Abstract

Magnetic nano-particles dispersed in a non-magnetic matrix is promising for storage technology. Additionally, such magnetic nano composite (MNC) materials have potential applications in the field of telecommunication, nano-capacitors, high frequency filters and bio-medical domains. Conventionally, Nano composite (NC) material comprises of sub 100 nm particles randomly distributed in a matrix material. The shape, size and distribution of the particles play an important role in determining the physical properties. The aim of this work is to develop ordered and aligned magnetic nanocomposite and explain composite behaviors in terms of behaviors of single nanowire. Hence, ordered and aligned ferromagnetic Nickel nanophase homogeneously dispersed in alumina matrix is developed. The matrix phase separates the magnetic nanophase and modifies the magnetic interaction, electrical transport and mechanical strength. Anodization of aluminum is used to fabricate nano-porous alumina matrix. Under certain controlled electrochemical conditions, anodization of aluminum results in a highly ordered hexagonal porous structure. Nickel is electrochemically deposited into these pores resulting in uniformly distributed magnetic nanowires of high aspect ratio. This ordered MNC is characterized for its mechanical, electrical, magnetic and tribological properties to explore the possibility of using for various possible applications with the focus to study the feasibility for magnetic storage application.

Ordered porous alumina is formed by a two-step anodization process. By optimizing the anodization conditions, the thickness and the pore size of the porous alumina layer is controlled. The interface between the porous structure and aluminum substrate comprise of thick and non-conducting barrier oxide layer. However, to deposit metal into the pores using electrodeposition technique, a conducting path should be established through this barrier layer. Hence, the barrier layer is thinned by reducing the anodizing voltage in steps and subsequent chemical etching. The pores are filled with Ni by pulsed electro-deposition. Uniform deposition is achieved by optimizing the pulse duty cycle. From electrical resistance measurements, the resistance of single nanowire is found to vary between 400 Ω to 700 Ω. Whereas, the composite resistance is measured to be about few ohms. The resistivity of the Ni within composite is 2.9 × 10-7 Ω-m, which is two orders higher than the bulk Ni, confirming larger scattering events at smaller scale. Electrical resistivity further gave information on structural details of the as developed MNC. It is found that during low frequency measurements only a fraction of nanowires take part in conduction. Rest of the nanowires are not conducting as a capacitive barrier layer separates Ni nanowire from base aluminum. Also, magneto-capacitance response at high carrier frequency is observed. Magnetic response of the nanocomposite is measured using magnetic force microscopy and magnetoresistance measurement. It is found that neighboring magnetic domains are dipole coupled which makes it difficult to change magnetization state of the composite

compared to single Ni nanowire. This has important implication for magnetic storage application. Mechanical hardness and elastic modulus of the single suspended nanostructure are characterized using atomic force microscopy (AFM) based indentation technique. Using nanoindentation it is found that for the MNC, inclusion of ductile metal improves the hardness of the brittle matrix by 40%. Finally, a macro scale experiment is designed to mimic magnetic read / write operation by allowing electrical current to flow from probe to sample under static load and dynamic load conditions. These experiments helped us to understand the effect of static and frictional force on the electrical response. Static and reciprocating electrical contact resistance measurement tool is developed. Monitoring contact resistance helps to understand, evolution of the real contact area, which affects both the electrical and tribological behaviors. It is observed that, the high electrical field increases wear rate of the composite. Subsequent chemical etching. The pores are filled with Ni by pulsed electro-deposition. Uniform deposition is achieved by optimizing the pulse duty cycle.

From electrical resistance measurements, the resistance of single nanowire is found to vary between 400 Ω to 700 Ω. Whereas, the composite resistance is measured to be about few ohms. The resistivity of the Ni within composite is 2.9 × 10-7 Ω-m, which is two orders higher than the bulk Ni, confirming larger scattering events at smaller scale. Electrical resistivity further gave information on structural details of the as developed MNC. It is found that during low frequency measurements only a fraction of nanowires take part in conduction. Rest of the nanowires are not conducting as a capacitive barrier layer separates Ni nanowire from base aluminum. Also, magneto-capacitance response at high carrier frequency is observed. Magnetic response of the nanocomposite is measured using magnetic force microscopy and magnetoresistance measurement. It is found that neighboring magnetic domains are dipole coupled which makes it difficult to change magnetization state of the composite compared to single Ni nanowire. This has important implication for magnetic storage application. Mechanical hardness and elastic modulus of the single suspended nanostructure are characterized using atomic force microscopy (AFM) based indentation technique. Using nanoindentation it is found that for the MNC, inclusion of ductile metal improves the hardness of the brittle matrix by 40%.

Finally, a macro scale experiment is designed to mimic magnetic read / write operation by allowing electrical current to flow from probe to sample under static load and dynamic load conditions. These experiments helped us to understand the effect of static and frictional force on the electrical response. Static and reciprocating electrical contact resistance measurement tool is developed. Monitoring contact resistance helps to understand, evolution of the real contact area, which affects both the electrical and tribological behavior. It is observed that, the high electrical field increases wear rate of the composite.