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Plasma-enhanced chemical vapor deposition of nanocomposite thin films

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Materials development has reached a point where it is difficult for a single material to satisfy the needs of sophisticated applications in the modern world. Nanocomposite films and coatings achieve much more than the simple addition of the constitutents - the law of summation fails to work in the nano-world. Plasma-enhanced chemical vapor deposition (PECVD) is a coating technology using chemically activated species - free radicals to construct thin films that may be modified by accompanied ion bombardment during deposition process. Physico-chemical properties of deposited films are controlled by deposition conditions. Thin films in a form of hydrogenated amorphous carbon-silicon (a-SiC:H) alloy were deposited on polished silicon wafers (100) from tetravinylsilane monomer using PECVD (13.56 MHz). The power ranging from 10 to 70 W and self-bias varying 120-680 V at a mass flow rate of 3.8sccm (3.0 Pa) were used to deposit films of thickness about 1 μm. The deposited films at a power of 10 W were of grain structure with a diameter of grains 20-100 nm. The diameter of some grains increased up to 0.5 μm with enhanced power at an expense of smaller ones, whose magnitude decreased. The bigger grains formed isolated islands in a relatively smooth matrix at a power of 50 W and the density of bigger grains increased forming agglomerates at a power of 70 W. The grain structure of all the films was extensively investigated by atomic force microscopy (AFM) using height, magnitude, phase, lateral force, and atomic force acoustic microscopy (AFAM) modes. The RMS roughness characterizing surface morphology of films increased from 3.4 nm (10 W) to 21.7 nm (70 W). Nanoindentation measurements were used to evaluate mechanical properties of the smooth matrix and bigger grains. The Young's modulus and hardness corresponding to the matrix increased with enhanced power from 11 GPa (0.8 GPa) at a power of 10 W to 81 GPa (8.8 GPa) at a power of 70 W, respectively. Surprisingly, the mechanical constants of bigger grains were lower than those of the matrix, e.g., the Young's modulus (hardness) was 42 GPa (3.5 GPa) for grains formed at a power of 70 W, i.e., half a magnitude in contrast to the matrix. Mostly, hard particles reinforce a softer matrix in composite films. However, our films include softer grains in a stiffer matrix resulting in higher toughness of deposited films - a new type of coatings.

Keywords
PECVD
nanocomposite
AFM
nanoindentation
Young's modulus