Conductivity enhancement of single ion tracks in tetrahedral amorphous carbon by matrix doping with B, N, Cu and Fe*

J. Krauser[1,#], A.-K. Nix[2], H.-G. Gehrke[2], H. Hofsäss[2], C. Trautmann[3,4], A. Weidinger[5]

[1]Hochschule Harz, Wernigerode, Germany; [2]Universität Göttingen, Germany; [3]GSI Helmholtzzentrum, Darmstadt, Germany; [4]Technische Universität Darmstadt, Germany; [5]Helmholtz-Zentrum Berlin, Germany

The irradiation of diamond-like tetrahedral amorphous carbon (ta-C) with swift heavy ions leads to conductive tracks. The increased conductivity along the ion trajectories is due to a transformation of the sp^3-rich phase (insulating) into a more sp^2-rich phase (conducting) of the material [1]. For any applications of conducting ion tracks [2], it is important that their conductivity exhibits Ohmic behavior and that the track conductivity is significantly larger than that of the surrounding matrix material. In the present study, we investigate if the conductivity of the ion tracks can be selectively enhanced by adding metal atoms (Cu and Fe) or other typical doping materials (B and N) during the growth process of the ta-C matrix layer.

The ta-C samples with film thickness of ~ 100 nm were produced at the University of Göttingen by means of low energy <u>m</u>ass <u>s</u>elected <u>i</u>on <u>b</u>eam <u>d</u>eposition (MSIBD) on heavily doped n-Si substrates. Doping of the ta-C films was performed by injecting the desired dopant into the ion source and then rapidly switching the mass separation magnet from ^{12}C to the dopant ion periodically. The doping concentration for all samples is about 1 at. % except for the ta-C:B sample which has a doping concentration of 2 at. %. Doped and undoped samples were exposed to 1-GeV Au or U ions at the UNILAC. The fluence was in the range of 1 - 5×10^9 ions/cm^2. The conductivity of individual ion tracks was analyzed by <u>a</u>tomic <u>f</u>orce <u>m</u>icroscopy (AFM) using a conducting tip.

Figure 1 shows I-V characteristics of single tracks in undoped and doped films. It is evident that the doping changes the current through the tracks drastically: N- and B-doping induces a moderate and Cu and Fe doping a strong increase of the currents. The I-V curves for B- and N-doped samples are still slightly bend whereas those for Cu- and Fe- doped samples are straight lines.

Figure 2 shows the conductivity of the tracks calculated from the slopes of the I-V curves at low voltages. Doping significantly improves the track conductivity. Cu is identified as most suitable, while B, N, and Fe dopants have the disadvantage to enhance the conductivity not only of the tracks but also of the unirradiated ta-C matrix. The incorporation of Fe can produce conducting paths through the ta-C matrix, degrading the resistivity of the unirradiated film and thus leading to a low conductivity contrast (not shown here).

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jkrauser@hs-harz.de

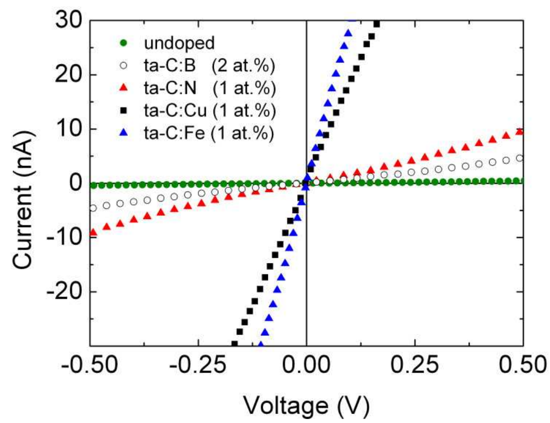

Figure 1: I-V characteristics of single ion tracks in undoped and differently doped ta-C samples. The dopant species and their concentrations are indicated.

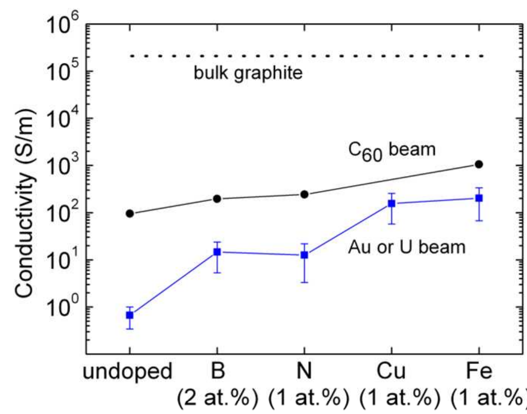

Figure 2: Conductivity of ion tracks for differently doped ta-C films. The beams were 1-GeV Au or U ions (for Cu) and 30-MeV C60 clusters [3]. The conductivities were calculated assuming a cylinder of 8 nm diameter and a length corresponding to the film thickness (100 nm).

References

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