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Magnetron Sputter Coating of Inner Surface of 1-inch Diameter Tube

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Tubes are of extreme importance in industries as for fluid channels or wave guides. Furthermore, some weapon systems such as cannons use the tubes as gun barrels. To increase the service life of such tubes, a protective coating must be applied to the tubes' inner surface. However, the coating methods applicable to the inner surface of the tubes are very limited due to the geometrical restriction. A small-diameter cylindrical magnetron sputtering gun can be used to deposit coating layers on the inner surface of the large-bore tubes. However, for small-bore tubes with the inner diameter of one inch (~25 mm), the magnetron sputtering method can hardly be accommodated due to the space limitation for permanent magnet assembly.

In this study, a new approach to coat the inner surface of small-bore tubes with the inside diameter of one inch was developed. Instead of using permanent magnets for magnetron operation, an external electro-magnet assembly was adopted around the tube to confine the plasma and to sustain the discharge. The electro-magnet was operated in pulse mode to provide the strong axial magnetic field for the magnetron operation, which was synchronized with the negative high-voltage pulse applied to the water-cooled coaxial sputtering target installed inside the tube. By moving the electro-magnet assembly along the tube's axial direction, the inner surface of the tube could be uniformly coated.

The inner-surface coating system in this study used the tube itself as the vacuum chamber. The SS-304 tube's inner diameter was 22 mm and the length was ~1 m. A water-cooled Cu tube (sputtering target) of the outer diameter of 12 mm was installed inside of the SS tube (substrate) at the axial position. The 50 mm-long electro-magnet assembly was fed by a current pulse of 250 A at the frequency and pulse width of 100 Hz and 100 usec, respectively. The calculated axial magnetic field strength at the center was ~0.6 Tesla. The central Cu tube was synchronously driven by a HiPIMS power supply at the same frequency of 100 Hz as the electro-magnet and the applied pulse voltage was -1200 V with a pulse width of 500 usec. At 150 mTorr of Ar pressure, the Cu deposition rate of ~10 nm/min could be obtained.

In this talk, a new method to sputter coat the inner surface of small-bore tubes would be presented and discussed, which might have broad industrial and military application areas.

Keywords: Magnetron sputtering, Tube's inner surface coating, Electromagnet, HiPIMS