Cluster-Assembled Nanophase (5 to 25 nm grains) Materials, Siegel, *Annu. Rev. Mater. Sci.* **21** (2991) 559.

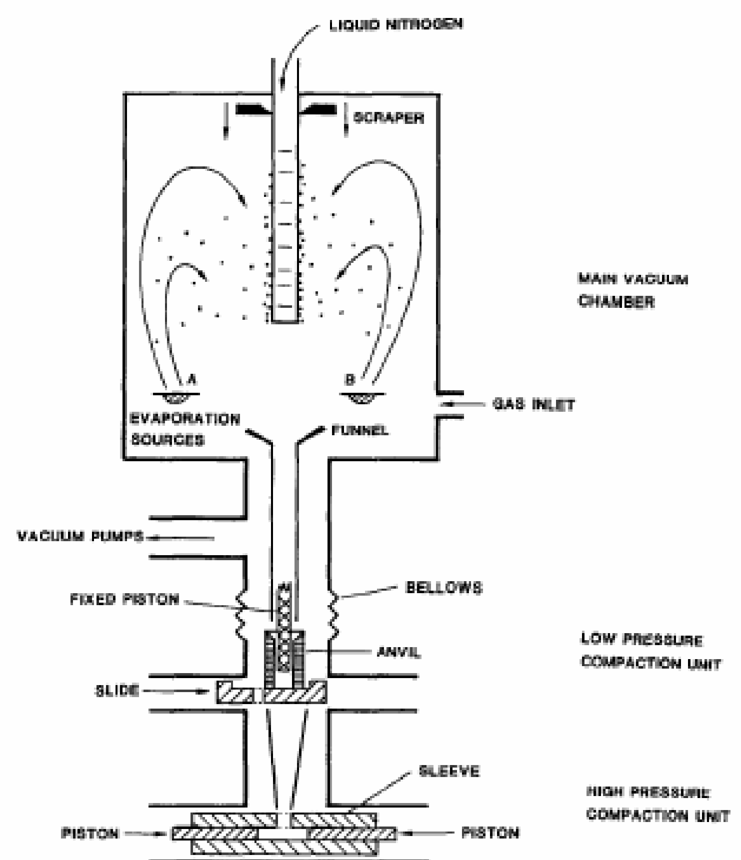
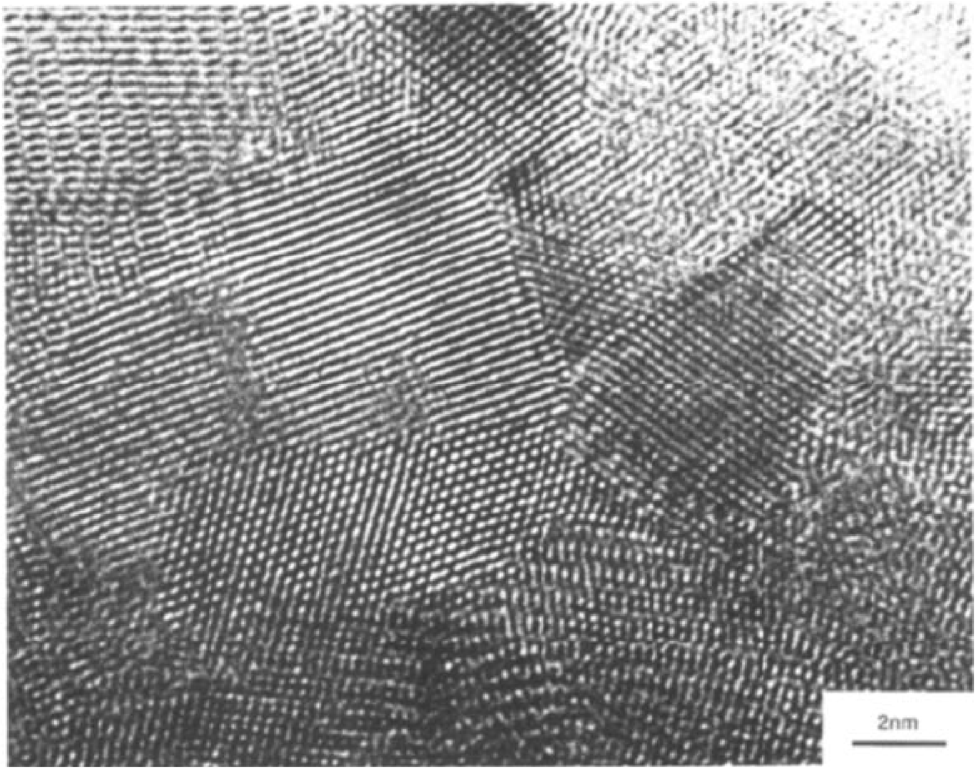


