Silicon Oxynitride: A Field Emission Suppression Coating

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Abstract

We have studied coatings deposited using our inductively-coupled RF plasma ion implantation and desposition system to suppress field emission from large, 3-D electrode structures used in high voltage applications, like those used by Thomas Jefferson National Accelerator Facility in their DC-field photoelectron gun. Currently time and labor-intensive hand-polishing procedures are used to minimize field emission from these structures. Previous work had shown that the field emission from polished stainless steel (27 μA of field-emitted current at 15 MV/m) could be drastically reduced with simultaneous deposition of sputtered silicon dioxide during nitrogen implantation (167 pA of field-emitted current at 30 MV/m). We have determined that this unique implantation and deposition procedure produces high-purity silicon oxynitride films that can suppress field emission from stainless steel regardless of their initial surface polish. However, when this implantation procedure was applied to large, 3-D substrates, arcs occurred, damaging the coating and causing unreliable and unrepeatable field emission suppression.

We have developed a novel reactive sputtering procedure to deposit high-purity silicon oxynitride coatings without nitrogen ion implantation. We can control the stoichiometry and deposition rate of these coatings by adjusting the nitrogen pressure and incident RF-power. Using profilometry, Auger electron spectroscopy, X-ray photoelectron spectroscopy, Fourier transform infrared spectroscopy, Rutherford backscattering spectrometry, elastic recoil detection analysis, and current-voltage measurements, we have determined that the elemental composition, chemical bonding, density, and electrical properties of the reactively-sputtered silicon oxynitride coatings are similar to those produced by nitrogen implantation during silicon dioxide deposition. Furthermore, high voltage tests determined that both coatings similarly suppress field emission from 6" diameter, polished stainless steel electrodes.

We determined a quantitative, predictive electron emission model to describe electron emission from our silicon oxynitride coatings. Although Fowler-Nordheim theory adequately describes field emission from metals, it does not apply to our dielectric coatings. Several models exist in the literature to describe electron emission from dielectrics. Based upon our high voltage field emission results, electron emission from our silicon oxynitride coatings is described by the Schottky and Poole-Frenkel emission models. These models predict that increasing the band gap, dielectric constant, and electron affinity of our silicon oxynitride coatings would further reduce field emission.