Surface charge measurements on different dielectrics in diffuse and filamentary barrier discharges

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The presented work reports on the successful extension of the surface charge diagnostics via the electro-optic Pockels effect of a bismuth silicon oxide (BSO) crystal to dielectrics used in common barrier discharge configurations, such as borosilicate glass, alumina and magnesia. The focus is on the impact of these dielectrics on the diffuse discharge in helium due to different secondary electron emission coefficients, and on the importance of the surface charge memory effect for the re-ignition behaviour of self-stabilized discharge filaments operated in helium-nitrogen mixtures.

1. Introduction

Previously, we reported on the measurement of surface charges in barrier discharges (BDs) using the electro-optic Pockels effect of a bismuth silicon oxide (BSO) crystal [1,2]. It was shown that the surface charge morphology and dynamics determine the re-ignition behavior of the discharge and its lateral appearance, known as surface memory effect. The present work [3] makes this powerful method accessible to common dielectrics, e.g., borosilicate glass, alumina and magnesia. Fundamental issues are addressed such as the quantitative evidence of the surface memory effect, and the estimation of SEE coefficients for the different dielectrics using Townsend's criterion for the breakdown voltage.

2. Discharge configuration and diagnostics

The discharge is operated inside a plane-parallel electrode configuration shielded by dielectrics on both sides to the gas gap of 3 mm. At the pressure of 1 bar, the diffuse glow-like BD is driven by sine-wave voltage in helium and self-stabilized discharge filaments are operated by square-wave voltage in helium with 10 vol.% nitrogen admixture. Surface charges are measured on borosilicate glass, alumina or magnesia covering the electro-optic BSO crystal. The surface charge diagnostics is based on the change in polarization of light, induced by surface charges on the BSO crystal and detected by a CCD camera. Additionally, current-voltage characteristics as well as the spatio-temporal development of the optical emission from the discharge are measured.

3. Selected results

Figure 1 highlights the outstanding importance of the surface memory effect. In (a), a reduction of the feeding voltage amplitude from 3.2 kV to 2.2 kV causes the transition from arbitrary distributed to self-stabilized discharge filaments, revealed by the averaged surface charge density distribution $\sigma(x,y)$. Each surface charge spot significantly enhances the local electric field across the gas gap, as shown in (b) by the recalculated gap voltage distribution just before the breakdown. At the surrounding region, where no surface charges are present, the gap voltage amounts to 1.6 kV. However, at the center of the surface charge spot, the gap voltage is more than 1 kV higher. This difference in gap voltage distribution explains the periodic re-ignition of the discharge filaments at the same positions as well as the loss in lateral order when the feeding voltage amplitude exceeds about 3 kV.

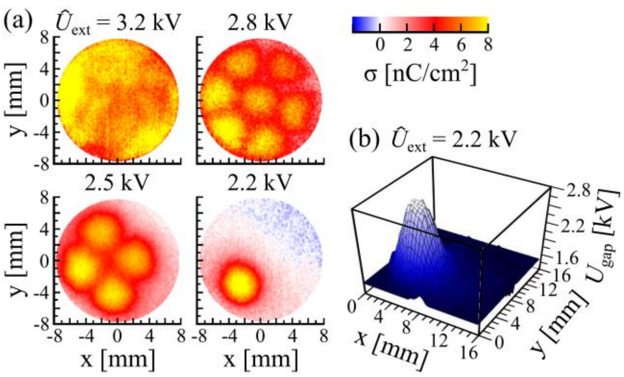

Fig. 1: (a) Surface charge density distribution $\sigma(x,y)$ after the filamentary discharge breakdown for different feeding voltage amplitudes U_{ext}, and (b) gap voltage distribution $U_{gap}(x,y)$. Borosilicate glass on top of the BSO crystal.

4. References

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