Figure 1 Schematic drawing of a gas-condensation chamber for the synthesis of cluster-assembled nanophase materials. The precursor material evaporated from sources A and/or B condenses in the gas and is transported via convection to the liquid-nitrogen filled cold finger. The powders are subsequently scraped from the cold finger, collected via the funnel, and consolidated first in the low-pressure compaction device, and then in the high-pressure compaction device, all in vacuum (from Reference 12).

Thermal evaporation of metals either in an inert gas or a reactive atmosphere. Metals, ceramics, semiconductors ...

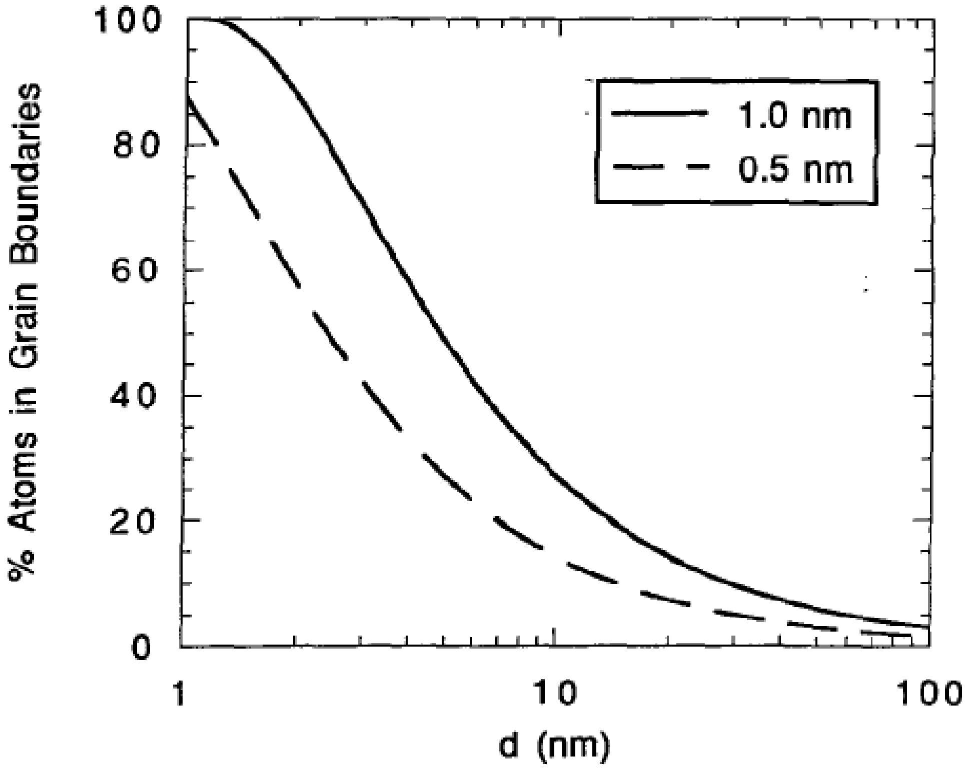
Compact pellets are produced in ultra high vacuum.

Cluster-Assembled Nanophase (5 to 25 nm grains) Materials, Siegel, *Annu. Rev. Mater. Sci.* **21** (2991) 559.



Nanophase Pd, with approx. 10 nm grains.

