X-ray diffraction from ripple structures on InSb created by femtosecond laser pulses

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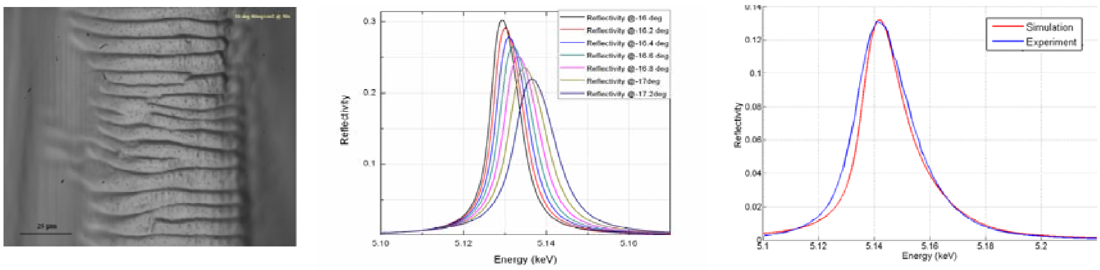
InSb was repetitively irradiated with femtosecond laser pulses with per pulse fluence between 10 to 100 mJ/cm^2 and varying angle of incidence. After some time, periodic patterns on the sample surface emerge (Fig. 1a) if the fluence is above a certain threshold that depends on the angle of incidence. The rippled structures were investigated using X-ray diffraction at grazing incidence on an asymmetric cut crystal as well as by atomic force microscopy (AFM), scanning electron microscopy (SEM), and energy dispersive spectroscopy (EDS). The variation of the ripple structures with laser angle of incidence and fluence is investigated. The x-ray diffraction experiments were performed at the D611 bending magnet beam line at MAX-lab. AFM, SEM, EDS measurements were performed at the Department of Physics.

Earlier studies on laser induced surface structure suggest that ripple structures arise from a standing wave that is produced due to interference of incident laser light with scattered or diffracted waves from surface disturbances.

All types of ripples described in the literature were found in our experiments. To create ripples it is enough to irradiate the sample close to the melting threshold. The first pulse causes random roughening, while subsequent pulses create periodic ripples (S+, S- and c fringes). The wavelength, polarization and incident angle of the laser radiation determine the spatial period. The S+ and S- ripples occur perpendicularly to the polarization while c fringes are parallel. The properties of the ripples are independent of the crystallographic orientation of the sample.

From X-ray diffraction measurements after laser exposure we find asymmetric rocking curves on areas with rippled surface structures. Due to the rippled surface the angle of asymmetry varies locally. These variations were estimated from ripple geometry measurements done with AFM and SEM. X-ray diffraction rocking curves for varying asymmetry angles were calculated (Fig. 1b). A weighted-average rocking curve was computed to account for locally varying asymmetry angles (Fig. 1c). This leads to an asymmetry in the shape of the averaged total rocking curve in good agreement with measured rocking curves from rippled InSb surfaces (Fig. 1c). The simulations suggest that the shape of the rocking curve is determined mainly by asymmetry variations.



(a) (b) (c)

Fig. 1: (a) optical microscope image of ripple structures on InSb, (b) simulated rocking curve shapes using different asymmetry angles, (c) comparison of experimental and simulated (normalized) rocking curves.