Memory effect in Dielectric Barrier Discharge operated in air at atmospheric pressure

PhD Overview :

Dielectric Barrier Discharge (DBD) can generate cold plasma over large-area surfaces at atmospheric pressure. DBD is frequently used for advanced surface engineering (activation and thin film deposition), including on heat-sensitive substrates, for example polymers derived from woody biomass. Discharges produced by such device are generally constituted of multiple microdischarges or filaments randomly distributed in time and space. Luckily it is also possible to obtain a diffuse or homogeneous DBD, although such regime is only observable over a limited range of operating conditions. In such system, the energy becomes transferred uniformly over the whole surface of the electrode and substrate. For coating application, the diffuse rather than filamentary regime allows the deposition of dense and homogeneous thin films. Coating deposition in diffuse DBD is currently done with nitrogen, helium, or argon as the carrier gas, but hardly in air. For advanced surface engineering, air-based or open-to-air devices operated in a diffuse regime open new perspectives: it becomes possible to obtain dense and homogeneous coatings at low cost directly in ambient air without gas consumption.

A diffuse discharge is the result of a memory effect related to previous discharges that create seed electrons before ignition of subsequent discharges. In nitrogen atmosphere, seed electrons are mostly produced by long-lifetime metastable molecules $N_2(A^3\ \Sigma_u^+)$ acting as an important energy reservoir. The addition of oxidizing gases induces a significant decrease of the $N_2(A^3\ \Sigma_u^+)$ population, such that 500 ppm of O_2 in nominally pure N_2 is typically enough to cause a transition from homogeneous to filamentary discharge. In air, the $N_2(A^3\ \Sigma_u^+)$ concentration is very low. However, recent experiments have shown that through judicious choice of the operating conditions, it is possible to obtain a diffuse discharge regime, although the memory effect and the origin of the seed electron remain poorly understood.

The driving motivation of this PhD thesis is to identify and analyse the mechanisms involved in the production of seed electrons in air based DBD. One of the objectives is to dissociate the phenomena occurring in the gas phase from the ones occurring on the dielectric surfaces. While gas phase aspects will be examined through electrical and optical emission spectroscopy diagnostics combined with collisional-radiative modeling, charge dynamics onto the dielectrics exposed to the DBD will be analyzed trough an adaptation of a Pockels setup. The air based DBD cell will also be mounted on a plasma sampling mass spectrometer equipped with differential pumping stages for detailed analysis of neutral and ionic species. This complete set of experiments will be used as building blocks for a better understanding of the memory effect in air DBD and the application of such device for thin film deposition.

Expected skills and qualifications :

We are seeking a strongly motivated person able to work independently and within a team. The candidate should have very good level of initiative, organization, along with a strong scientific spirit. Applicants should have a strong interest in atmospheric-pressure plasma science and

technology and in the development and characterization of advanced plasma reactors. We are seeking for a person with outstanding experimental skills in physics, electrical and optical diagnostics, as well as some basics in programming for data analysis. The qualification required for this thesis is a master's degree in physics, engineering, or similar discipline. A formation in plasma science or plasma processes are very desirable.

Duration : 36 months
Start Date : September 1st, 2022
Location : The thesis is a co-supervision between Université de Toulouse (Laboratoire Laplace) in Toulouse, France and Université de Montréal (Canada Research Chair in Physics of Highly Reactive Plasmas) in Montréal, Canada. The successful candidate is expected to spend 2 years in Toulouse and 1 year in Montréal.

Diversity :
The supervisors aim to achieve excellence in research and research training while strengthening the promotion of best practices in equity, diversity, and inclusion. The Université de Toulouse and Université de Montréal fully subscribe to these objectives and, through their Equal Access Employment Program, invite applications from women, visible minorities, ethnic minorities, Aboriginal people, and persons with disabilities. They also invite applications from people of all sexual orientations and identities. At the applicant's discretion, identification to one or more than one of the abovementioned groups can be indicated in the motivation letter.

To Apply :
Please send the following documents by e-mail to antoine.belinger@laplace.univ-tlse.fr :

- Short cover letter describing your motivation for applying for the position and how your experience and expertise match the research topic.
- CV, including lists of relevant courses taken, research/industry projects performed, relevant experience and contact details of at least 1 reference.

Supervisor :

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