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Discharge analysis of atmospheric pressure glow discharge in micro-scale dielectric barrier gap

Content

Atmospheric pressure gas discharges have widespread applications – ozone synthesis, UV and VUV generation, disinfection, materials processing, etc. Generation of atmospheric pressure plasmas in bare electrode systems encounter instabilities that cause glow to arc transition due to thermionic emissions caused by ion bombardment on cathodes. To prevent such transition, dielectric barriers are used on the electrodes to limit the ion bombardment which in turn limits the secondary emission and hence the discharge current. Such discharges are called Dielectric Barrier Discharges (DBD). To decrease the voltage requirement of these discharges, one obvious way is to decrease the gap distance, typically hundreds of micrometers. This has a disadvantage of having a low plasma volume – since sheath itself covers few tens of micrometers at atmospheric pressure. An alternative way to create high pressure discharges is micro-hollow cathode structure –where a hollow cathode, an insulator layer and anode (which may or may not be hollow) are sandwiched together. On application of voltage between anode and cathode the electrons start exhibiting pendulum effect because of the repulsion from cathode sheath. This effectively increases the collisions per length, that in turn increases the plasma density but these are prone to electrode erosion due to ion bombardment. A combination of both the advantages of dielectric barrier discharge and micro hollow cathodes –less erosion of the electrodes and high plasma density –has been attempted in a device typically called Dielectric barrier based Micro-hollow cathode (DBMHC). This work aims to analyze different discharge phases in DBD based MHCD device. For this purpose, a cylindrical anode protruding co-axially in a cylindrical hollow cathode structure has been explored whose inner walls are coated with SiO2. To substantiate, simulations have been carried out in COMSOL 5.3. It is seen that there are three major discharge phases in this device configuration – ignition phase, transition phase and hollow cathode phase. After primary ignition of electrons in the low gap region of the device, ignition and transition phase go hand in hand. During this phase the bulk electrons are trapped in the self-consistent electric field while the fast electrons dump their energy in the hollow cathode discharge region. Also, there is a migratory electron flux which when balanced against the fast electron flux forms the hollow cathode discharge. It is also observed that the hollow cathode discharge once formed is sustained throughout for complete cycle of operation. The metastable and excited species have greater mass fraction than the ionized species. Also, the electron temperature is ~3.2 eV on an average. The proposed analysis suggests that DBD discharge created in micro-scale can be used for UV/VUV generation and for a range of applications related to it.

Summary

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