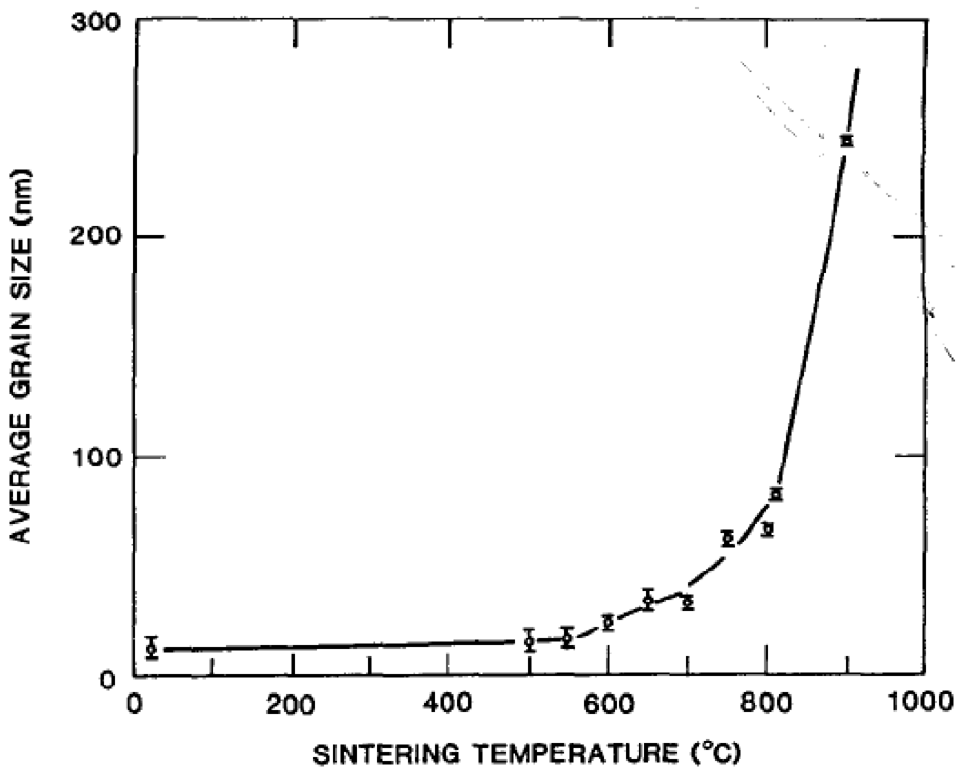
Cluster-Assembled Nanophase (5 to 25 nm grains) Materials, Siegel, *Annu. Rev. Mater. Sci.* **21** (2991) 559.



Nanophase materials are mostly grain boundary – structurally different from bulk materials.

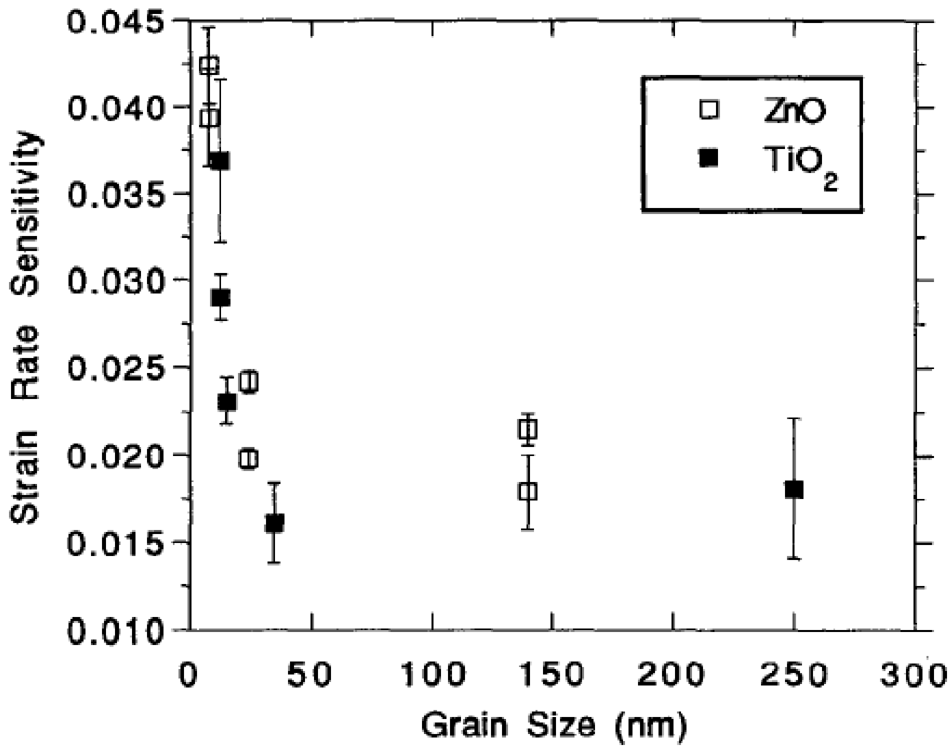
The plots are for different grain boundary thicknesses (1.0 and 0.5 nm)

