Editorial: Particle interaction with afterglow plasma and non-quasi-neutral plasma

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Editorial: Particle interaction with afterglow plasma and non-quasi-neutral plasma

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Editorial on the Research Topic
Particle interaction with afterglow plasma and non-quasi-neutral plasma

Introduction

When immersed in a plasma environment, small nano-to micrometer sized solid particles undergo electrical charging by collecting charged species from the plasma. Once charged, these particles interact in peculiar ways with the surrounding plasma, triggering a widespread of interesting physical phenomena. Such systems, also known as complex or dusty plasmas, have been investigated for a few decades already.

Until now, theoretical frameworks have been mainly developed for the charging of particles in steady and quasi-neutral plasmas and their interaction with them. However, recent works have revealed that particles charge and interact rather differently in cases where the surrounding plasma becomes non-neutral. These cases include pulsed operation of plasmas, an afterglow plasma after the sustaining power is extinguished (i.e., a temporal afterglow plasma), an originally steady plasma that flows into a region where the Debye length exceeds the macroscopic plasma confinement length scale (i.e., a spatial afterglow plasma) and a combination of the latter two (i.e., spatio-temporal afterglow plasma). Recent experiments and numerical simulations have demonstrated that originally highly negatively charged particles become—when residing in an afterglow plasma—significantly less negatively charged, uncharged, or even positively charged. The exact elementary processes leading to (de)charging of such particles in afterglow plasmas, and their interaction with them, remain to be revealed.

The above identified lack of knowledge together with the increasing importance regarding the understanding of these systems from scientific point of view (e.g., in plasma physics, aerosol science and astrophysics) and from application point of view (e.g., for plasma-enabled nanoparticle synthesis and material processing, particle mitigation in semiconductor industry and space exploration, and air pollution monitoring and control), have led to recently renewed research efforts.

The current research topic focusses around theoretical, experimental and numerical work on plasma (de)charging and plasma-particle interaction in afterglow plasmas and in non-quasi-neutral plasmas and their applications. In general, it aims to provide a review of the state-of-the-art knowledge regarding these systems and define topics to be investigated in the near future.

Contributions

The current research topic contains four invited contributions, of which two reviews - one about low pressure temporal dusty plasma afterglows by Couëdel and the other about nanoparticle decharging in atmospheric pressure plasma afterglows by Staps. Two other contributions are original research articles regarding the preservation of a dust crystal as it falls in an afterglow plasma by Chaubey and Goree and regarding an experimental observation of a spatio-temporal plasma afterglow inducing an additional neutral drag force on falling microparticles by van Huijstee et al.

In the review article by Couëdel, the dynamics of low pressure temporal complex plasma afterglows are discussed as well as the elementary particle (de)charging processes therein. The different stages in particle decharging are connected to peculiar—but for afterglow plasmas inevitable—processes such as electron temperature relaxation and the ambipolar-to-free diffusion transition, while also the presence of electric fields on these processes is discussed. Highlighted are not only experimental and theoretical results, but also the basics of temporal afterglow modeling are being brought to the attention.

The review article by Staps focuses around the impact of increasing the gas pressure towards atmospheric values on the physics concerning the interaction between dust grains and afterglow plasmas. The author describes similarities between atmospheric pressure and low pressure complex afterglow plasmas in terms of the four stage model (i.e. electron temperature relaxation, ambipolar diffusion, ambipolar-to-free diffusion transition and free diffusion) generally applied to low pressure dusty plasma afterglows. The work of Staps finally gives an overview of research gaps and opportunities in the field of atmospheric pressure dusty plasma afterglows.

In the original research article of Chaubey and Goree, the authors presented experiments that visualized the evolution of the crystalline structure of a set of plasma confined microparticles after the discharge was terminated. As expected, after switching off the plasma, particle confinement was lost and the particles started to fall towards the lower electrode. However, remarkably, during their entire fall the microparticles remained ordered in the same crystalline structure as initially. This arrangement was observed to remain until the particles reached the lower electrode by which they were bounced back and scattered laterally introducing the loss of the structured arrangement.

Finally, van Huijstee et al presented—in an original research article as well—the experimental observation of an additional drag force exerted on a microparticle that fell through a low pressure spatio-temporal afterglow plasma. In the reported experiments, it was shown that microparticles falling downstream at terminal velocity through a spatial afterglow of an inductively coupled plasma, experienced a sudden force in the direction of the former plasma bulk region just after the plasma was terminated. Verified by numerical simulations, this additional neutral drag force was attributed to gas cooling in the former active plasma region followed by the redistribution of neutral gas through the experiment volume.

Perspectives

From the contributions to this Research Topic it becomes clear that developments in scientific and application fields have recently opened up interest in afterglow plasmas that interact with individual particles and structured arrangements of particles. In order to understand the elementary physics in these systems and to develop and verify predictive modeling, ongoing experimental, numerical, and analytical efforts are needed and warmly welcomed by the field.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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