Western Nanofabrication Facility

MEMS Manufacturing of Dielectric Barrier Discharge Plasma Actuators

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Actuators are an integral component in flow control systems. The dielectric barrier discharge (DBD) plasma actuator, herein referred to as a plasma actuator, is a novel type of flow actuator. Several studies have demonstrated the potential of plasma actuators for reducing the effect of separation on airfoils (see review article by Moreau for examples, [2]). Applications of these devices to industry have been restricted by a number of practical limitations related to the present material and fabrication methods used. One of the goals of the Flow Control and Experimental Turbulence (FCET) group is to advance the fabrication process of plasma actuators and validate the resulting devices as a precursor to their deployment in industrial applications.

The DBD plasma actuator consists of two asymmetrically arranged electrodes separated by a dielectric material as shown in Figure (a). When a sufficient AC voltage is supplied, the asymmetrical electrode configuration creates an electric field that weakly ionizes the air above the buried electrode forming plasma discharge. The charged plasma experiences a Lorentz force in the presence of the electric field causing a net body force in the direction of decreasing electric field potential. This body force draws the ambient (neutrally charged) air towards the wall and jets fluid away from the exposed electrode. An in-depth description of DBD plasma actuator physics can be found in the review by Moreau [2].

Typically, plasma actuators are made using self adhesive layers of copper foil tape for the electrodes and polymide (Kapton) tape as the dielectric. This method of manufacturing is simple and inexpensive. However, these actuators suffer the consequence of material degradation and geometrical imperfections which are impractical for precise experimentation. To address these limitations, a MEMS process is employed.

The process by which copper and aluminium electrodes are deposited onto an akali-free borosilicate glass substrate is as follows. The substrate is subjected to a twenty minute oxygen plasma cleaning process to eliminate surface contaminants. Two types of photoresistive material, LOR followed by S1827, are then spin-coated onto the glass substrate. The combination of resists provides an undercut in the physical mask after development for metal lift-off. The photoresist layer is exposed to UV light in the desired pattern using the MA6 Mask aligner. The exposed area is then chemically dissolved with photolithographic developer (MF319) to expose the substrate surface. A two minute oxygen plasma clean is used to ensure the substrate is clean prior to sputtering. A 2.5 µm cumulative layer of metal is then deposited onto the substrate with the Edwards sputtering tool under an argon plasma. A layer of copper electrode is deposited first followed by a thin protective layer of aluminium. PG remover solvent is used to lift-off the metal deposited on the remaining photoresist while metal deposited directly onto the substrate remains intact. This process is repeated on both sides of the substrate. Figure (b) shows the bottom view of a plasma actuator fabricated by the FCET at The Western Nanofabrication Facility in London, Ontario.

Recently, arrays of the MEMS actuators manufactured at The Western Nanofabrication Facility were successfully used to control the transient growth mechanism inherent to bypass transition at the FCET lab (Hanson et al., [1]). Current research projects at the FCET lab include further development of the aforementioned applications as well as the detailed performance evaluation of MEMS manufactured actuators and those using typical methods.

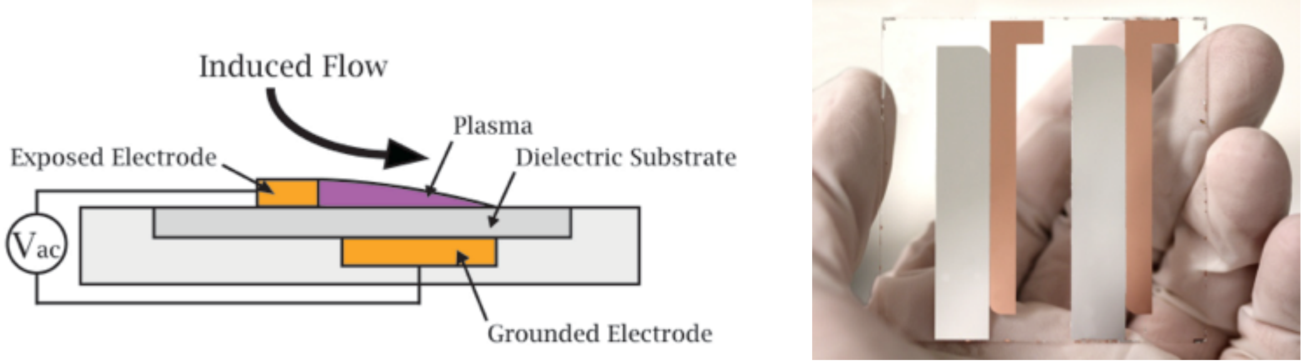

Figure (a) The 2D cross-section of a DBD plasma actuator. (b) Bottom view of a MEMS plasma actuator shows the aluminium coating of the grounded electrode while the copper layer of the exposed electrode can be seen through the glass substrate.

1. Hanson, R. E., Lavoie, P., Bade, K. M., and Naguib, A. M., “Steady-State Closed-Loop Control of Bypass Boundary Layer Transition Using Plasma Actuators," *50th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition*, Nashville, Tennessee. No. AIAA 2012-1140, 2012.
2. Moreau, E., “Airflow Control by Non-Thermal Plasma Actuators," *Journal of Applied Physics D: Applied Physics*, Vol. 40, 2007, pp. 605-636.

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