Cluster-Assembled Nanophase (5 to 25 nm grains) Materials, Siegel, *Annu. Rev. Mater. Sci.* **21** (2991) 559.



Ceramics with small grain sizes sinter more readily. Here the size dependence of sintering temperature of TiO_2 is shown.

Cluster-Assembled Nanophase (5 to 25 nm grains) Materials, Siegel, *Annu. Rev. Mater. Sci.* **21** (2991) 559.



Nanograined ceraimics are highly sensitive to strain rate (they can be “superplastic”) allowing them to be formed into shapes like a ductile metal.

High tensile ductility in a nanostructured metal, Wang, Chen, Zhou, Ma, *Nature* **419** (2002) 912.

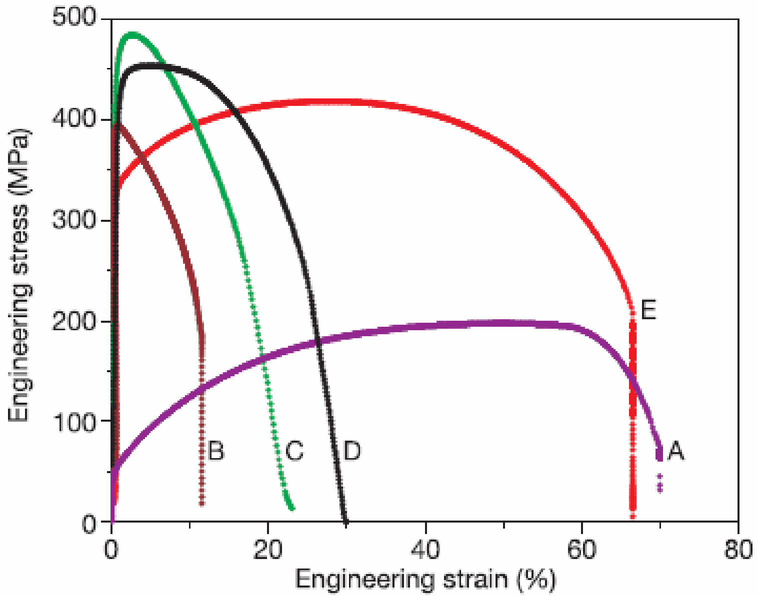
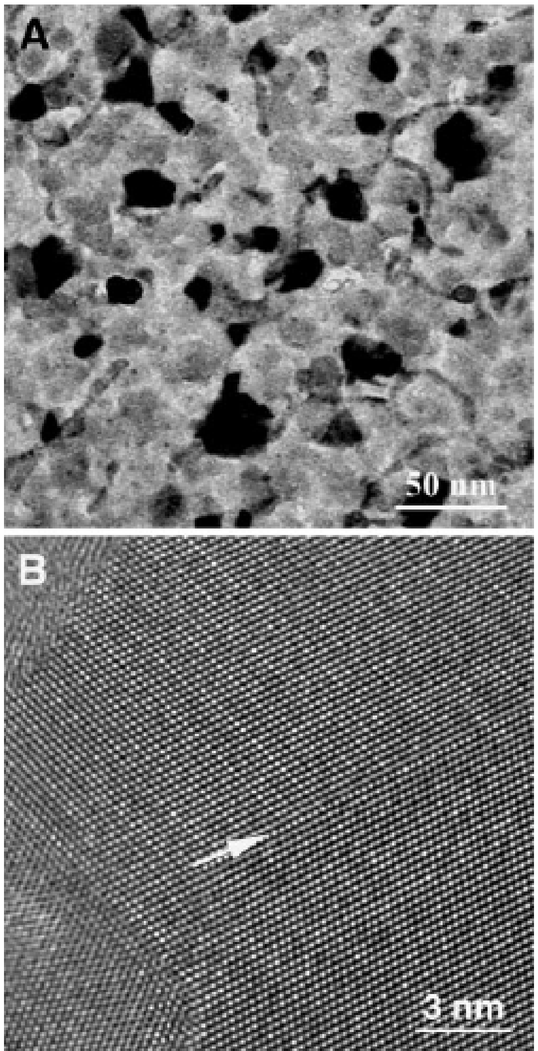


