Designing radial and axial heterostructure of Te/Telluride nanowires by controlled dewetting

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Semiconductor nanowires with modulated structure show promising application in nanoelectronics, photonics and fundamental understanding of electron transport in quantum confined system. Among these semiconductors, Te (having low band gap 0.031eV) finds broad application in the field of thermo-electrics, optoelectronics and memory devices. Tellurium based semiconductor like lead Telluride, Bismuth Telluride, Antimony Telluride are extensively used as thermoelectric material. Moreover, heterostructures of nanomaterials are known to show enhanced properties as compared to their individual counterpart. Though there are existing techniques like Molecular beam epitaxy (MBE), lithography for fabricating periodic heterostructures (super lattice); but a simple and general scheme to achieve superlattice 1-D nanostructure with coherent interface is still challenging. Here, we demonstrate a facile synthesis method and illustrate a formation mechanism of Te-PbTe 1D-hetrostructute. These wires have been further converted to superlattice nanowires of PbTe and Bi_2Te_3.

Here, initial Te nanowires have been synthesized via microwave method which are found to be single crystalline in nature, with diameter 10-100 nm and having growth direction [0001]. To obtain Te-PbTe heterostructure, $PbAc_2$ has been reduced using hydrazine hydrate as reducing agent and the morphology of these nanowires have been found to be beaded with periodically spaced beads present along the length of nanowires. HRTEM images of these nanowires reveals that these are single crystalline and [0001] of Te is parallel to [111] of PbTe. Detailed 3-D structure and composition of these beaded nanowires have been investigated using STEM-EDXS tomography with a tilt series ranging from $+70^{o}$ to -70^{o}. Z-contrast of orthoslices confirms the presence of unreacted Te at the core and PbTe on the beads and volume rendering confirms the cubic shape of PbTe. Further various controller experiments have been performed to understand the growth of these nanowires and it has been observed that reduction of Pb on Te nanowire surface forms a this shell of PbTe due to interdiffusion of Te/Pb which eventually dewets to form cube shaped PbTe. Further surface energy calculation confirms that dewetted cube shaped PbTe is more favorable. The spacing between these periodic beads have been found to be varying with rate of addition of reducing agent and precursor concentration.

These Te-PbTe nanowires have been further converted to PbTe-Bi_2Te_3 superlattice nanowires which retains the single crystalline nature and shows interesting rectifying behavior. Moreover, these superlattice nanowires are very important since previous theoretical study predicts that such 1-D superlattice structure with ultrathin diameter could be a potential candidate for thermo-electric application due to phonon-trapping.

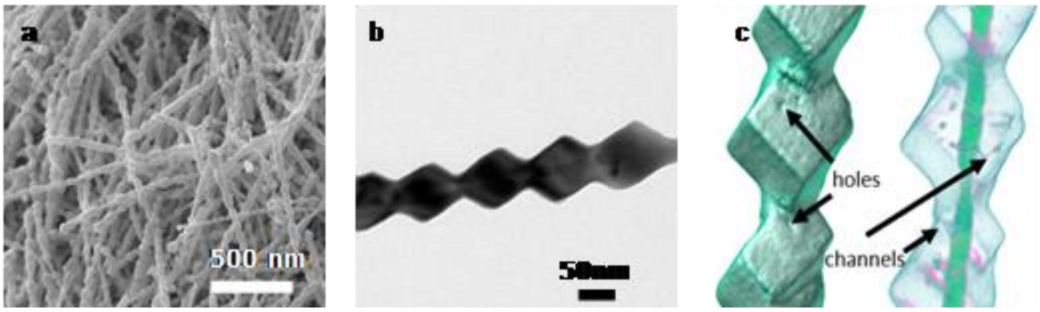

Fig (a-c) represents the SEM micrograph, TEM image of single nanowire and volume rendering as obtained from HAADF-STEM tomography showing presence of cavity.