CSC-RUB PhD Project Proposal

Title: Ignition Physics in Nanosecond Plasmas in Liquids

Sector of research: Dr. rer. nat.

Degree awarded: Physics

Keywords: Nanosecond Plasma, Modelling, Spectroscopy, Plasma electrolysis, liquid-solid-plasma interface

Supervisors of PhD project:

Prof. Dr. Achim von Keudell, Chair for Experimental Physics II ''Reactive Plasmas'',
Faculty for Physics and Astronomy

Email: Achim.vonKeudell@rub.de; Orcid: 0000-0003-3887-9359

Jun-Prof. Dr. Maria Elena Innocenti, Theoretical Physics I, RUB

Research focus of supervisor:

Research area of Prof. von Keudell are non equilibrium reactive plasmas at low, atmospheric and high pressures. Emphasis is on real time diagnostics using laser spectroscopy, emission spectroscopy, probe methods and mass spectrometry to unravel elementary processes in the plasma and at the plasma surface boundary. This is complemented by fluid and kinetic modeling in cooperation with partners. Current topics are plasma supported electrolysis to design targeted species conversion based on renewable energies, the understanding of high power pulsed magnetized discharges to manufacture excellent ceramic metastable materials and fundamental surface processes during plasma catalysis as the interaction of vibrationally excited species with complex catalysts.

Publications: 163 publications, H index 47.

Nanosecond pulsed discharges in distilled water-Part II: line emission and plasma propagation
von Keudell, A; Grosse, K; Schulz-von der Gathen, V
PLASMA SOURCES SCIENCE & TECHNOLOGY 29, 85021 (2020)

Nanosecond plasmas in water: ignition, cavitation and plasma parameters
Grosse, K; Held, J; Kai, M; von Keudell, A
PLASMA SOURCES SCIENCE & TECHNOLOGY 28, 85003 (2019)

Electron density, temperature and the potential structure of spokes in HiPIMS
Held, J; Maass, PA; Schulz-von Der Gathen, V; von Keudell, A
PLASMA SOURCES SCIENCE & TECHNOLOGY 29, 25006 (2020)

Non-equilibrium excitation of CO_2 in an atmospheric pressure helium plasma jet
Urbanietz, T; Boke, M; Schulz-von der Gathen, V; von Keudell, A
JOURNAL OF PHYSICS D-APPLIED PHYSICS 51, 345202 (2018)

RUHR UNIVERSITÄT BOCHUM

Pattern Formation in High Power Impulse Magnetron Sputtering (HiPIMS) Plasmas
Held, J; von Keudell, A
PLASMA CHEMISTRY AND PLASMA PROCESSING 40, 643 (2020)

Summary of research plan

Background: Plasmas in direct contact with liquids or plasmas inside liquids allow a high mass transfer of reactive species from the gas phase into the liquid. If these plasmas in liquids are interfaced with solids, very fast and efficient reaction rates for surface reactions can be realised. Such systems are relevant for the field of degradation of toxic organic compounds in liquids, plasma enhanced anodization of metal surfaces inside an electrolyte, or as a method to recover a catalytic surface in an electrochemical cell. The dynamic of the plasma can be well followed starting with ignition due to field effects at the solid-liquid interface. As a result, pressures in the GPa range and temperatures of a few 1,000 K reaching the boiling temperature of tungsten have been reached. The high pressures and high temperature may cause liquid ruptures or/and the transition of water into a super critical fluid. This state of matter allows electron acceleration in the medium and the development of a discharge. Electron densities up to 10^{25} m^{-3} have been reached, as being deduced from Stark broadening of the hydrogen Balmer series. The combination of nanosecond plasmas with electrolysis allows an ultimate flexibility regarding any desired plasma/liquid properties based on the strong non-equilibrium that is created.

Study objective: The ignition process of these nanosecond plasmas is not well understood and consists presumably of a combination of field effects at the electrode liquid interface and of the field ionization of water molecules. This will be analysed with fast spectroscopy and modelling in cooperation with a theoretical group at TuE Eindhoven

Expected Results: It is assumed that ignition occurs via field effects directly in the liquid as being opposite to electron impact ionization in gases. This hypothesis will be tested and the results being published.

Methods: Emission spectroscopy, Stark broadening, fast camera measurements, fluid modeling. Alle infrastructure is available.

Candidate Requirements: MSc degree in physics mandatory. Methodological expertise in experimental physics preferred. Good English language skills.

Motivation for CSC application (max 250 words): The project is integrated in the Coordinated research centre 1316 (www.sfb1316.rub.de), where 23 PIs and 30 PhD students work together on transient atmospheric plasmas for novel methods of energy conversion. This CRC also operates an integrated training programme-