Range Distributions of Low–Energy Carbon Ions in Tetrahedral Amorphous Carbon Thin–Films

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Subplantation was early recognized as being the basic process in low–energy ion growth of diamondlike materials and has also to be considered for the description of diamond nucleation in bias enhanced nucleation processes. 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 [1]. The problem in testing the complex models is that experimental information other than film structure versus ion energy is missing to a large extent.

We present for the first time measurements of range distributions for carbon ions having energies in the relevant energy range between 22 eV and 692 eV. Amorphous ^{12}C films have been grown by mass–separated ion–beam deposition [2]. Subsequently, ^{13}C ions were implanted with the same energy. ^{13}C depth profiles were 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 [3,4]. Due to an improved calibration procedure depth scale of the measured profiles is given with an accuracy of $\pm\, 0.7 \times 10^{15}$ at/cm^2 corresponding to $\pm$ 0.7 ^{25}Mg(p,γ)^{26}Al A for a supposed density of 2 g/cm^3 near the surface. These data are directly compared to range calculations based on the binary collision approximation (TRIM96/2000 [5] and TRIM.SP [6]) and to molecular dynamics (MD) calculations [7] which extend the considered atomic interactions on a time scale up to 15 ps including the thermal spike phase (see Fig.1).

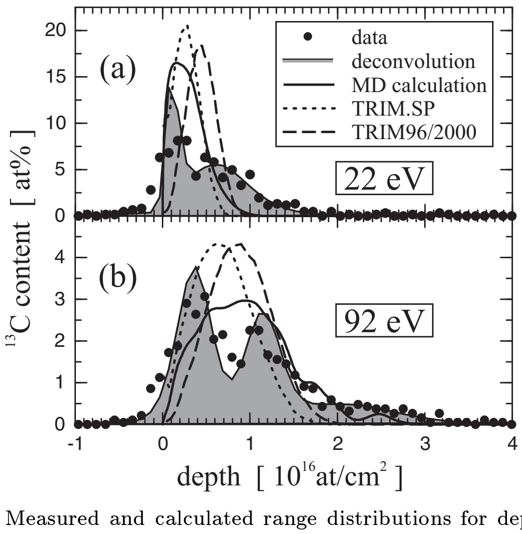

Fig. 1: Measured and calculated range distributions for deposition energies (a) E_{Ion} = 22 eV and (b) E_{Ion} = 92 eV.

The measured mean ion ranges which are in the dimension of one monolayer for carbon ions with energies below 30 eV show a good match to respective TRIM96/2000 and TRIM.SP calculations (Fig.2(a)). The fact that the shape of the measured profiles is better reconstructed by MD calculations is attributed due to density fluctuations (Fig.1 and Fig.2(b)). The portion of ions incorporated in subsurface sites strongly increases for energies between 20 eV and 50 eV (Fig.2(c)).

The experiment allows a crucial test of models for the subplantation scheme and may serve as input for improved calculations.

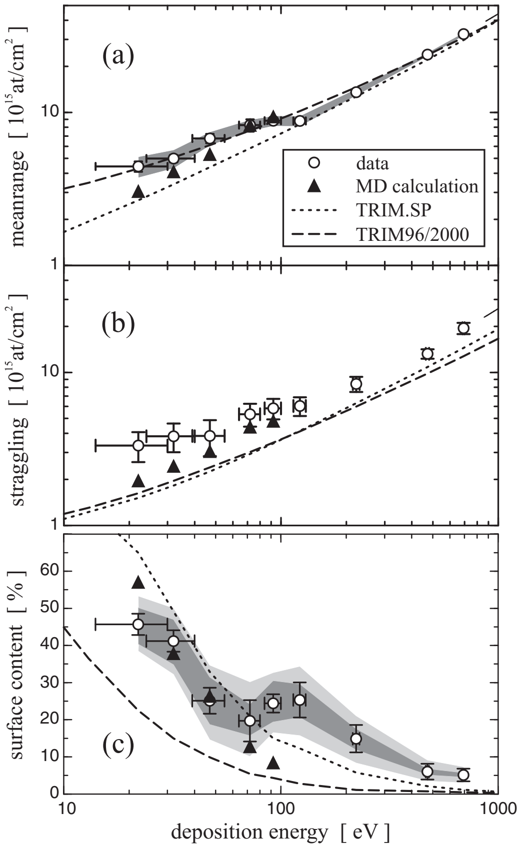

Fig. 2: Measured and calculated (a) mean ion ranges, (b) straggling of the ion range and (c) portion of ions incorporated within the topmost 3×10^{15} at/cm^2. The error bars depict the respective errors due to statistics and the uncertainty of the apparatus function, the gray shadowed area visualizes the offset error due to the uncertainty of zero thickness, the light–gray shadowed area in (c) the error due to statistics and the uncertainty of the apparatus function at the extreme of the uncertainty of zero thickness.

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