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PIC/MCC simulations of field emission driven microdischarges

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ABSTRACT

The aerodynamic flow control using plasma has been shown to demonstrate great ability with potential applications in both subsonic and supersonic flow regimes [1]. In the past, both numerical and experimental work has been done on dielectric barrier discharges (DBD) as a plasma actuator of cm and mm scale [2]. The plasma, which is ionized gas with free electrons and ions, in cm–mm scale plasma actuators, is generated when sufficient electric filed passes through the gas to ionize it. Typically thousands of volts of potential is required to create high electric fields which then accelerate electrons to create ions by impact ionization. However, at the micron scale in addition to impact ionization, field emission at the electrode is also a source of electrons which in turn ionize the molecule. In addition to this, the breakdown potential is also lower at the micron scale for the same pressure as is observed from the modified Paschen curve. This study deals with the numerical modeling of the DC voltage driven DBD micro plasma actuator in Argon gas at 1 atm using particle in cell method with Monte–Carlo collisions [3] with field emission and the effect of the body force generated by this microdischarge on the macroscale flow using computational fluid dynamics. The DBD is modeled with kinetic approach because of the micron scale characteristic length of the device which leads to a Knudsen number, K_n ~ 0.4 which is rarefied. The body force per unit volume generated by the ions in the electric field is, $f_b = eE\,(n_i - n_e)$ [4], where e is the magnitude of electron charge, E is the electric field, n_i is the ion number density, and n_e is the electron number density. Preliminary simulations of the micronscale DBD with copper electrodes of each 100 μm length and 1 μm thick, separated by 1 μm thick and 200 μm long dielectric with relative permittivity of 10, indicated an average $f_b = 2 \times 10^6$ N/m^3. The body force is introduced into the FLUENT simulation of 2D rectangular channel (0.5 mm x 5 mm) flow at multiple locations at the wall. The results for 250 V micron scale DBD show an increase in wall velocity of 2 m/s and an increase of 1.8% in exit mass flow rate, because of field emission alone. The results considering AC voltage and effect of variation of the gap between electrodes will also be presented.

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