Figure 1 Engineering stress–strain curves for pure Cu. Curve A, annealed, coarse-grained Cu; B, room temperature rolling to 95% cold work (CW); C, liquid-nitrogen-temperature rolling to 93% CW; D, 93% CW + 180 °C, 3 min.; and E, 93% CW + 200 °C, 3 min. Note the coexisting high strength and large uniform plastic strain as well as large overall percentage elongation to failure for curve E.

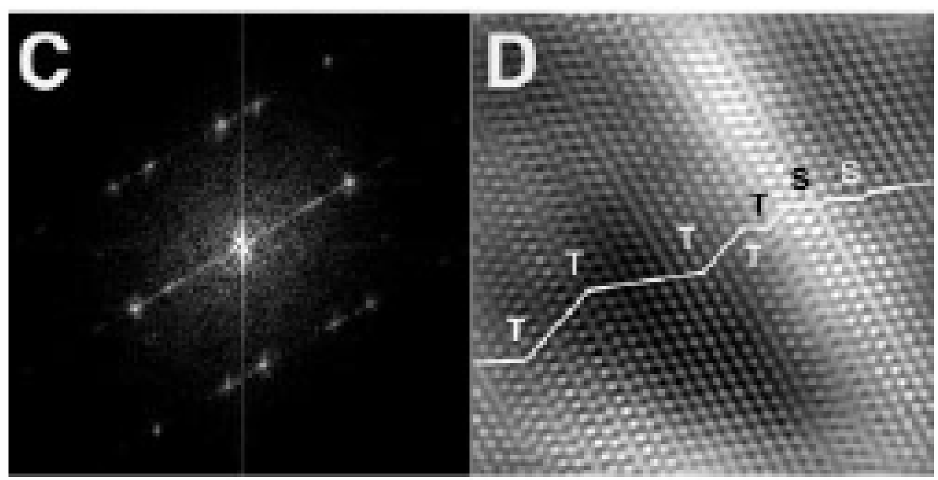
By devising a treatment procedure that allows a Cu sample to have two different grain sizes, the hardness of nanophase copper can be combined with the formability (ductility) of Cu with larger grain sizes.

Nanophase Materials

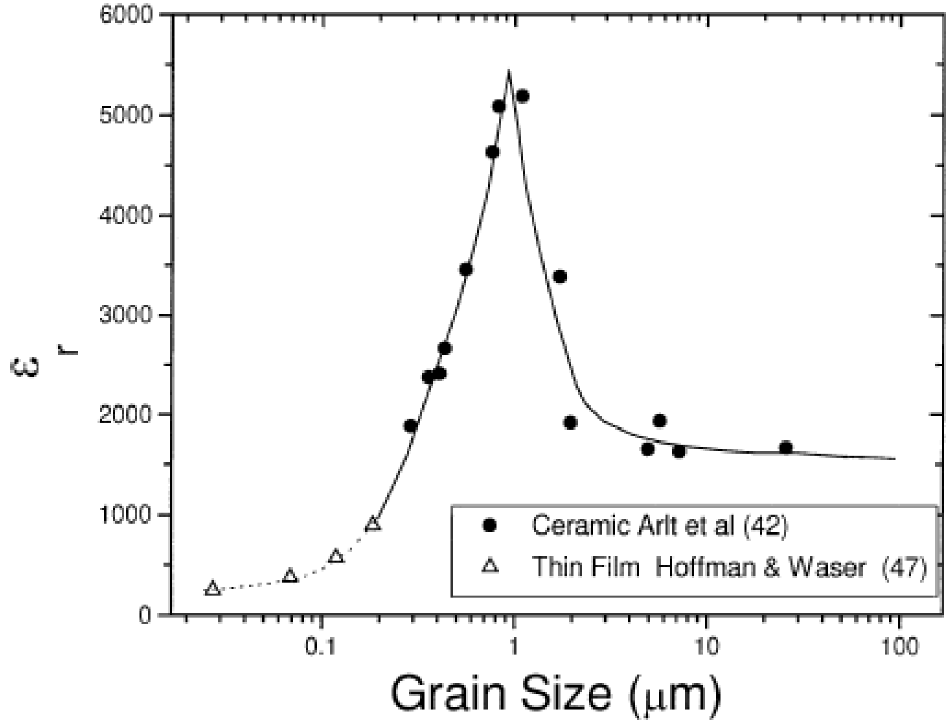
Deformation twinning in nanocrystalline Al, Chen, Ma, Hemker, Sheng, Wang, Cheng, *Science* **300** (2003) 1275.



