# Modification of metal containing carbon films by swift heavy ion irradiation


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Properties of nanocomposite films comprised by silver 10-20 nm particles immersed in carbon matrix were investigated. The films were deposited onto silicon or glass substrates by means of sputtering or using fullerene beam. Swift heavi ion irradiation was done using 120 MeV Ag or Au ions at IUAC. Change in silver nanoparticle size during irradiation was found. Conductive tracks were formed by swift heavy ions. Track conductivity raises with amount of silver increase.


## Introduction:

**1. Object of investigation:**

Carbon films are of great interest due to their unique properties.

SHI <=> $v_{ion} > v_{e\_orb}$ $S_e > 1$ keV/Å

**2. Background & motivation:**

Nanowire formation by SHI in taC have been demonstrated

J. Krauser J. Appl. Phys., 94, 1950 (2003)

A one-to-one correspondence between the hillocks and the current peaks @low fluence

Track diameter was found ~8nm as confirmed by XTEM.

Same effect in C60 film under SHI irradiation was also found

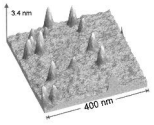
Kumar *et al. J. Appl. Phys.* **101**, 014308 (2007)

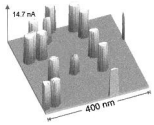
Field electron emission was investigated and promising route to produce same-aligned structures was proposed Gehrke et al. J. Appl. Phys. **107**, 094305 (2010)

Increase in wire conductivity is still needed

Metal nanoparticle evolution (elongation) under SHI irradiation was found

Metal doping or even Me nanoparticle embedding is a possible route.




## Experimental procedure

**Substrates** - Si and glass pieces of 1×1 $cm^2$

some covered by 40-50 nm gold layer as C-AFM contact

***taC*** films were grown by Ar beam sputtering deposition

$C_{60}$ films were grown by thermal evaporation from Ta boat

**Ag** was either glued on sputtered HOPG target or co-sputtered during fullerene evaporation

**Ion irradiation** 120 MeV Ag ions **at IUAC, New Delhi.**

**Sample charachterization techniques**

**Conductive AFM** – surface topography and local conductivity

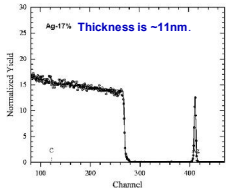
**RBS** – film composition investigation

**TEM** – nanoparticle size and structure

**UV-visible absorption spectroscopy** – NPs properties

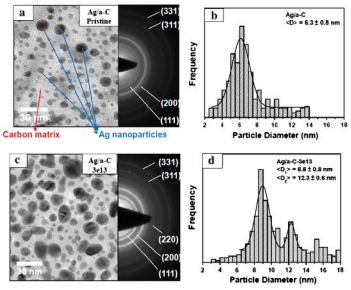
**Raman scattering** – carbon bond structure

## taC – Ag films :

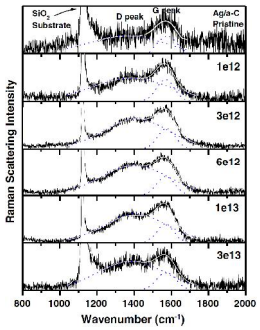



RBS spectrum of Ag/a-C thin film along with the RUMP fit.

**17% Ag is much above the solubility limit of Ag in carbon => NPs form**

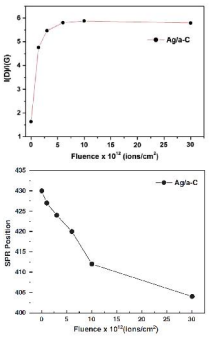


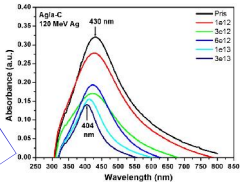

Bright field images of pristine Ag/a-C film (a) and NPs size distribution (b) film irradiated with 120meV Ag ions (c) and NPs size distribution (d). Bimodal distribution is seen




The spectra of pristine Ag/a-C film shows widespread asymmetric band formed by the superposition of **broad D** and comparatively **sharp G** bands (amorphous graphitic)

Intensity of **D** peak increases **G** peak is almost unaffected by ion irradiation




UV-visible absorption spectra of pristine and irradiated films of Ag/a-C

The SPR peak is broad due to

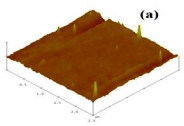
- the large size distribution of Ag NPs
- the partial absorption by thin film of a-C

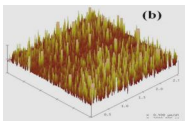
A small shoulder at lower wavelength end is due to the variety of shapes of NPs

Possible explanations for the blue shift in SPR wavelength with irradiation may be

(i) mixing with glass substrate, (ii) oxygen contamination,
(iii) mixing at metal-carbon interface,
(iv) slight change in shape of the particles, and
(v) change in the microstructure of a-C by swift heavy ion irradiation

## $C_{60}$ films




The topographic (a) and current (b) C-AFM images show formation of conducting tracks in the sample after 120 MeV Ag irradiation. The vertical rods in (b) represent the current flowing through the conducting ion tracks

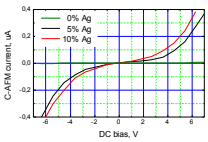
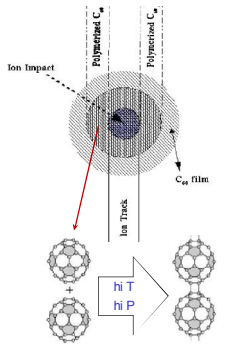



Fig. (c) shows the *I–V* characteristics of the nanowire as measured by C-AFM

Schematic to show the conducting region in the ion track and polymerized region formation at ion hit point.




the formation of C60 dimer

Kumar et al. J. Appl. Phys. 102, 044305, (2007)

## Conclusions

- ✓ A blue shift of ~26 nm in the SPR wavelength of Ag NPs was obtained by 120 MeV Ag ion irradiation. This shift is explained by the graphitic transformation of a-C matrix
- ✓ The average size of Ag NPs increases upon swift heavy ion irradiation and a bi-modal distribution was obtained at a fluence of $3\times10^{13}$ ions/$cm^2$.
- ✓ The growth of Ag NPs can be explained in terms of dissolution and re-precipitation of Ag during the thermal spikes produced by ions
- ✓ $C_{60}$ films containing different amount of Ag were grown and irradiated
- ✓ SHI irradiation of C60 films raises conductive nanowire formation due to of ion track formation and polymerization of surrounding region. The polymerized zone is further explained on the basis of high pressure and temperature around the track.
- ✓ Nanowire conductivity increases with the amount of Ag in the film