Properties of DLC Films grown by Plasma Immersion Ion Implantation and Deposition

G. Thorwarth [a], J.W. Gerlach [b], W. Assmann, and B. Stritzker [a]
[a] Lehrstuhl für Experimentalphysik IV, Universität Augsburg [b] IOM, Leipzig

The requirements on the mechanical performance of modern materials frequently require an enhancement of the workpiece surface beyond the bulk properties and often coincide with the need for special additional attributes of the modified surface. Diamond-like carbon (DLC) is a class of materials known to exhibit excellent wear resistance properties and good corrosion resistance; the addition of dopants into its amorphous carbon structure has been shown to have a great influence on some key properties such as electrical conductivity and hydrophobicity. However, the deployment of DLC in the field of engineering including biomedical implants requires the understanding and development of economic coating processes suited for the treatment of complex shapes.

Plasma immersion ion implantation and -deposition (PIII&D) is a method combining layer deposition with ion bombardment from a plasma surrounding the workpiece. In the investigated process, a growing polymeric layer resulting from plasma deposition of heavy hydrocarbons is being subjected to bombardment of argon ions, leading to DLC layer growth with deposition rates of several μm/h [1]. ERDA analysis using Au ions at 200 and 190 MeV allowed for the quantification of hydrogen, argon and dopant elements in the layer and thus a more detailed understanding of the deposition process.

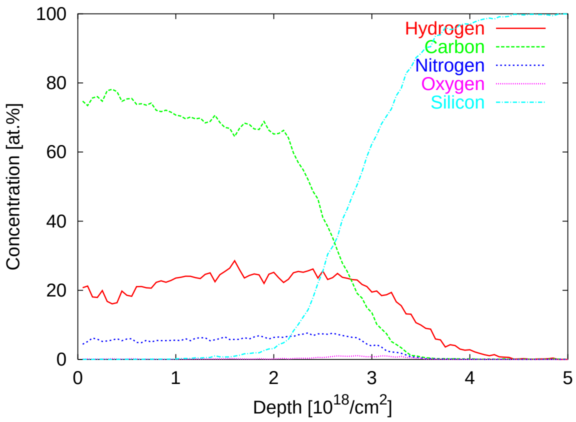

Fig. 1: ERDA depth profiles for a nitrogen doped DLC layer.

It was found that the layer properties including the hydrogen and argon content are determined by the energy density encountered during film growth, which is mainly due to Ar ion bombardment. Its magnitude can be described by the quantity DU/d, where D is the total implanted Ar ion fluence, U the pulse voltage used to accelerate the ions from the plasma, and d the layer thickness.

Regarding the hydrogen content, the increasing ion bombardment with rising DU/d results in a densification of the carbon films and a stronger hydrogen loss in favor of more carbon-carbon bonds; the same effect was observed for the Au ion bombardment during measurement. Fig. 1 shows this transition of the hydrogen content from more polymeric material to highly compressed DLC.

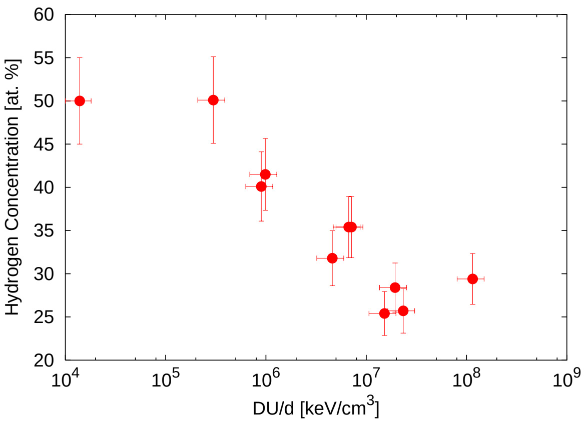

Fig. 2: Hydrogen content of various undoped DLC layers deposited with PIII&D.

The structural impact of this hydrogen loss and the increasing ion damage can be observed via structure sensitive methods such as Raman spectroscopy (see Fig. 3) as well as XPS and EELS. Raman spectroscopy carried out with visible photons shows clear changes in the "D" and "G" peak intensities, which are attributed to the aromatic ring breathing and sp^2 C=C stretching modes in the films, and which allow conclusions to the sp^3/sp^2-ratio of film bonds. The Raman data suggest a clear decrease of the films' sp^3/sp^2 ratio with increasing DU/d, which is confirmed by XPS measurements. The presence of a distinct nanohardness maximum for a DU/d value of 3×10^7 keV/cm^3 indicates that the C-C sp^3 type bonds generated by the loss of hydrogen are graphitized by additional ion bombardment.

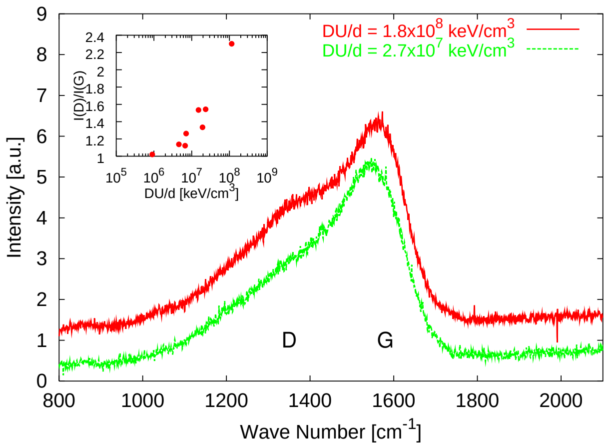

Fig. 3: Raman spectra of undoped PIII&D DLC films.

References

[1] G. Thorwarth, C. Hammerl, M. Kuhn, W. Assmann, B. Schey and B. Stritzker, 4th AEPSE conference, **Jeju, Korea** (2003)