Nanograined Al prepared by vapor deposition on NaCl substrates cooled to liquid N_2 temperatures. Deformation by griding results in the formation of twin boundaries between grains.

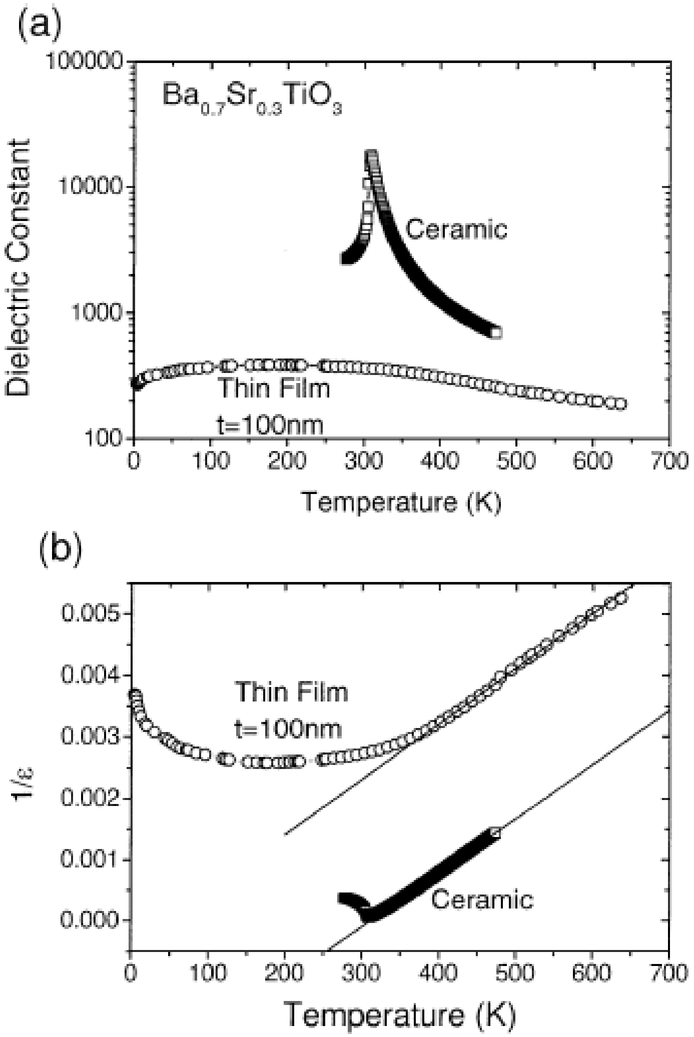


The properties of ferroelectric films at small dimensions, Shaw, Trolier-McKinstry, McIntyre, *Annu. Rev. Mater. Res.* **30** (2000) 263.



