Mixing of Low–Energy Carbon Ions

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Subplantation was early recognized as being the basic mechanism in low–energy ion growth of diamondlike materials and has also to be considered for the description of bias enhanced diamond nucleation. A number of theories modelling the evolution of diamondlike phases have been proposed. However, the precise details of the subplantation and relaxation processes remain unclear. The problem in testing the complex models is that experimental information other than film structure versus ion energy is missing to a large extent. Mixing and range distributions of the utilized ion species are ideal data to survey subplantation growth models.

Range distributions of low-energy carbon ions are reported in our previous work [1,2]. Here, we present for the first time measurements of mixing distributions for carbon ions at energies in the relevant energy range between 12 eV and 692 eV. Amorphous 12 nm thick ^{12}C films are grown by mass separated ion beam deposition [3]. Subsequently, 5×10^{14} at/cm^2 ^{13}C are implanted at the same energy. In a final step additional 9×10^{16} at/cm^2 ^{12}C are deposited. The atomic mixing is characterized via the alteration of the ^{13}C range profiles induced by subsequent ^{12}C bombardment. ^{13}C depth profiles are measured by high–resolution elastic recoil detection (ERD). Utilizing a deconvolution procedure in the framework of Bayesian probability theory the uncertainty of each deconvoluted profile and of all terms deduced therefrom is quantified [4]. These data are directly compared to calculations based on the binary collision approximation (TRIDYN [5]) and to molecular dynamics (MD) simulations [6] which consider atomic interactions on a time scale up to 15 ps including the thermal–spike phase. Additionally, mixing distributions are derived from a transport calculation based on the measured range distributions.

Fig. 1 shows the measured and calculated ^{13}C mixing distributions at ion energies $E_{ion} = 47$ eV, $E_{ion} = 122$ eV and $E_{ion} = 692$ eV. At energies below 222 eV the measured mixing profiles are clearly broader than respective TRIDYN and MD calculations, but match to the results from the transport calculation within the experimental uncertainties (Fig. 1(a,b)). This approves the measured range distributions as well as the relevance of the observed discrepancies between the range profiles from theory and experiment [1,2]. At energies above 472 eV the experiment is well reconstructed from TRIDYN simulations (Fig. 1(c)). Thus, the atomic mixing is dominated from effects of the collisional cascade at these energies.

Three mechanisms resulting in the observed differences between the measured and theoretical mixing distributions as well as range distributions have to be considered: thermal induced self diffusion during thermal spike, mobility solely of the deposited ion after the collisional stage and a 3–dimensional surface structure of the carbon films on atomic scale as a structural precondition for diamondlike film growth. The experiment allows a crucial test for models of the subplantation scheme and may serve as input for improved calculations.

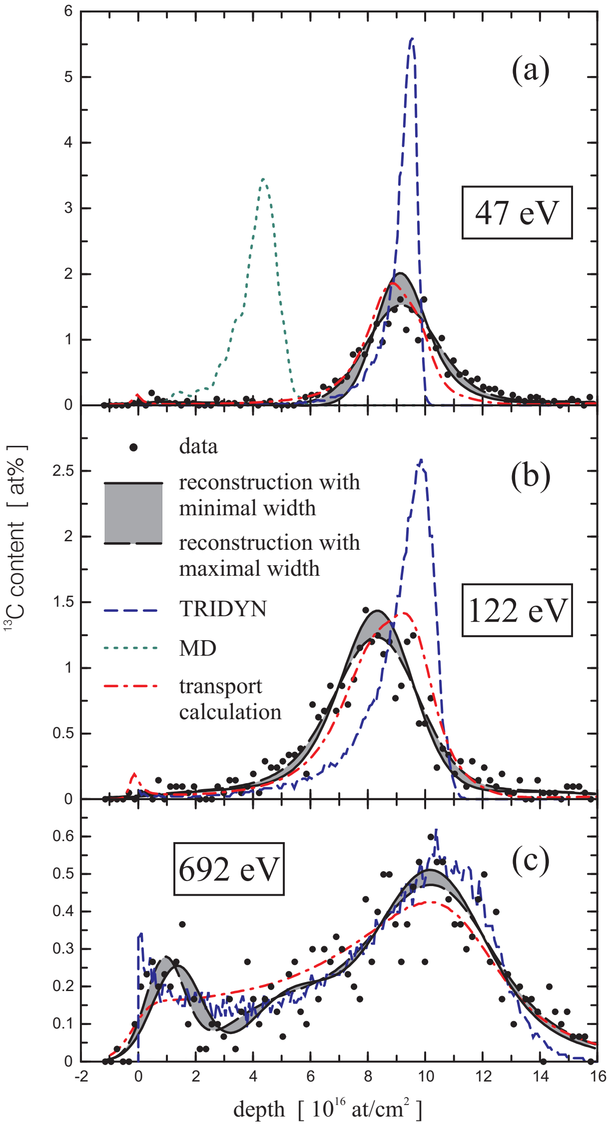

Fig. 1: Measured and calculated ^{13}C mixing distributions at ion energies which are shown in the plot. TRIDYN and transport calculations are carried out for a 9×10^{16} at/cm^2 thick ^{12}C cap layer. The MD simulation is performed for ion energies $E_{ion} \leq 92$ eV and a 5×10^{16} at/cm^2 thick ^{12}C cap layer due the high CPU time consumption.

References

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