Selective area epitaxy of in-plane HgTe nanowires on CdTe(001) substrate

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Topologically protected system as HgTe/CdTe [2] are of great interest for the future of electronic, spintronic and quantum technologies [1]. Nevertheless, its device integration remains challenging. Selective area growth (SAG) of in-plane nanostructures on SiO_2 masked substrate by MBE is a promising technique to address this issue enabling the realization of complex 1D networks, with accurate control of dimensions, geometry and material quality [3]. Thus, we evidence the major levers for SAG of HgTe nanostructures: the growth temperature (GT), the equivalent 2D thickness and the opening geometry. Figure 1 displays several micron long in-plane nanowires (NWs) grown along the three crystal directions (<110>, <$1\bar{1}0$>, or <100>) as well as networks and diamond structures with well-defined cross-junctions. A good selectivity is achieved with very little parasitic growth on the mask even for growth temperature as low as $140°C$. Figure 2 exhibits the influence of the GT on the growth of a ring structure. The higher the GT the more visible the side faceting, the outer rim turning into an octagon, revealing the morphology anisotropy as function of the in-plane orientation. Indeed, <$1\bar{1}0$>-oriented ridges show $\{111\}$A facets with adatoms accumulation on the sides of the top surface as shown in Figure 3. The latter also demonstrates the morphology evolution of NWs as function of the deposited nominal thickness: increasing the thickness enables the formation of a triangular cross-section with smooth $\{111\}$A facets. The transmission electron microscopy image in Figure 4 reveals the crystalline structure of a <110>-oriented NW: the center of the nanostructure shows a trapezoidal shape with $\{111\}$B facets and two grains on the sides made of $\{001\}$ planes but tilted of $\pm 70.5°$, as the symmetry with respect to $\{111\}$ planes. Figure 4 also highlights the continuous epitaxial relation between the CdTe substrate and the HgTe NW. No evidence of misfit dislocations have been found despite the strain in the HgTe lattice. This set of parameters can be used to grow NWs showing a sharp substrate interface and tune their morphology before performing transport electronic measurements.

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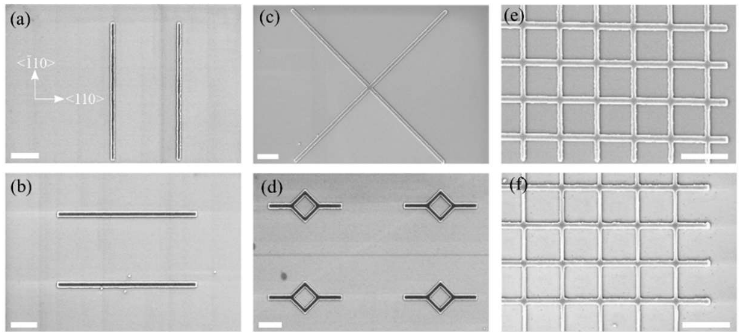

Fig. 1 Top-view SEM images of HgTe nanostructures grown on a patterned CdTe(001) substrate. For images (a)-(d) the opening width is 100 nm and the growth temperature is 140°C. (e)-(f) SEM micrographs of 50 nm-wide <110>/<1$\bar{1}$0> type NW network grown at, respectively, 140°C and 180°C. The scale bar is 1 µm.

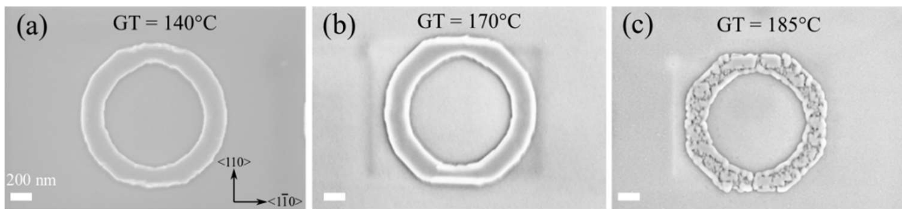

Fig. 2 Top-view SEM images of three HgTe ring nanostructures grown at (a) 140°C, (b) 170°C, (c) 185°C.

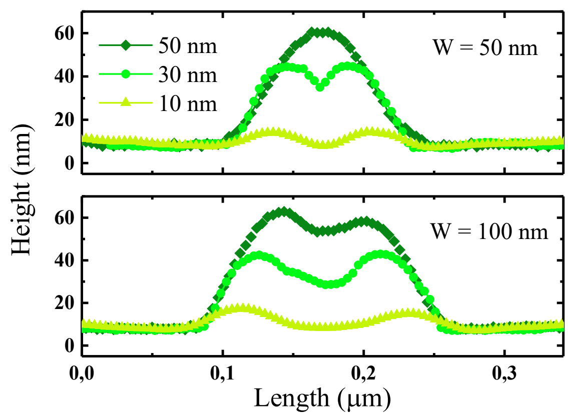

Fig. 3 Change in the NW cross section morphology for three different nominal thicknesses for two <1$\bar{1}$0>-oriented NWs whose width is 50 nm (top) and 100 nm (bottom).

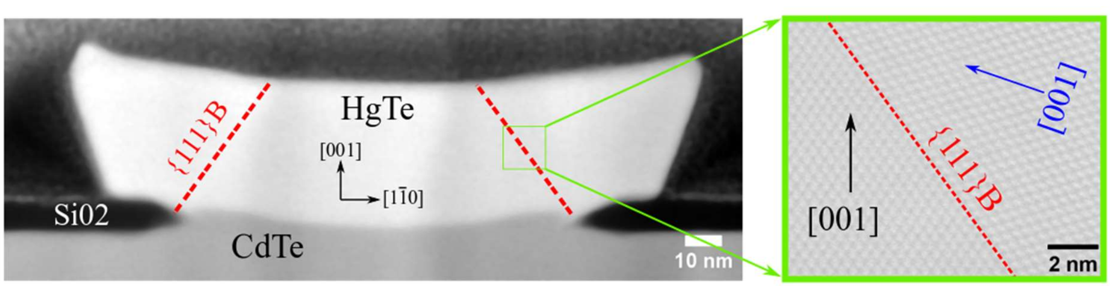

Fig. 4 STEM image of the transversal cross-section of a [110]-oriented NW. The two red dashed 54.7°-tilted lines correspond to grain boundaries of {111}B facets between the center and the side grains. The green outline square is a zoom-in of the grain boundary highlighting the 70.5°tilted [001]-orientation of the grains.