^{16} cm^{-3} and cooling from 6 to 1 eV. Hydrodynamic expansion is the primary driver, alongside recombination and elastic collisions.

The second part examines a1 kHz pin-pin discharge. By integrating streak imaging and OES, we characterize the glow-to-spark transition. These measurements provide novel insights into the ultrafast constriction and ionization dynamics governing the regime transition.

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THERMAL PLASMAS FOR ADVANCED GASIFICATION PROCESSES

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Abstract. Gasification processes which produce syngas from plastic waste or biogenic residues are of increasing importance for establishing material cycles. Thermal plasmas can be used to couple electrical energy into the process, reduce CO_2 emission and increase the syngas quality. This paper reports on first steps of the establishment of a plasma assisted gasification process. As a new approach, an autothermal gasification has been used as a starting point. A DC arc between graphite electrodes was introduced in a test reactor. The oxygen supply was reduced to come close to an allothermal process, and the quality of the produced syngas could be improved. Peculiarities of arc stability and electrode erosion as well as requirements for the power source are given in the paper. Advantages and disadvantages of such a free burning arc in comparison with the use of plasma torches will also be discussed with respect to energy efficiency and impact on the gasification process.

STATE-SENSITIVE REACTIONS IN COLD PLASMAS

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Abstract. The main motivation behind our research lies in the chemistry of the interstellar medium (ISM). The typical temperatures in the ISM are on the order of 10-100 K. Under such conditions, many thermally activated chemical processes are inhibited, while reactions that proceed via long- lived reaction complex (e.g., tunneling, or radiative processes) may become enhanced. At the same time, the low number densities of the ISM lead to slow thermalization and consequently, the internal-state populations are often far from equilibrium. State-specific reaction rate coefficients are therefore needed to understand the influence of the available internal energy of reactants on the ISM chemistry. Our secondary motivation is the need for the most detailed data for benchmarking of theoretical models and gaining a deeper understanding of the reaction dynamics. We study the collisions at thermal kinetic energies down to 10 K in a 22-pole radiofrequency trap and we use mass spectrometry to analyze the reactants and products. The talk will present the results of our recent studies of the H3+ + H2 collision

system, where we investigated the inelastic collisions that lead to the change of H3+ nuclear spin, as well as the process of H3+ vibrational quenching. In these experiments, the internal state of H3+ was monitored using laser induced reactions and leak-out spectroscopy methods.

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PROBING ION DRAG AND ELECTRIC FIELD FORCES IN 2F CCPS USING OPTICALLY TRAPPED MICROPARTICLES

