

NON-THERMAL ATMOSPHERIC PRESSURE PLASMAS FOR AERONAUTIC APPLICATIONS

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Abstract. Dielectric barrier surface discharges (DBD) have the potential to act as flush mounted flow control devices for separation control and other aeronautic applications. A pulse-sustained plasma with the ions driven by a DC bias voltage is proposed for optimum performance. While characterizing these devices, it was found that their performance is severely limited by surface charge build-up. That charge builds up rapidly and remains for as long as hours. Work in this paper shows that the surface charge can be mitigated by using a reversing DC bias potential or by using a constant DC bias potential with a partially covered electrode.

1. INTRODUCTION

Many recent studies have demonstrated the utility of dielectric barrier discharge (DBD) plasma actuators with offset electrodes (Figure 1a) for aerodynamic control.¹⁻⁵ In particular, they have been shown to suppress boundary layer separation in low-speed flow on airfoils, so there has been great practical interest in developing this technology further. Typically, these DBD discharges are driven by high peak-to-peak sinusoidal voltages (tens of kilovolts), and they produce surface jets that are in the direction of the offset covered electrode, as shown by the arrow in Fig. 1a. Understanding the physics of the process is still proceeding, with the current picture being that charge separation and attachment of electrons to the surface play a critical role. Modeling in our laboratory captured that process,⁶ and, with that insight, we predicted that a voltage waveform consisting of high-voltage nanosecond repetitive pulses superimposed on a DC bias voltage would produce significantly enhanced wall jet velocities compared with those generated with the conventional sinusoidal voltage. In this case, the plasma is generated and the charge separation formed by the repetitive short ionization pulses, and the momentum transfer to the neutral gas occurs due to the ions that are driven by the charge separation enhanced by the DC bias voltage. The advantage of this non-self-sustained discharge is that the parameters of ionizing pulses and the driving bias voltage can be varied independently, which adds efficiency and flexibility to control and optimization of the actuator performance. The nanosecond pulses accelerate electrons to high velocity between collisions, so the ionization process is more efficient, and the timing and repetition rate of the pulses can be optimized to minimize power and maximize thrust. The DC bias avoids the intermittent generation of thrust characteristic of AC driven systems, and thus can have a 100% duty cycle.

However, laboratory measurements with this pulse plus DC waveform did not yield the increased performance predicted. Upon closer inspection we observed that the jet velocity was high for a few pulses when the DC was turned on, but slowed significantly thereafter.⁷ From this observation we determined that surface charge, which built up over a number of pulses, was limiting the performance. This charge opposes the applied DC potential. This build-up process is not captured in the model because subnanosecond time steps are necessary, and the long build-up time exceeds the few microsecond single CPU computational limit. Further experiments^{8,9} have shown that the same surface charge builds up in the conventional sinusoidal-driven DBD configuration, so it is important to develop approaches that will minimize its effect.