HIGHLY ORDERED GERMANIUM NANOSTRUCTURES GROWN BY MOLECULAR BEAM EPITAXY ON TWIST BONDED SILICON (001)

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In silicon thin film bonded to silicon substrate by molecular bonding, the film rotation, in respect to the substrate, generates networks of regularly spaced screw and mixed interface dislocations, related respectively to the twist and the tilt disorientation [1]. The network of twist and tilt dislocations, modify the surface energy allowing the precise control of surface topography [2]. In this work, we investigated the germanium growth on a silicon films 10 nm thick, bonded to the silicon substrate with a standard tilt disorientation of ~0.5° and twist angle: (i) 2.2° and (ii) 20°.
For our low twist angle (2.2°) bonded silicon substrate, the interface is composed by a screw dislocation network with a period of 10 nm and an array of tilt dislocations with a period of 110 nm. In figure 1(a) we show the surface topography (AFM observations) after the deposition of 8 monolayers of germanium. The distance between adjacent lines of dots corresponds to the period of the tilt dislocation array. On the plane-view transmission electron microscopy image, figure 1(b), one can see simultaneously the screw dislocation network, the tilt dislocation array (dislocation lines), and the germanium dots. The germanium dots grow forming a linear arrangements governed by tilt dislocation lines.
For high twist angle of 20°, the strain field generated by the twist dislocation network on the surface of the bonded film is negligible. For such high twist angles, the period of twist dislocations is lower than 1 nm. Consequently, only a one dimensional array of tilt (mixed) dislocations lines, with a period of few tenth of nm, induces a strain field in the bonded film, which propagates up to the surface. The orientation of this tilt dislocation lines in respect to the main crystallographic orientation of the film can be differently choose. In Figure 2, we show AFM observations of germanium dots grown on two different substrates, A and B. For both substrates tilt and twist angles are the same but substrates differ by the orientation of tilt dislocation array: for A substrate the tilt dislocation lines is almost parallel to the [100] direction (5° misalignment) of the bonded film, while for the B substrate they are oriented close to the [110] direction (10° misalignment). On both bonded substrates, the germanium hut islands grow in highly ordered linear rows which are parallel to the interfacial dislocation arrays. Moreover, the distance between two rows of hut islands on substrate A and B is identical to the distance between two rows of tilt dislocations.
In our contribution we will show that the observed organization in germanium deposition for low and high twist angle silicon bonded substrates is due to the strain field generated on the silicon surface by interfacial tilt dislocations.

References :

[1] Q. -Y. Tong, U. Gösele, Materials Chemistry and Physics, Vol. 37 (2), 1994, p 101-127.
[2] A. E. Romanov, P. M. Petroff, and J. S. Speck, Appl. Phys. Lett., 74, 2280 (1999).

Figures:

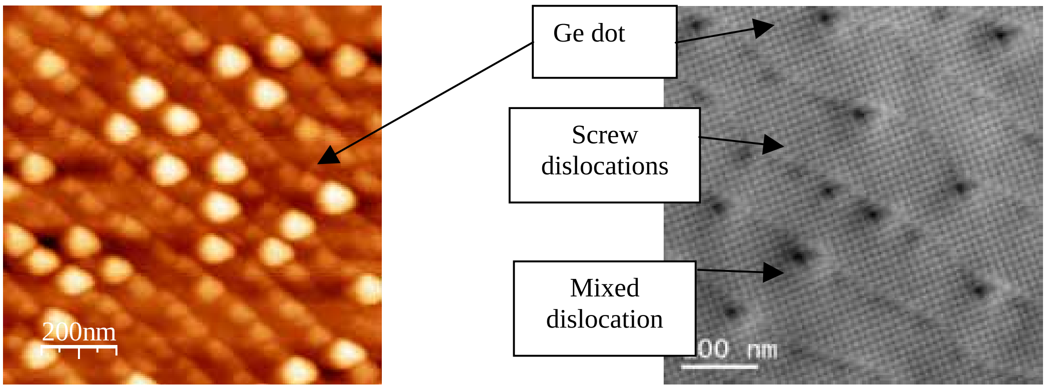

Figure 1: (a) AFM observation after growth of 8 ML of germanium. (b) Plan-view TEM observation of the same sample: one can observe the screw dislocation network, the tilt dislocation array and the germanium dots.

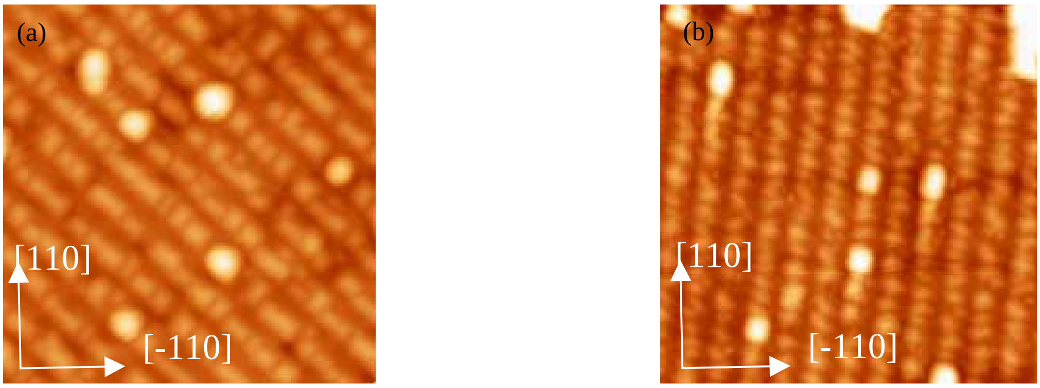

Figure 2: Atomic force microscopy observations of 8 ML of germanium grown at a substrate temperature of 600°C, on: (a) substrate A and (b) substrate B.