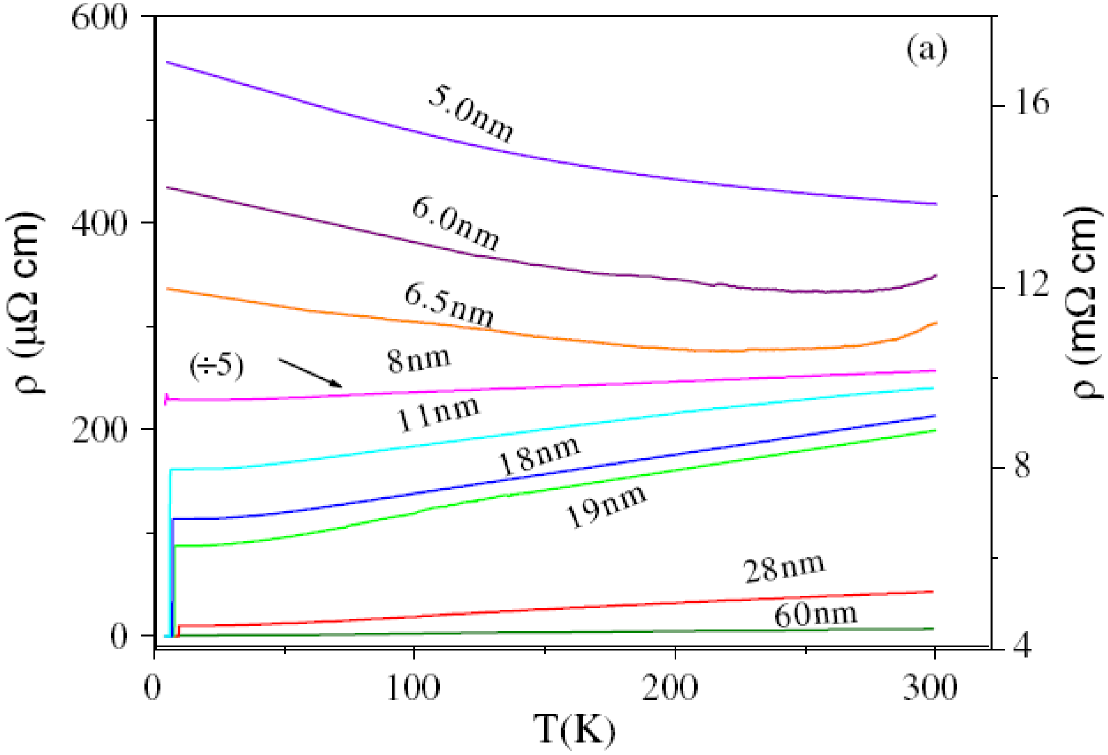
Ferroelectric materials display a strong size dependence because of *depolarizing* fields at their interfaces.

The properties of ferroelectric films at small dimensions, Shaw, Trolier-McKinstry, McIntyre, *Annu. Rev. Mater. Res.* **30** (2000) 263.



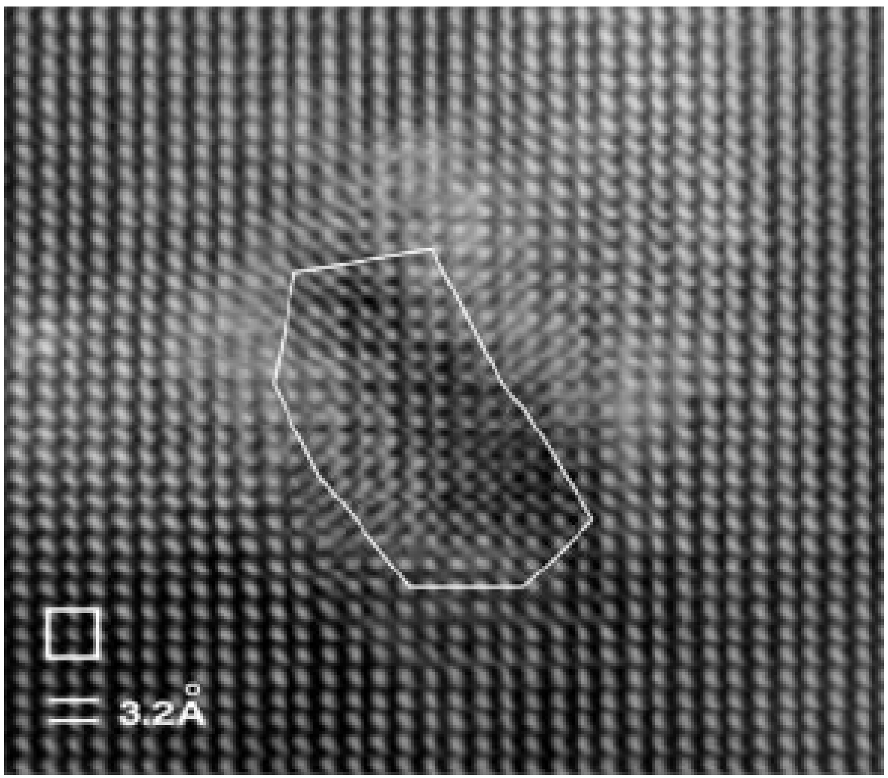
There are additional effects in thin film samples having to do with microstructure *etc.*

