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4P17

Effect of Carrier Gases on Plasmas for Oxide Etching

Chunshi Cui, John Trow and Ken Collins
Applied Materials, Inc.
974 E. Arques. Ave., Sunnyvale, CA 94086, USA

Abstract

Oxide etch of sub-quarter-micron structures has become more and more critical for new generation ULSI devices. This requires very high selectivity of oxide to mask materials (e.g. photo-resist) and stopping layers (commonly Si3N4). Such selectivity is strongly affected by both electrical and chemical properties of an oxide etching plasma including the plasma density, the electron and ion energy distributions, the degree of dissociation and ion to neutral ratio controlling the neutral and ionic species distributions.

In this study, various plasma diagnostics were carried out in an Inductively-Coupled-Plasma (ICP) oxide etcher at Applied Materials. The inductive power was coupled with two inductive-coils through a semiconducting roof. The plasma density was controlled by the source rf power with linear response over large range of power. The bias power was applied through a ceramic ESC that controls the DC bias therefore the ion energy. In order to achieve high selectivity, C4F8 gas was used as the main etching gas for it's high C/F ratio. The C4F8 molecule can have multi-step dissociation resulting in very rich neutral and ionic spectra. Three carrier gases, He, Ar and Xe, were chosen as a vehicle to vary the plasma characteristics since they have very different ionization thresholds ***Ei*** and atomic mass (***Ei*** ~ 24, 15 and 11eV and ***M*** = 2, 40 and 131 respectively).

The chemical compositions were measured using an energy selective ion mass spectrometer (IMS) and optical emission spectroscopy (OES). The electron energy distribution and density were measured with a Langmuir probe. It was found that the type of carrier gas can significantly change the chemical species, effective electron temperature and density of the plasma. The impact of such plasma differences on oxide etch was demonstrated by physical sputtering and chemical etching of the top of an oxide via hole namely faceting.

4P18

Fabrication of Duplex Coatings on Biomedical Titanium alloys by Plasma Nitriding, Metal Plasma Immersion Ion Implantation, and Reactive Plasma Oxidation

Y. X. Leng, X. B. Tian, Z. M. Zeng, X. C. Zeng, B. Y. Tang, P. K. Chu
Department of Physics & Materials Science
City University of Hong Kong
83 Tat Chee Avenue, Kowloon, Hong Kong, China

P. Yang, J. Y. Chen, N. Huang, and Z. R. Zhou
Department of Materials Engineering, Southwest Jiaotong University, Chengdu 610031, China

Owing to outstanding properties such as high strength to weight ratio, exceptional resistance to corrosion, and excellent biocompatibility, titanium alloys are attractive in biomedical applications such as artificial joints, heart valves and fixation pins. The good biocompatibility of titanium alloys is associated with the formation of a passivating oxide film on its surface. However, a surface film formed at room temperature in air is thin and easily removed. In order to increase the film thickness, methods such as physical vapor deposition (PVD), thermal oxidization, and ion beam enhanced deposition (IBED) have been used. It has been shown that the rutile type titanium oxide films have good biocompatibility, and when the thickness of the oxide film exceeds 40nm, its blood compatibility can exceed that of LTIC (Low Temperature Isotropic Pyrolytic Carbon) that was once regarded to be the most advanced materials for artificial heart valves. In spite of these excellent properties, premature failure of titanium oxide coated titanium alloys occurs if the substrate deforms plastically under a high load. The titanium oxide films will debond from the substrate to result in adhesive failure. In order to make titanium oxide films that possess good blood compatibility and can withstand a high contact stress, we are using a novel hybrid plasma fabrication technique combining plasma nitriding and plasma immersion ion implantation (PIII). The titanium alloys are first nitrided in a nitrogen plasma and then the TiO_x coating is produced by plasma immersion ion implantation utilizing titanium metal plasma and reactive plasma oxidation. The Ti-N layer produced by plasma nitriding can withstand a high contact stress, and the titanium oxide coating generated by PIII yields improved biocompatibility and tribological properties. In this paper, the plasma fabrication processes are described. In addition, the tribological properties are assessed by measuring the microhardness and wear resistance, whereas the microstructures and surface characteristics are evaluated by using glancing x-ray diffraction, atomic force microscopy, and transmission electron microscopy. Our results show that titanium alloys with surface duplex PIII-TiO_x / Ti-N films have better load bearing capacity than that of PIII-TiO_x films.