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Abstract. Boundary regions of capacitively coupled radio-frequency (CCRF) plasmas govern ion acceleration, momentum and energy transfer, as well as plasma–surface interaction. Yet, these boundary regions, i.e. the sheath and presheath, remain experimentally difficult to access, particularly for dual-frequency (2f) excitation where the relative phase between the frequencies modifies discharge symmetry via the Electrical Asymmetry Effect (EAE) [1,2]. While the EAE enables global control of plasma parameters, its local manifestation in boundary-layer forces has remained largely unexplored experimentally. In this contribution, optically trapped microparticles are employed as localized, non-invasive force probes to directly resolve the electrostatic field force in the sheath [3,4] and the ion drag force in the presheath [5] of low-pressure single- and dual-frequency CCPs driven at 13.56 and 27.12 MHz. A tightly focused laser beam forms a three-dimensional optical tweezer that stably confines a single SiO_2 microparticle ($2r_p \approx 7\ \mu m$). The displacement of the trapped probe particle from its equilibrium position provides a direct measure of the net plasma force acting on it. By vertically scanning the particle through the discharge via controlled electrode movement [6], spatially resolved force profiles are obtained across bulk, presheath, and sheath. A central aspect of the method is the tunability of the trap stiffness. The electrostatic field force in the sheath reaches several tens of piconewtons and, therefore, requires high trapping powers for stable particle confinement. In contrast, the ion drag force in the presheath is roughly an order of magnitude smaller, typically only a few piconewtons. By systematically reducing the laser power, the trap sensitivity increases, enabling – for the first time under these discharge conditions – direct and quantitative measurements of the ion drag force in the presheath. This controlled transition between force regimes allows a separate and spatially resolved determination of both dominant boundary forces within a single experimental framework. The measured force profiles provide an experimentally based mapping of the classical plasma structure [5]. In the quasi-neutral bulk, the net force on the particle is negligible. Entering the presheath, a distinct ion drag force emerges, reaching a pronounced maximum near the sheath edge, where ion acceleration and momentum transfer are strongest. Further toward the electrode, the electrostatic field force rapidly dominates, reflecting the increasing electric field strength in the non-neutral sheath. This force-based delineation offers a direct and intuitive identification of plasma regions without relying solely on emission or potential measurements. From the measured electric field force profiles, particle charges are derived using different electric field models [4]. In addition, integrating the force curves yields the mechanical work required to move the particle through the sheath, providing a model-independent charge estimate. The resulting charge values, on the order of several thousand elementary charges, are consistent with OML predictions and literature data, thereby supporting both the force measurements and the underlying field assumptions. Under dual-frequency excitation, both the electrostatic field force and the ion drag force exhibit a pronounced dependence on the relative RF phase. While global quantities such as the DC self-bias vary symmetrically with phase, the local force magnitudes and spatial distributions show significant asymmetries around 90° phase angle, reflecting phase-dependent electron heating and ionization dynamics in the bulk. These bulk modifications propagate into the boundary layers due to changes in electron density [7], sheath thickness, electric field strength, and ion flux. The measurements, therefore, provide direct experimental evidence that the Electrical Asymmetry Effect not only controls global discharge parameters but also modulates local force balances in the presheath and sheath. Overall, the presented approach establishes optically trapped microparticles as highly sensitive, spatially resolved probes of boundary-layer physics in capacitively coupled plasmas.

By enabling the direct and separate quantification of electrostatic field and ion drag forces – despite their substantial difference in magnitude – the method provides new insight into ion acceleration, momentum/energy transfer, and local force coupling under phase-controlled excitation. These results advance the fundamental understanding of 2f CCP boundary dynamics and open a diagnostic pathway toward force-resolved investigations of complex plasmas and plasma–surface interaction regimes that are otherwise experimentally inaccessible.

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DEGRADATION OF TOXINS BY VACUUM ULTRAVIOLET RADIATION ARISING FROM COLD PLASMAS

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Abstract. Low-pressure gaseous plasma radiates over a broad range of wavelengths, but the most intense radiation usually occurs in the vacuum ultraviolet (VUV) range. Photons with energies between about 6 and 10 eV will break bonds in the surface film of any organic material. The penetration depth of such energetic photos is well below a micrometer, so only the surface film of organic material will be affected. The method is useful for tailoring the surface properties of polymers that are otherwise difficult to functionalize, and which are virtually impossible to functionalize using standard plasma treatments. Several examples of industrial applications of VUV radiation for tailoring the surface properties of organic materials will be presented, with a focus on agricultural applications. Among other things, irradiation with VUV photons causes rapid degradation of toxins. The brief treatment time of a few seconds enables detoxification, as toxins are usually present at minute levels on the surface of agricultural products.

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ADVANCES IN LOW-PRESSURE PLASMA DEPOSITION OF MULTIFUNCTIONAL COATINGS FOR SUSTAINABLE SOLUTIONS IN OPTICS, ENERGY, AEROSPACE AND MANUFACTURING

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Abstract. Surface engineering using low-pressure plasma processing allows one to develop new solutions for advanced applications in optics, energy, aerospace, manufacturing, biomedical and others. Control of energetic interactions at the surface of growing films can be used to selectively adjust the films' micro/nanostructure. This presentation will illustrate the progress and new opportunities for passive and active coating systems by describing new and novel synthesis methods, namely: a) Ion Beam

Assisted Chemical Vapor Deposition (IBA-CVD) of hybrid organic- inorganic elastic optical coatings for ophthalmic lenses; b) High Power Impulse Magnetron Sputtering (HiPIMS) for optical coatings for energy control in smart windows and micro/nanosatellites; (c) Pulsed Hollow Cathode PECVD coatings for the protection inside narrow tubes and cavities; and (d) Low Duty-cycle Cylindrical Magnetron Sputtering (LDc-CMS) for the protection of new-generation aircraft engines and manufacturing components.

