Thermal conductivity reduction in thermoelectric nanowires

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Thermoelectric materials enable to convert thermal energy into electrical energy and vice versa. They hence can be used for power generation or refrigeration, their efficiency being evaluated through their figure of merit $ZT = S\, T\lambda 2\sigma$, where S, σ, λ and T are respectively the Seebeck coefficient, the electrical conductivity, the thermal conductivity and the absolute temperature. During years, the most commonly used thermoelectric material was bulk Bi_2Te_3 whose figure of merit at room temperature was limited to 1 at maximum. Large scale applications demand to improve this value to at least 3. The development of nanotechnology has recently attracted attention and has led to a renewed interest for thermoelectric materials. Indeed, the nanostructuration could reduce the thermal conductivity without reducing the electrical conductivity when at least one dimension of the material is smaller than the phonon mean free path and larger than the electron mean free path[1]. These nanostructured materials, such as nanowires, would then behave as phonon glasses and electron crystals. There is hence a double challenge: the development of chemical processes to grow optimized nanowires and then their characterization, and more particularly concerning the thermal conductivity, the development of experimental methods to measure it at nanometric scale. Using 3ω-SThM (Scanning Thermal Microscopy)[2], we studied various kinds of semiconductor nanowire arrays embedded in a matrix to experimentally evaluate their thermal conductivity and identify the physical mechanism responsible for the possible thermal conductivity reduction. The diameter of the investigated nanowires varies from 50 nm to 500 nm. The three kinds of investigated nanowires are:

- Si nanowires because Si is very abundant and the most used semiconductor in microelectronics, its processing is current and low-cost. In addition, Si nanowires seem to be very promising since numerous theoretical studies have shown that nanostructuration of Si could largely reduce its thermal conductivity in comparison with bulk Si,

- Bi_2Te_3 nanowires since as a bulk, Bi_2Te_3 is the most commonly used thermoelectric material. Its nanostructuration can let us hope promising results

- SiGe nanowires since a few theoretical models seem to indicate that SiGe nanowires might be even more promising than Si nanowires for thermoelectric applications.

References:

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