Structural, mechanical and thermal behavior of carbon films produced by C_{60}^{+} beam

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INTRODUCTION

The potential applications of carbon-based materials have prompted many theoretical and experimental researches on this area. A wide range of structures obtained from fullerene C_{60} has been particularly interesting because of their hardness. However, it is not possible to produce large samples from classical methods based on high energy/temperature.

We have deposited hard hydrogen-free carbon films by accelerating C_{60} ions at deposition energies (E_{dep}) between 100 and 2000 eV. The experimental evidence shows that the characteristics of the films depend on E_{dep} [1,2].

We present here a study of the structural, mechanical and thermal behavior of films deposited at energies between 200 and 1000 eV.

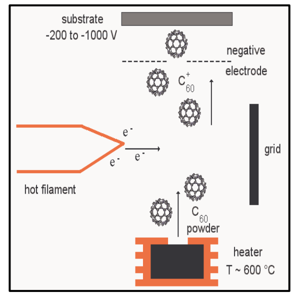
EXPERIMENTAL

➢ ***Sample preparation***

- Thickness of the obtained films ~ 0.2 µm.
- Substrates:
  - silicon wafer mirror-polished, Ar-sputtering at 4 keV.
  - a-C: thin film (~ 0.2 µm) from a C^+ beam (2,5 keV).
  - polished copper chemically cleaned.

➢ ***Sample characterization***

- Thermal behavior: vacuum annealing at 700 °C (1 hr).
- Raman spectroscopy: Ar+ laser, line 514.5 nm.
- Hardness: Nanoindentor Shimadzu DUH-202 (Vicker indenter). The resolutions are 1 nm in depth and 0.1 mN in load.

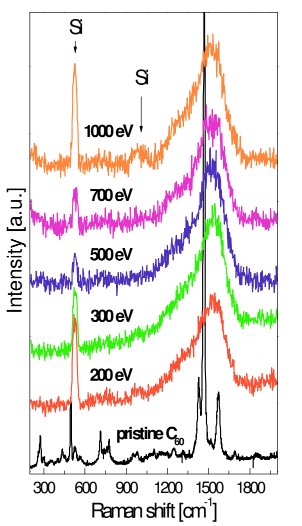


Scheme of the deposition process made in order to obtain carbon thin films from a C_{60}^{+} beam.

RESULTS

Structural properties: Raman Spectra

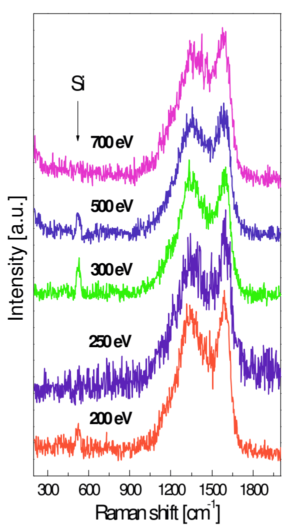
As-grown samples



Raman spectra of the as-grown samples as a function of the deposition energy and Raman spectrum of pristine C_{60} evaporated on a silicon substrate.

The spectra of our samples are similar to that of amorphous carbon: a broad band centered at about 1520 cm^{-1} (G-peak) with a shoulder at 1350 cm^{-1} (D-peak). Nevertheless, two bands around 700 and 1480 cm^{-1} resemble the structure of pristine C_{60}.

Annealed samples



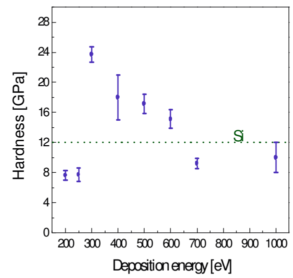
Raman spectra of the annealed samples at 700 °C as a function of the deposition energy.

After annealing process at 700 °C, spectra become similar to microcrystalline graphite one (D band at 1350 cm^{-1} and G band at 1580 cm^{-1}). However, gaussian fittings suggest the presence of C_{60} band around 1480 cm^{-1}.

Mechanical properties:

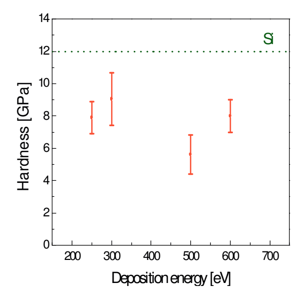
Hardness

As-grown samples



Hardness of the as-grown samples as a function of the deposition energy. The dotted line corresponds to the hardness of silicon wafer.

Annealed samples



Hardness of the annealed samples as a function of the deposition energy. The dotted line corresponds to the hardness of silicon wafer.

Adherence

It has seen under optical microscope that some films, deposited on silicon wafer, develop buckling and delamination (photograph) because of the internal stress.

In the order to obtain films with good adherence, have made deposition processes on other substrates: a-C and copper.

The films with best adherence have got for those deposited on a-C. It could be attributed to the amorphous characteristic of the substrate, which would permit the material to reduce his internal stresses.

X100 microscope photograph of the film obtained on the silicon substrate.

CONCLUSIONS

From Raman spectroscopy, the microstructure of the as-grown films is similar for samples obtained at different deposition energies. However, hardness and thermal behavior are quite different.

From hardness measurements, it is clear that there is a step rise at E_{dep} close to 300 eV.

After annealing at 700 °C, the obtained hardness measurements are considerably higher than typical hardness values of annealed a-C, nevertheless Raman spectra resemble the characteristic one of graphitized a-C.

The hardness results obtained as a function of the deposition energies are very interesting and prompt us to study the microstructure of these materials using additional techniques, like EELS, PAS, etc.

REFERENCIAS

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