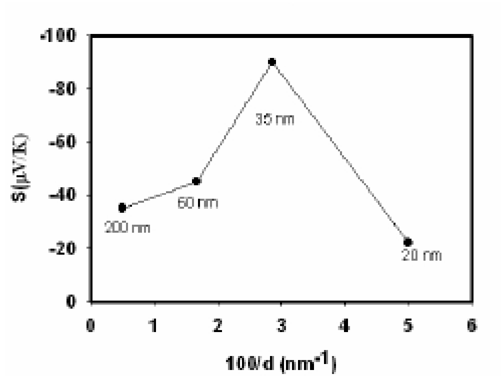
Nanowire Thermoelectrics (DoD, ARL-ARO)

Despite longstanding theory predicting enhanced thermoelectric performance in quantum confined structures and numerous experimental attempts to verify these predictions, quantum enhancement effects have been observed in quantum well and quantum dot systems, but no such effects have been reported for 1D quantum wire systems, despite the fact that they were originally expected to show the strongest effect. Research by Professor Huber at Howard University has finally provided the explanation. He prepared an array of densely packed, highly oriented, crystalline Bi nanowires by injecting molten Bi under high-pressure into the cylindrical channels (20-200nm) of anodized aluminum (porous Al_2O_3). Exhaustive transport studies on individual wires have finally established that surface states play an important role in determining the thermoelectric properties of the wires. In essence, the wires need to be considered as a three carrier system – with bulk electrons, bulk holes and negative surface charges all playing a role. The surface charge can be viewed as an outer sheet about 10 nm in depth that dominates the low temperature (below 100K) thermoelectric properties and then at higher temperatures reduces the effective wire diameter. Recent room temperature thermopower measurements have now observed a strong quantum enhancement effect in the Seebeck coefficient that peaks in nanowires around 35 nm in diameter, see figure. The discovery is particularly relevant to Army efforts to develop high performance thermoelectric coolers for its cooled IR detectors.



A. Nikolaeva, D. Gitsu, L. Konopko, M. J. Graf and T. E. Huber, "Quantum Interference of Surface States in Bismuth Nanowires probed by the Aharonov-Bohm Oscillation of the Magnetoresistance," Physical Review B77 075332 (2008).