PLASMA TECHNOLOGIES PROVIDING NEW CAPABILITIES IN BIOMEDICINE

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Abstract. Powered by renewable electricity, plasma processing technologies, which require minimal amounts of gaseous reactants and generate virtually no waste, can provide sustainable solutions to many materials and chemical processing needs. Here, we present plasma processes that enable the creation of bio-instructive and biomimetic surfaces for wide-ranging applications in biomedicine, eliminating the need for multi-step wet chemical treatments. Materials used in biomedicine are selected according to bulk properties required for particular in vivo and in vitro applications. However, their surfaces almost always provide suboptimum biological microenvironments and do not promote the desired biological responses. Here, we will describe our toolkit of sustainable and readily scalable plasma surface modification processes that enable resilient and tailorable biofunctionalization on all surfaces of complex structures and materials. Scale-up is in progress for the commercial production of tuneable, bespoke, biomimetic cell culture microwell plates. As cell behavior is directed by biochemical signals and local stiffness, our strategy is to enable reagent-free covalent immobilization of biomolecules and hydrogels onto the cell-contacting surfaces. Energetic ion implantation into carbon-based surfaces or surface coatings creates buried radicals whose unpaired electrons migrate to the surface and form covalent bonds with proximate molecules. We will describe processes that create these reactive surfaces on any material or structure, including complex 3D structures, nano/microparticles, and microscale porosity. Fabrication of fully transparent microelectrode arrays for stimulation and readout for electroactive cells will also be described. For structures created by 3D bioprinting, which is not compatible with low pressures, we developed a localized atmospheric pressure plasma treatment. Functional molecules that can be immobilized include, but are not limited to, oligonucleotides, enzymes, peptides, aptamers, cytokines, antibodies, cell-adhesion extracellular matrix molecules, histological dyes, and hydrogels. Controlled application of the functional molecules via droplet dispensing or contact printing enables the immobilization of biomolecular and hydrogel patterns onto the plasma-activated surfaces. Immobilised molecular orientation is controlled using electrostatic manipulation during the reagent-free solution phase immobilisation process. A toolbox of plasma processes, such as those described, can provide the capability to create biomimetic cell culture systems to direct cell behaviours with a new level of accuracy for applications in drug discovery, cell therapy, diagnostics, and personalized medicine, addressing current and emerging needs in biomedicine and biotechnology.

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PLASMA NITRIDING OF POWDER BED FUSION METALS: INTERPLAY BETWEEN ADDITIVE MANUFACTURING MICROSTRUCTURES AND SURFACE PERFORMANCE

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Abstract. Powder bed fusion (PBF-LB/M), an additive manufacturing (AM) process, has become a mature processing route for high-performance metallic components, enabling not only design freedom but also microstructures fundamentally different from those produced by conventional metallurgy. Rapid solidification, cyclic reheating, and steep thermal gradients promote characteristic features, including melt-pool patterns, cellular and columnar substructures, local microsegregation, and residual stresses. Although post-processing heat treatments can mitigate some of these effects, they may also modify surface reactivity and diffusion behaviour during subsequent thermochemical treatments. Plasma nitriding is a highly adaptable surface engineering method for improving the performance of metallic materials in demanding tribological and corrosive environments. Through nitrogen diffusion activated by glow discharge, nitrided layers with hard nitride-containing zones can be formed at relatively low temperatures, resulting in increased surface hardness, wear resistance and, in many cases, improved corrosion performance. However, the distinctive features of additively manufactured microstructures can strongly modify nitrogen transport mechanisms and the kinetics of layer formation, thereby affecting both the architecture and the properties of the nitrided case. In this presentation, the plasma nitriding of several PBF-LB/M-fabricated alloy groups, including stainless steels, tool steels, nickel-based alloys, titanium alloys and aluminium alloys, will be discussed. Particular attention will be devoted to AM-induced microstructural features, such as melt-pool morphology, cellular substructure, nanoscale oxide inclusions, porosity, and retained stresses, and to how these factors influence nitrided layer development, microstructural stability, and surface performance. The effects of processing parameters on tribological behaviour and corrosion response will be presented, highlighting practical routes toward improved surface reliability for additively manufactured components. Where relevant, a brief outlook will address ongoing efforts to extend plasma-assisted nitriding concepts to additional alloy families, including aluminium alloys, where surface activation and oxide-related challenges remain key considerations.

