Bottom-up engineering of thermoelectric nanomaterials and devices from solution-processed nanoparticles

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The conversion of thermal energy to electricity and vice versa by means of solid state thermoelectric devices is extremely appealing. However, its cost-effectiveness is seriously hampered by the relatively high production cost and low efficiency of current thermoelectric materials and devices. To overcome present challenges and enable a successful deployment of thermoelectricity in its wide application range, materials with significantly improved performance need to be designed and engineered. Nanostructuration can help in several ways to reach the very particular group of properties required to achieve high thermoelectric performances. Nanodomains inserted within a crystalline matrix can provide high charge carrier concentrations without significantly influencing their mobility, thus reaching very high electrical conductivities. Nanostructured materials containing grain boundaries efficiently scatter mid- and long-wavelength phonons, thus contributing to reduce thermal conductivity. Furthermore, nanocrystalline domains can enhance the Seebeck coefficient by modifying the density of states and/or providing type- and energy-dependent charge carrier scattering. All these potential advantages can only be reached when engineering a complex type of material, a nanocomposite, with an exquisite control over structural and chemical parameters at multiple length scales. Since current conventional nanomaterial production technologies lack such level of control, alternative strategies need to be developed and adjusted to the specifics of thermoelectricity. A particularly suitable approach to produce nanocomposites with unique level of control over their structural and compositional parameters is their bottom-up engineering from solution-processed nanoparticles. In this presentation, I will describe our progress in this field, including the synthesis of nanoparticles with precisely engineered composition and surface chemistry, their combination and consolidation into nanostructured materials, the strategies to electronically dope such materials and the attempts to fabricate thermoelectric devices using nanoparticle-based nanopowders and inks.