SUCCESS STORY

PlasmArc4Green
Simulation, Modelling and Monitoring of Plasma and Arc based Processes for Green Metal Production.

Programme: COMET – Competence Centers for Excellent Technologies

Programme line: COMET-Module

Type of project: PlasmArc4Green-Project 2, 01.07.2024-30.06.2028, multi-firm

ADVANCING ARC SIMULATIONS FOR GREEN TECHNOLOGIES

KINETIC MODELING OF NEAR-CATHODE PLASMA INTERACTIONS

Understanding the physical processes in the near-cathode region of atmospheric pressure arcs is a longstanding challenge in plasma science. Despite its critical role in arc behavior and electrode lifetime, the lack of detailed computational models has limited the ability to predict or optimize processes such as plasma-solid interactions, electron emission, and sheath formation.

This gap is particularly significant in the context of modern metallurgical processes, where the transition to more sustainable technologies requires precise control of plasma arcs. To address this challenge, a new simulation tool is developed in the frame of project 2 *Plasma-Solid Interaction* of the COMET Module *PlasmaArc4Green*. The tool, a Particle-in-Cell (PIC) code, simulates the kinetic behavior of charged particles in the near-cathode region of an atmospheric pressure arc.

The core of the approach lies in the implicit PIC method, which allows for larger time steps and greater numerical stability for high density plasmas compared to traditional explicit PIC schemes. The code is written in C++ and uses **PETSc** and **MPI** for efficient parallelization. The current implementation successfully integrates state-of-the-art PIC approaches to resolve the plasma sheath and adjacent regions.

The simulation outputs include electric field and potential profiles, particle densities, and diagnostic quantities such as collision frequencies and currents. These results provide insight into the mechanisms of charge separation, ion acceleration, and sheath development—key processes in arc physics and electrode design. The model also serves as a reference for building more efficient **multifluid models**, enabling faster simulations without sacrificing physical accuracy.

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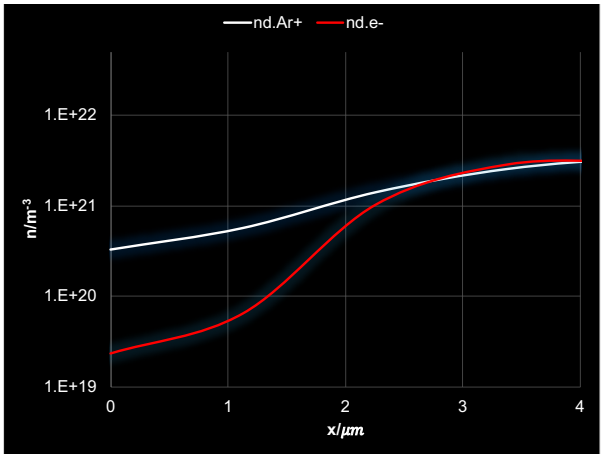
Impact and effects

The *PlasmaArc4Green* COMET Module marks a step toward closing the modelling gap in plasma-solid interaction research. These findings provide a pathway toward improved predictive models in industrial applications where cathode performance and erosion play a decisive role.

Furthermore, the data can support validation of boundary conditions in continuum-scale simulations, like multi-fluid simulations, used in materials processing and metallurgy.



Density Profiles in the Near Cathode Region, © K1-MET

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- Primetals Technologies Austria GmbH, AT
- RHI Magnesita GmbH, AT
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