



11th International Conference on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

Nano-nanocomposites: An emerging class of materials

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Abstract – We review some of our recent results on bi-phasic nanodispersions and point out that such materials often exhibit substantially different properties as compared to their individual constituents. A systematic understanding of such systems should allow us to have a greater control over materials engineering. We discuss the applications of such nano-nanocomposites in optoelectronics, superconductivity, etc.

The possibility of obtaining some degree of control over different physico-chemical properties by means of varying the size and shape of the crystallographic grains constituting bulk matter is quite well known. In this paper, we review our recent results on nano-nanocomposites (NNC), which may be defined as a random, bi-phasic nanodispersion, in which the characteristic size of *both* phases present is in nanometers. This is a subset of the larger family of nanocomposites, which commonly consist of one phase nanodispersed in an extended matrix phase. NNCs afford the possibility of tuning physico-chemical properties *via* a large number of parameters, such as the nature of the components, the composition, and the size and morphology of both the phases. Such systems are especially interesting in situations where their properties are not simple linear superpositions of the properties of the individual nanocrystalline species. I will discuss three such special cases, underlining the role played by NNCs in quite distinct areas of materials physics. Typically, such bi-phasic NNCs were synthesized as co-sputtered thin films on specific substrates such as silicon.

(a) We studied a semiconductor-semiconductor NNC: CdS-ZnO, consisting of densely packed, randomly intermixed, nearly uniform sized arrays of individual CdS and ZnO nanoparticles, the characteristic grain size for each phase being about 3 nm. The motivation was to investigate whether some degree of electronic passivation of the surface states of CdS nanoparticles can be achieved by the surrounding ZnO nanoparticles. This system showed very interesting properties such as greatly enhanced photoluminescence [1], photoconductivity [2], as well as non-linear optical properties [3].

(b) The transport properties of a NNC consisting of a superconductor and a normal metal were found to be predominantly controlled by the superconducting proximity effect, which plays a significant role in such systems only when the size of the superconducting particles is less than the coherence length. We studied two physically distinct types of systems: (i) a NNC comprising of inter-dispersed superconductor (Pb) and normal metal (Ag) particles [4], and (ii) nanometer-scale superconducting particles (Pb and Sn) embedded in a metallic (normal or superconducting) matrix such as Al [5]. In both cases, we found that the component ratio and nature of the dispersion play a crucial role in controlling the superconducting properties of the NNC.

(c) There are certain apparently amorphous systems such as Ag-Ni, Cu-Nb, Ag-Cu, and Ag-Fe, whose local structure is controversial since they are formed from metals which have a large positive enthalpy of mixing, and which should therefore have been immiscible. Using three dimensional atom probe tomography and extended x-ray absorption fine structure analysis, we have established that there is indeed nanoscale phase separation (or clustering) within the amorphous phase in immiscible alloy systems such as Cu-Nb, which substantially reduces the Gibbs free energy of the undercooled liquid and stabilizes the amorphous phase. The Cu-Nb system is thus a metal-metal NNC that is actually a nanoscale phase-separated alloy of 'immiscible' metals [6,7]. We have made a detailed study of the interesting thermal evolution of such a nanostructured system.

References

- [1] P. Ayyub, P. Vasa, P. Taneja, R. Banerjee and B. P. Singh: J. Appl. Phys. 97 (2005) 104310.
- [2] P. Vasa, P. Taneja, P. Ayyub and B. P. Singh: J. Phys.: Cond. Matt. 14 (2002) 281.
- [3] P. Vasa, P. Ayyub and B. P. Singh: Appl. Phys. Lett. 87 (2005) 063104.
- [4] S. Bose and P. Ayyub: Phys. Rev. B 76 (2007) 144510.
- [5] S. Bose, V. Bhattacharya, K. Chattopadhyay and P. Ayyub, Acta Mater. 56 (2008) 4522.
- [6] R. Banerjee, A. Puthucode, S. Bose and P. Ayyub: Appl. Phys. Lett. 90 (2007) 021904.
- [7] R. Banerjee, S. Bose, A. Genc and P. Ayyub: J. Appl. Phys. 103 (2008) 033511.