Optical and Microstructural Studies of 'Diamondlike' Carbon Films Using Spectroscopic Ellipsometry*

by

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Introduction

"Diamondlike" carbon (DLC) is a hard carbon which is amorphous but has a large ($\leq$40 atomic percent) hydrogen content. There is a strong analogy between DLC and the amorphous hydrogenated silicon which is of such great interest lately. The DLC films are semitransparent and amazingly resistant to chemicals and adverse environments. These materials are of fundamental scientific interest, and have potential for optical coatings and other applications as well.

Samples and Experiments

Samples were prepared by rf plasma deposition mainly from a methane gas source, and are deposited on a variety of substrates including single crystals of silicon, germanium, cadmium telluride, mercury cadmium telluride, as well as on fused silica. Using spectroscopic ellipsometry the real and imaginary parts of the dielectric constant ε_1 and ε_2 measured as a function of photon energy from 0.4 ev to 6 ev. The thickness and optical properties of films were determined by accounting for the substrate and interfacial layer effects. Optical properties were determined unambiguously, with no preassumptions regarding for example, the thickness. Microstructural information was obtained using effective media approximations. In addition, transmission electron microscopy was used to examine microstructure. Environmental tests were made to test durability, including 24 hour exposure to steam, cooling to 100K, soaking in solvents, rubbing with abrasives, and soaking in acids.

Results and Discussion

Figure 1 shows the real and imaginary part of the dielectric constant as a function of photon energy near the onset of optical absorption. The extinction coefficient is lower than the sensitivity of ellipsometry ($\sim$0.001) in the red to infrared wavelengths. The onset of absorption in the blue fits a Tauc dependence $\alpha h\nu \propto (h\nu - E_{gap})^{1/n}$ where α is the absorption coefficient, E_{gap} is the "optical bandgap" consistent with amorphous materials, and n is a parameter equal to 2 for our sample. In the 300 nm wavelength region there is an additional weak absorption which is likely due to microscopic regions of pi bonding origins. We have used the Bruggeman effective medium theory to model the microstructure. Assumed components are: diamond, graphite, voids, and selected polymers. Fits to the data are also made assuming a model of

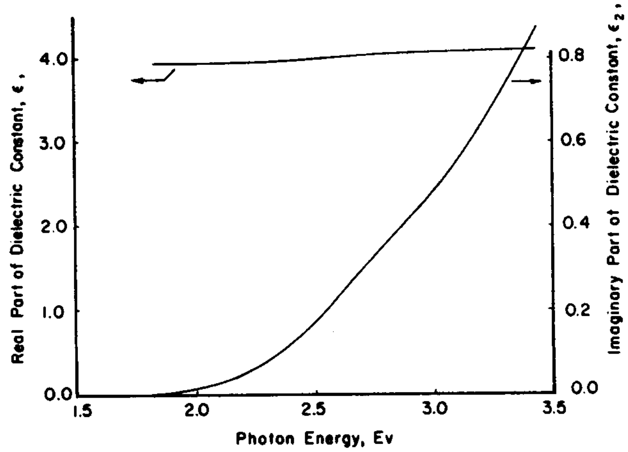

Figure 1. The dielectric constant as a function of photon energy.

Lorentzian oscillators. Best fits of data from several samples are compared.

Transmission electron microscopy is used to determine microstructure of the samples. In general the samples are found by electron diffraction photos to be completely amorphous. The only features of an unusual nature are the occasional presence of void regions of dimension 800 $\pm$ 200 Å.

The final experimental results to report are of a practical nature: we have deposited DLC on silicon single crystal wafers and performed the following tests relevant to using DLC as protective coatings for optical components, etc:

- 10 minute immersion in trichloroethylene
- 10 minutes in acetone
- 10 minutes in ethyl alcohol
- 24 hours in NaCl solution
- 24 hours in steam at atmosphere and 100^{o}C
- 24 hours at 100K, and thermal cycling.

Rubbing and adhesion tests were made after each of the above and after combinations of the above. Only occasional failure was found, and this was attributable to a dirty deposition chamber prior to deposition.

Conclusions

Our experiments show that DLC films are composed of a mixture of carbon, hydrogen, and voids (no impurities), and are totally amorphous. These films adhere to numerous substrates including several used as infrared detectors. The absorption coefficient in the infrared is exceptionally low, and the films are not removed after exposure to several adverse chemical environments.

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