Report on experiment 02-02-808
(12 December 2013 – 18 December 2013)

Irradiation-induced amorphization and recrystallization in SiC single crystals: a combined GISAXS – GIXRD study

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The aim of the present experiment was to investigate the amorphization mechanisms in ion irradiated SiC single crystals. For this purpose (001)-oriented 3C-SiC single crystals have been irradiated with 100 keV Fe ions for increasing fluence prior to the XRD/GISAXS experiments. Selected crystals (amorphized or partially amorphized) have also been subjected to swift heavy ion (SHI) irradiation (Pb, 0.87 GeV) in order to promote epitaxial recrystallization. All experiments have been conducted on the Kappa diffractometer of the BM2 beamline. XRD and GISAXS data have been recorded sequentially using the precise sample positioning allowed by the Kappa diffractometer.

Coplanar θ-2θ scans recorded on the (002) reflection of 3C-SiC are displayed in Fig. 1. It can be observed that ion irradiation results in the formation of a heavily strained thin surface layer (low intensity signal on the low angle side). The maximum level of strain within the damaged layer can be deduced from the position of the highest order fringe in the scans. Upon increasing fluence the strain level increases from 1.2% up to 8%.

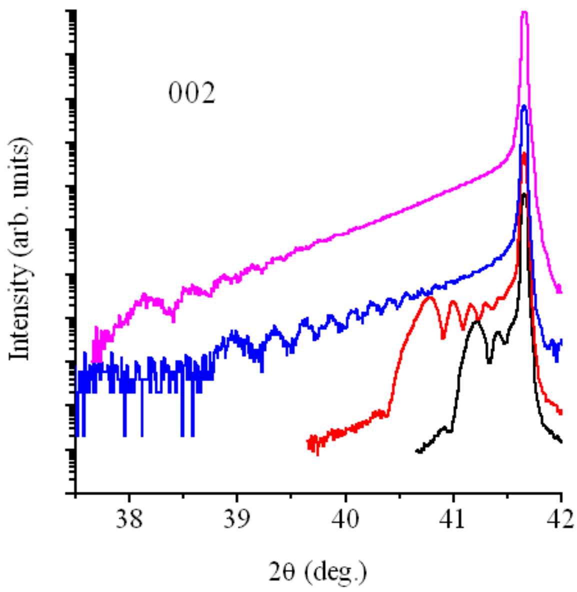

Fig. 1: (002) θ-2θ scans for increasing ion fluence (bottom to top)

Surprisingly, even for these huge strain levels, the damaged layer remains perfectly pseudomorphic with respect to the underlying (unirradiated) substrate as attested by the (113) reciprocal space maps (Fig. 2) : the streak emanating from the damaged layer is parallel to the *L* axis and perfectly aligned with the reflection from the substrate (no shift in the in-plane reciprocal lattice coordinates can be observed).

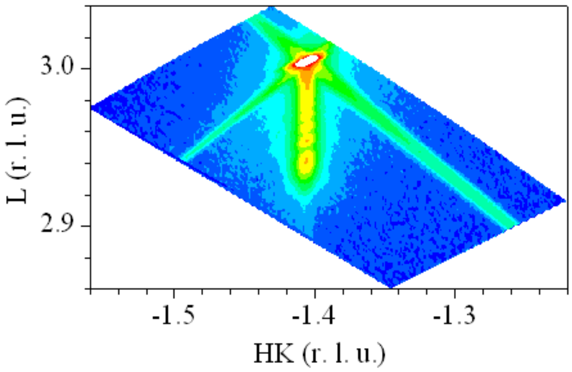

Fig. 2 : (113) reciprocal space map corresponding to the second fluence.

No significant diffuse scattering could be observed in co-planar geometry, suggesting that the amorphization takes place without the creation of any structural defects. In order to enhance the scattering from the damaged region, in-plane (400) scans and maps have been recorded (at the critical angle), Fig. 3.

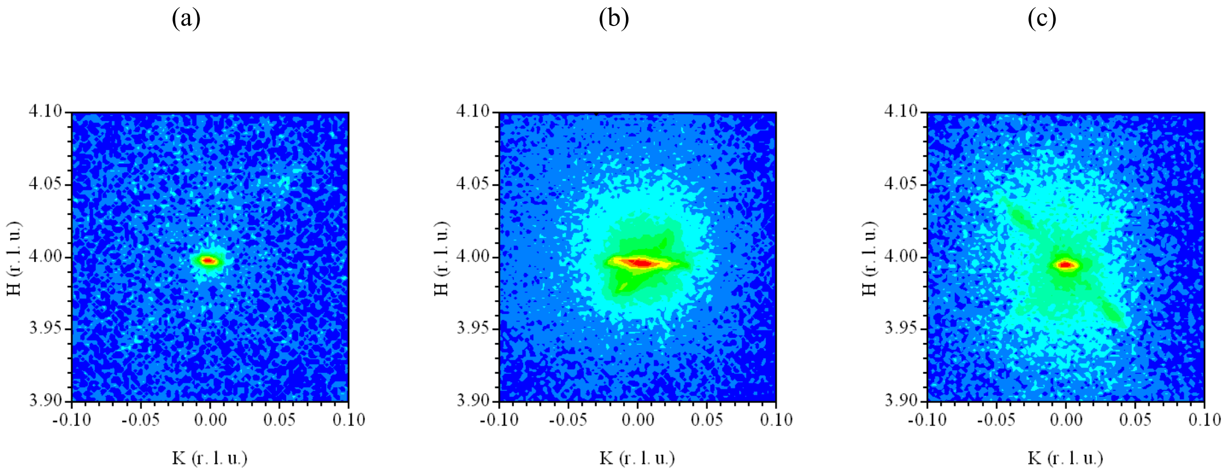

Fig. 3 : in-plane (400) reciprocal space maps for increasing fluence (a-b) and SHI irradiated crystal (c).

At the critical angle, the penetration depth is ~ 18 nm. These maps show that ion irradiation induced a very weak diffuse scattering and peak broadening in the subsurface layer. Further SHI irradiation induces a partial recovery of the crystal (the crossed streaks are due to stacking faults natively present in 3C-SiC).

The amorphization is supposed to take place by the nucleation and growth of amorphous clusters. GISAXS experiments were planned to determine the mesostructure of the damaged layer (cluster size, shape and distribution). Unfortunately the configuration used in our experiment didn't allow to record any significant GISAXS signal. The absence of GISAXS signal may be caused by different factors: weak electron density contrast between crystalline and amorphous SiC (7-10%), weak concentration of amorphous clusters, diffuse interface between amorphous clusters and crystalline matrix, surface roughness of the irradiated crystals, etc.