Size induced metal–insulator transition in nanostructured niobium thin films: intra-granular and inter-granular contributions, Bose, Banerjee, Genc, Raychaudhuri, Fraser, Ayyub, *J. Phys.: Condens. Matter* **18** (2006) 4553.



bcc-Nb films suptter deposited on Si. Size was controlled by controlling Ar gas pressure in chamber and sputter power. Sizes from XRD line broadening.

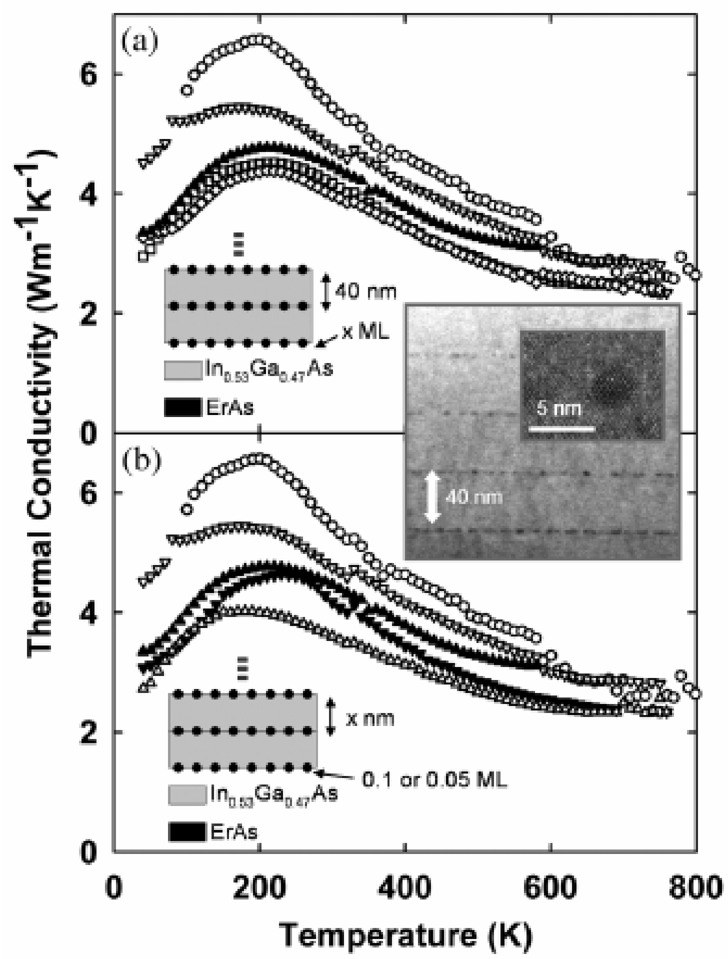
Cubic $AgPb_mSbTe$: Bulk Thermoelectric Materials with High Figure of Merit, Hsu, Loo, Guo, Chen, Dyck, Uher, Hogan, Polychroniadis, Kanatzidis, *Science* **303** (2004) 818.



(AgSbPb)Te bulk materials materials with the rock salt structure precipitate Ag and S b rich particles which decrease the thermal conductivity and increase the figure of merit.

$$ZT = \frac{\sigma\,\alpha^2}{(\kappa_e + \kappa_L)} \bullet T$$

Thermal Conductivity Reduction and Thermoelectric Figure of Merit Increase by Embedding Nanoparticles in Crystalline Semiconductors, Kim, Zide, Gossard, Klenov, Stemmer, Shakouri, Majumdar, *Phys. Rev. Lett.* **96** (2006) 045901.



ErAs (rock salt) particles embedded in (In,Ga)As.

$$ZT = \frac{\sigma \, \alpha^2}{(\kappa_e + \kappa_L)} \bullet T$$