Structure, magnetic and mechanical properties of rapidly solidified Ni-base magnetic shape memory alloys and Fe, Ni-Au alloy, barcode nanowires

Abstract

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The first part of the presentation gives a detailed investigation on the structure and magnetic properties of the rapidly solidified $Ni_{50}Mn_{25}Ga_{25}$, $Ni_{50}Mn_{(25-x)}Co_xGa_{25}$(x = 2, 5, 8, 11), $Ni_{50}Co_{23}Fe_2Ga_{25}$ Heusler alloys. Second part of the presentation mainly deals with structure, magnetic and mechanical properties of Ni-Au alloy, Ni-Au barcode and Fe nanowires.

Initially this talk gives an overview on the microstructures which form during melt spinning and during subsequent heat treatments of Ni-base Heusler alloys. Depending on the composition of the system and the solidification speed during melt spinning, microstructures can form which ranges from fine grained austenite, tweed to martensite. Moreover this presentation talks about the careful theoretical analysis of the aspects concerning about the evolution of microstructure addressing at all length scales (atomistic, microscopic and macroscopic) in combination with high-class crystallographic and microscopic investigation. Also it links the microstructure with a careful assessment of magnetic properties which govern the performance of magnetic shape memory alloys. Further to that, this talk also addresses a new $Ni_{50}Co_{23}Fe_2Ga_{25}$ Heusler alloy undercooled at different undercoolings by a novel electromagnetic levitation route. Depending upon the degree of undercooling and the solidification rate during electromagnetic levitation, microstructures from austenite to martensite will form and they also related with the corresponding mechanical and magnetic properties.

Later part of the talk presents the phase evolution and their effect on magnetic properties of both electro deposited and annealed Ni-Au alloy/Ni-Au barcode nanowires. Very fine nano crystalline metastable Ni-Au phase to a unique HCP-Ni phase apart from FCC Ni, FCC Au phases has been obtained in either Ni-Au alloy or barcode nanowires based on the processing history such as electrodeposition or annealing. Upon annealing, a new metastable HCP-Ni phase evolved in both Ni-Au alloy and barcode nanowires. Fine nanocrystalline metastable Ni-Au phase improves magnetic properties, where as the new Ni-HCP phase results in significant magnetic softening. Overall, studies showed that the phases present in the nanowires and thus the magnetic properties correlates directly. Therefore, one can design the nanowire arrays by the combination of different processing conditions according to final desired magnetic properties for widespread of applicability in different fields.

Moreover, the talk also presents in-situ nano-mechanics and tensile properties of polycrystalline 'Fe' nanowires. A high Temperature XRD (HTXRD) study on 'Fe' nanowires up to 500ºC reveals that there is a stabilization of micro strain with improvement in grain size. Based on the structural analysis, we have performed in-situ nano-tensile tests for as deposited "Fe", 300ºC / 1h and 500ºC / 1h annealed samples. The tensile test results shows that, there was a significant improvement (4 to 5 times) in fracture strength about 2.5 GPa on 300ºC / 1h annealed samples despite of larger grain size when compared with the as deposited Fe nanowires samples. Molecular dynamics simulations suggest that, an interesting phenomenon called grain boundary shear and crack initiation is happening during tensile pulling. This is much easier for the large grain size and hence easier the crack propagation which in turn results in intergranular fracture of 'Fe' nanowires samples.

In summary, this presentation concludes that, the magnetic and mechanical properties are strong function of the crystal structure and phases that prevail at the room temperature as per the processing history of the rapidly solidified Ni-base Heusler alloys as well as both Ni-Au and Fe nanowires.