Topic: Micro-Actuators

MAGNETIC NANOCRYSTAL MODIFIED EPOXY PHOTORESIST FOR MICROFABRICATION OF AFM PROBES

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Abstract

Nanocomposites based on an organic polymer and inorganic nanocrystals (NCs) represent a class of high impact functional materials able to convey the unique size and shape dependent properties of nano-objects to highly processable resists.[1] In this work, a novel magnetic nanocomposite based on a negative tone epoxy photoresist and magnetic colloidal Fe_2O_3 NCs has been manufactured for fabricating AFM probes. Epoxy-type photoresist grant superior lithographic performances when patterned by standard near- ultraviolet (UV) optical lithography, providing structures with high aspect-ratio and nearly vertical sidewalls. Such resists are at present employed in optical and micromechanical applications for the fabrication of optical waveguides, microfluidic systems and scanning probes.[2] However, these materials lack of any inherent functionality, e.g. electrical conductivity, luminescence, magnetism, piezoresistivity and dielectricity. Hence, the incorporation of NCs can confer them new properties maintaining the patterning resolutions required for the manufacturing of highly miniaturized devices. These added properties can be interesting for the fabrication of novel micro/nanoelectromechanical systems (MEMS/NEMS).

The current challenge consists on incorporating NCs in the photoresist host matrix to add functionality preserving at the same time the polymer photostructurability. The NC addition has relied on the efficient dispersion of pre-synthesized functional nanosized fillers into the pre-made epoxy photoresist, by using a common solvent as recently reported by the authors in the incorporation of highly luminescent CdSe@ZnS NCs in the same epoxy photoresist.[3] Here, the magnetic properties, UV-photostructurability and mechanical characteristics of the nanocomposite have been investigated. The results show that, after the incorporation, the Fe_2O_3 NCs preserve their magnetism which is conveyed to the photoresist and retained after the UV-lithography process (Figure 1).

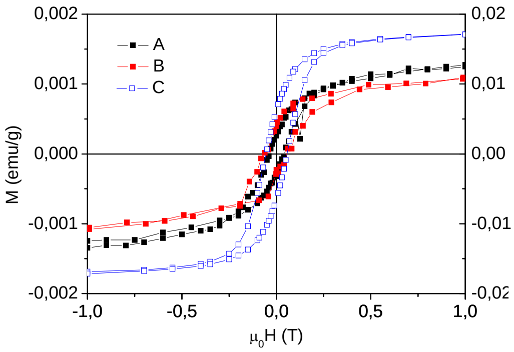

Fig.1. Hysteresis curves of Fe_2O_3 NC modified epoxy photoresist nanocomposite films spin-coated on silicon UV- (black line) and not UV-exposed (red line) compared to that of the Fe_2O_3 NCs in chloroform (blue line). The enlargement of the loop in the ± 1 T field region is shown.

Uniform high aspect ratio 3D microstructures with a resolution down to few micrometers have been fabricated by processing the nanocomposite with conditions comparable to those used for the pure photoresist, attesting for the preservation of the outstanding lithography performance of the polymer (Figure 2).

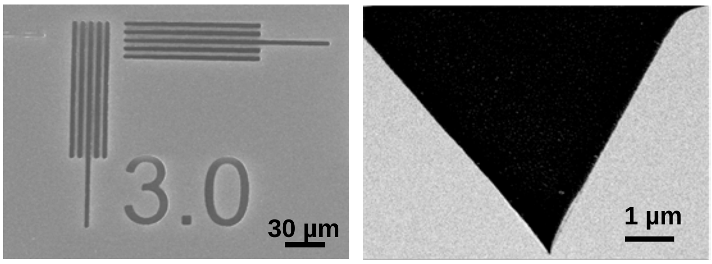

Fig. 2. SEM images of finger-like features and AFM tip formed of the Fe_2O_3 NC modified epoxy photoresist. The radius of the apex of the tip is below 30 nm. The tip has been coated with a Au layer for preventing charging effect.

The incorporated organic-capped Fe_2O_3 NCs improve the stiffness and hardness of the photoresist matrix (data not reported) making the final material extremely interesting for manufacturing miniaturized polymer-based MEMS/NEMS devices. The nanocomposite has resulted suitable for fabricating AFM probes, characterized by straight cantilevers, low stress-gradient, sharp tips (Figure 2) and high quality factors. The fabricated AFM probes have demonstrated to provide good surface imaging performances, both in air and in liquid, superior than those obtained with pure epoxy based photoresist AFM probes and comparable with those of commercial silicon AFM probes.

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