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ACTIVE PLASMA STERILIZATION FOR MICROBIAL DECONTAMINATION FOR TERRESTRIAL AND SPACE APPLICATIONS

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Abstract. Weakly and partially ionized air plasmas are of strong fundamental and practical research interest. These charged particles have shown excellent efficacy for biological decontamination for ground and space applications. The core technology is a set of electrodes separated by a sufficient potential difference to produce oxygen and nitrogen reactive species, including short-lived metastable and charged particles. We will discuss key findings, advancements, and challenges for select practical applications of this technology. Plasma sterilization and the interaction of process plasmas with pathogens and organic and inorganic materials will also be discussed. Proof-of-concept demonstration experiments show the effectiveness of the technology in safely and efficiently sterilizing various hardy microorganisms, including *Escherichia coli*, *Geobacillus stearothermophilus* (spore and non-spore variants), *Deinococcus radiodurans*, and viruses such as HCoV-OC43 and SARS-CoV-2. Electron microscopic images (before and after exposure) have shown little to no material degradation due to effective ozonation during sterilization for both porous and non-porous materials, such as aluminum, Polycarbonate, Orthofabric, and Kevlar.

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NOVEL BIPOLAR HIPIMS PULSE CONFIGURATIONS FOR ENERGY-FLUX-CONTROLLED GROWTH OF ALN SEMICONDUCTOR THIN FILMS

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Abstract. High-power impulse magnetron sputtering (HiPIMS) is an advanced thin- film deposition technique that delivers high target power in short pulses, thereby increasing ionization compared to conventional DC sputtering. However, many ions still have low energy, so substrate biasing is often used to enhance energy transfer to the growing film. For insulating surfaces where direct biasing is impossible, bipolar HiPIMS (alternating negative and positive pulses with a floating substrate) offers a partial solution. However, rapid charging of insulated surfaces limits energy transfer. This study aims to optimize bipolar HiPIMS pulse configurations to explore the potential for enhancing energy transfer, even on insulating surfaces. Various pulse configurations (unipolar, bipolar, chopped unipolar, and chopped bipolar HiPIMS) were applied under unbalanced magnetic fields with the same average power. Total energy flux to a substrate was measured using a passive thermal probe at a floating and ground potential. Moreover, the depositions on insulating substrates or films with various capacitances were simulated by connecting a defined external capacitor between the probe and the ground. Finally, AlN films were deposited on a floating substrate holder and analyzed by X-ray diffraction using ω-scan (rocking curve) measurements of the AlN (0002) reflection to evaluate crystalline quality and c-axis alignment for different pulse configurations. Thermal probe measurements confirm that chopped unipolar pulses enhance the energy flux to the substrate compared to standard HiPIMS. For chopped bipolar configurations, the increase in energy flux varies with the substrate capacitance. At low capacitance, ion acceleration occurs only at the start of each positive pulse, before the substrate surface is fully charged, resulting in a slight increase in energy flux. For medium capacitance, chopping the positive pulse amplifies the increase of energy flux due to longer charging time and substrate neutralization during pulse off-times. Finally, with high capacitance, ion acceleration is sustained throughout the positive pulse regardless of its length, as for a grounded substrate. These effects were also verified by analyzing the deposited film properties. A significant reduction in the rocking curve full width at half maximum (FWHM) was observed for films grown using chopped bipolar HiPIMS, indicating improved crystalline quality and enhanced c-axis alignment compared to standard HiPIMS.

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