

Nanowire arrays of Bi₂Te₃ for Thermoelectric Applications

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Thermoelectric materials are those which can convert heat into electricity and vice versa. These materials appear as a promising way to recover power from the heating produced in most of the motors and machines, which is usually wasted [1]. Their main disadvantage is their low efficiency, which depends on their figure of merit (ZT), which is defined as $ZT=(S^2 \cdot \sigma \cdot T)/\kappa$, where S stands for the Seebeck coefficient, σ , κ are the electrical and thermal conductivity, respectively, and T is the absolute temperature. Nowadays, the increase of this ZT is the main objective to optimize them for practical device fabrication. In 1993 a theoretical work presented suggested that a way to enhance their efficiency is by quantum confinement of the electron charge carriers [2]. Therefore, a great effort is being made in demonstrating experimentally this prediction.

One way of achieving this quantum confinement is reducing the dimensions of the material, which can be accomplished by fabricating wires of thermoelectric materials with wire diameters within the nanoscale range. Moreover, nanowire array configuration has some advantages over films, mainly due to a higher freedom in the design of morphology and composition. In our case, we have studied the nanowire formation and properties of Bi₂Te₃, which is a thermoelectric material that has been thoroughly studied in both bulk and film configurations. The fabrication and optimization of these nanowire arrays in order to obtain more efficient thermoelectric devices is the aim of this work.

First of all, Bi₂Te₃ films were grown via electrochemical deposition, following the fabrication procedure described in Martín-González et al. [3,4]. These films were optimized and their morphology (SEM micrographs, see Figure 1), structure (XR-diffraction), and transport properties (Seebeck coefficient and electrical resistivity) were characterized. Finally, films with a well defined crystal orientation (c-axis parallel to the substrate plane, which is the best direction for the thermoelectric performance in this material, see Figure 2) with a homogeneous composition were obtained.

Once this procedure was well established, the method was modified in order to give rise to nanowire arrays in a similar way. To this end, nanoporous anodic aluminium oxide membranes with a nominal pore diameter of 200nm from Whatman® were used. Prior to the growth of the nanowires, all membranes were coated with an evaporated layer of 50 nm Cr and 1500 nm Au. The synthesis of the nanowires was made inside these matrices by electrodeposition. The membrane was placed into electric contact with a Cu plate through the metallic layer, which served as back electrode, forming the working electrode of the electrochemical cell, in a similar arrangement to that described for the growth of Bi₂Te₃ films. Samples grown with different applied potentials between the electrodes and for different time periods were fabricated. SEM micrographs showed that the nanowires have grown along the whole width of the alumina template (Figure 3), giving rise to well oriented wires of Bi₂Te₃. Novel methods developed for the measurement of the thermoelectric-relevant parameters in these structures, comprising the electrical conductivity and thermal conductivity measurement will be presented.

References

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Figures

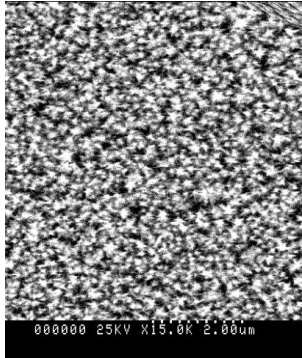


Figure 1. SEM micrograph a Bi₂Te₃ film grown by electrodeposition.

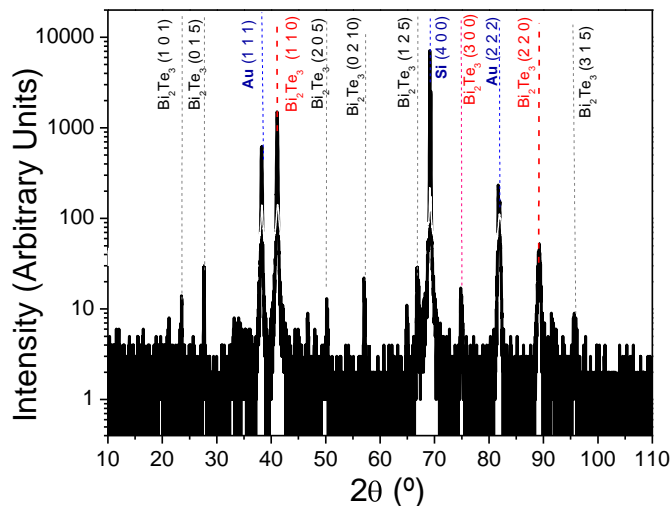


Figure 2. X-Ray Diffraction data from a Bi₂Te₃ film. Apart from the peaks corresponding to the substrate (Au and Si), the most important diffraction occurs for Bi₂Te₃ oriented along (110), (2 2 0) and (3 0 0), that is, the sample is oriented with the c-axis parallel to the substrate plane (Ref. Natl. Bur. Stand. (U.S.) Monogr. 25,3 (1964) 16)

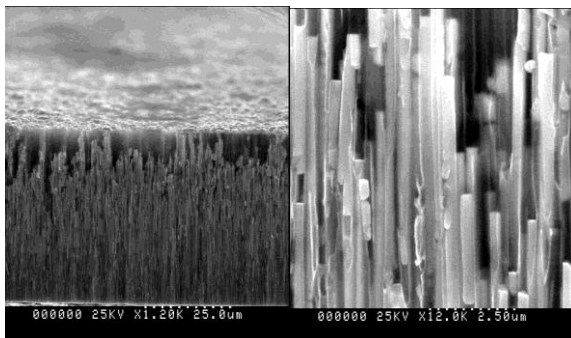


Figure 3. Different micrographs of the cross-section of nanowire arrays of Bi₂Te₃ grown by electro-deposition in an alumina matrix prepared at IMM.

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