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The nature of plastic deformation of zincblend semiconductors resulting from AFM scratches

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Abstract -The defect structure resulting from scratching zincblend crystals with an atomic-force microscope was studied by atomic force microscopy (Fig.1) and transmission electron microscopy (Fig.2). The nature of the deffect structure is important due to the fact that they can act as nucleation sites for nanostrucutre gorwth [1,2]. The plastic deformation is found to depend on the direction of the scratch and on the velocity of dislocations at room temperature.

Recent studies have shown that nanoindentation can be used to grow dot patterns [1] and that the growth is due to the presence of screw dislocations rather than to the morphology of the indentation pit [2]. The nature of a crystalline substrate may as well be modified by the controlled introduction of dislocations while scratching with an AFM tip. In this work, scratches were performed by an atomic force microscope with a diamond tip along the [110] an [100] crystalographic directions. The surface of the scratches were imaged by AFM. Transmission electron microscope (TEM) samples were prepared in cross section using a focused ion beam. TEM was performed under various diffraction conditions in order to determine the nature of the crystal defects. The defect structure corresponding to the two sets of scratches is found to be significantly different.

AFM analysis of the lithographed crystal surface as seen in figure 1a-d shows that the scratches along the <110> crystallographic direction introduces regular slip lines at separations of ~150 nm perpendicular to the scratch direction (Fig 1a,b). On the oder hand, scratch lines produced along the <100> directions exhibit irregular cracks at its edges (Fig 1c,d). TEM observation of the scratches along the <110> direction presents mainly screw-type dislocations introduced by a rotation of the two {111} planes generating a butterfly-like pattern. Scratches along the <100> direction shows dislocations closer to the surface, possibly due to the interlocking between dislocations, and to melting of the near surface region by frictional heat. The localized nature of the defect structure suggests that the dislocations velocities at room temperature are well below the AFM tip velocity during scratch.

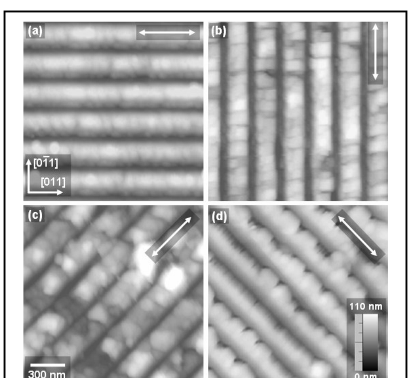

Figure 1: AFM images of scratches performed on InP along different directions.

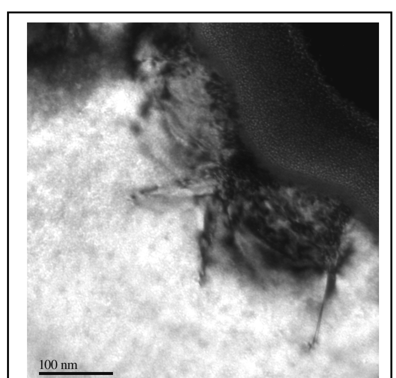

Figure 2: TEM on scratches along the <110> direction.

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