Tellurides based Nanowires: Understanding Growth Mechanism and Building Complex Heterostructures

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Telluride based nanostructures have been extensively used as thermoelectric materials. The property of a thermoelectric material is given by the dimensionless figure of merit, $ZT=\alpha^2\sigma T/\kappa$, where α is the Seebeck coefficient, σ is the electrical conductivity and κ is the thermal conductivity of the material, and T is the temperature. Higher σ and lower κ improve the figure of merit for the material. Low-dimensional structures, such as nanowires and superlattice thin films are found to have high ZT value owing to low thermal conductivity due to the phonon-blocking effect in these nanostructures. In our previous work[1], we have designed, by simple wet chemical method, PbTe/Te heterostructures by controlled dewetting of PbTe thin film into periodic arrangements of PbTe cubes along Te wire. In this work we propose an easy wet chemical route to control the growth of radial heterostructures of Te/Bi_2Te_3 and Te/Bi_2Te_3/PbTe core shell nanowires.

Core shell configuration of the Te/Bi_2Te_3 nanowires is obtained by reduction of Bi precursor on the Te nanowire template. X-Ray diffraction analysis confirms the presence of rhombohedral phase of Te and Bi_2Te_3 in Te/Bi_2Te_3 wires. High resolution electron microscopy image analysis shows that the wires have a growth direction of [0001], as shown in fig 1 b, the wires have low enegy defects like twin boundaries and stacking faults and are devoid of any high angle grain boundary defects. A clear interface between Bi_2Te_3 and inner Te core can be identified in the bright field TEM (Fig 1 a) and HR-STEM images. STEM-EDS mapping and analysis along the length of the wires confirm the core-shell configuration, as shown in fig 1 (c). Time dependent morphology and elemental composition evolution of the radial heterostructured nanowires was also studied using electron microscopy techniques. At the very initial stage an amorphous shell of Bi_2Te_3 forms around the Te nanowires, which gradually crystallizes into a single crystal with epitaxial relation with the inner Te core. The presence of amorphous layer has been confirmed by diffuse dark field imaging.

Core shell configuration of Te/Bi_2Te_3/PbTe was also explored by successive reduction of Bi and Pb precursors on Te wire template. The core shell interface could be modulated by altering the sequence of addition of Bi and Pb precursors. It is interesting to note that composition of PbTe and Bi_2Te_3 in these complex radial heterostructures can also be controlled in order to give rise to p-n junction series across the diameter of the wire. An insight into the mechanism of growth of these heterostructures helps us to engineer the nanoarchitecture of the material as desired for different applications.

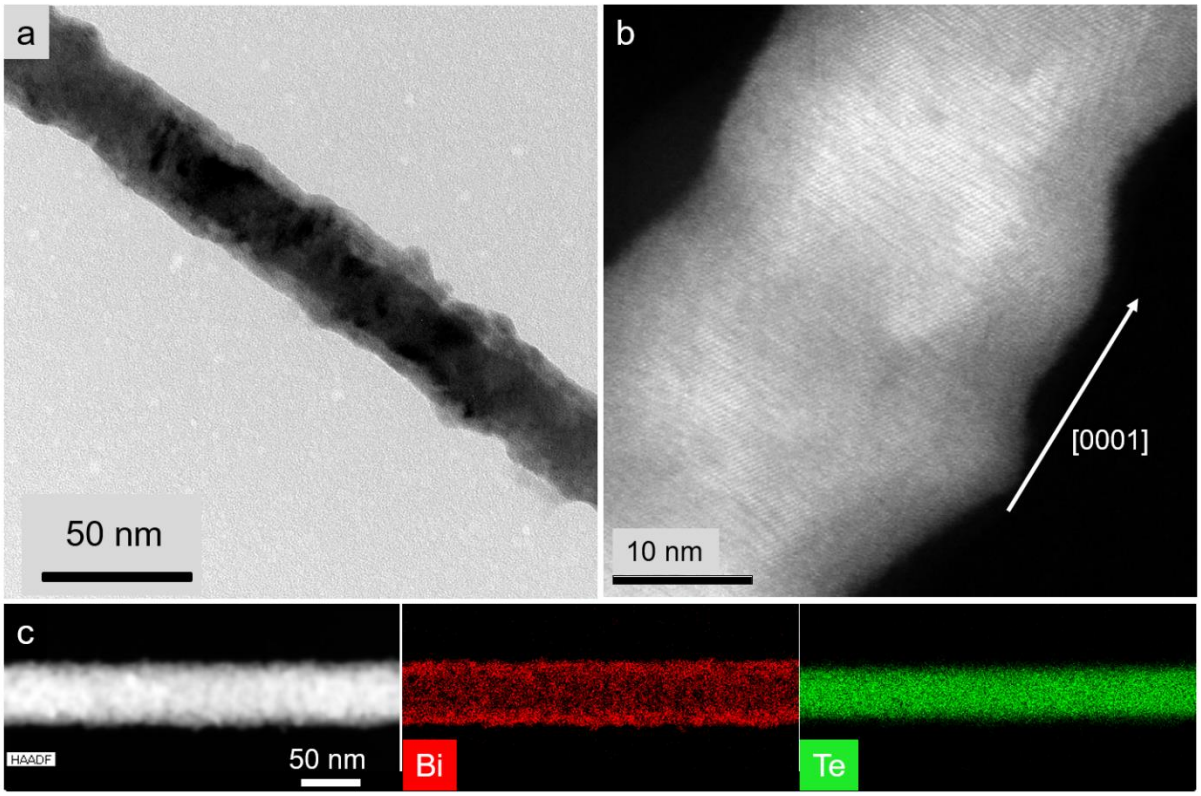

Figure 1. Bright field TEM image and high resolution STEM images of Bi_2Te_3 wires are shown in a and b respectively. c shows STEM EDS mapping of core shell Bi_2Te_3 wires.

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Reference:

1. Abinash Kumar; Subhajit Kundu; Debadarshini Samantaray; Paromita Kundu; Daniele Zanaga; Sara Bals; N. Ravishankar, Designing Diameter-Modulated Heterostructure Nanowires of PbTe/Te by Controlled Dewetting. *Nano letters* **2017,** *17* (12), 7226-7233.