

ABSTRACT

The prime focus of this research is to fabricate high aspect ratio nanostructures on large area of polystyrene surface so that they can be availed for actual practical applications. Micro/nanostructures enhance several properties of the material due to increased surface area-to-volume ratio but the various ways of modifying the surface of the material offer resolution and cost limitations. Therefore, there is a need to develop a method for fabricating structures on a wider surface area. The surface morphology of polystyrene has been modified with different nanostructures by utilizing a method of hot embossing. This method assisted in large area coverage with nanofeatures.

A cost-effective and micron-resolution hot embossing set-up was developed. It is capable of patterning polymers as well as soft metals. High-temperature range, micron resolution movement of the stage at a desired speed, controlled motion of mould towards substrate and high load capacity are some of the salient features of indigenously developed machine. The developed set-up overcomes the limitations of available fabrication techniques which can make nanostructures to a very small area ($500\ \mu\text{m} \times 500\ \mu\text{m}$). It is capable of fabricating structures on the area of $5\ \text{cm} \times 10\ \text{cm}$ with micron resolution which is otherwise not possible with available methods.

Different moulds with nanofeatures were prepared to obtain nanoholes and nanowires on the large area of polystyrene. DC electrodeposition was utilized to deposit nickel into the high aspect ratio holes of the alumina template and COMSOL 5.5 simulation was employed to understand the filling pattern during electrodeposition. A nickel shim with vertically standing nickel nanowires of diameter $400\ \text{nm}$ and length $50\ \mu\text{m} - 70\ \mu\text{m}$ was produced after dissolving the anodized aluminium oxide (AAO) membrane which was then used as a mould to produce high aspect ratio nanoholes of average diameter $250\ \text{nm}$ and length $20\ \mu\text{m} - 30\ \mu\text{m}$ on large

area of polystyrene. Shrinkage offered by polystyrene helped in reducing the diameter of the replicated nanoholes. Fabricated surface with nanoholes was further characterized for wettability and was found to exhibit a hydrophilic nature with a reduction of 56.2° in water droplet contact angle.

The physical vapour deposition method was utilized for filling up the pores of the AAO membrane with copper followed by sintering thereby producing a copper mould with nanowires of diameter 400 nm and length 5 μm . Nanoholes were replicated using this mould of nanowires. Hot embossing parameters were manipulated to obtain high shrinkage in the polystyrene thus creating nanoholes of very small diameter i.e., 25 nm to a maximum of 215 nm. The patterned surface was characterized by anti-reflectance and a reduction from 16.8% to 5.5% was observed in reflectance spectra.

The electroless method was also used to form a layer of nickel on each and every intricate detail of the AAO membrane thereby strengthening it to be used as a mould. When used for manipulating polystyrene surfaces at different hot embossing parameters, nanowires of polystyrene having unique shapes were produced. Flat tip nanowires of diameter 400 nm and length 30 μm - 50 μm and cup-shaped tip nanowires of average diameter 380 nm and length 40 μm - 60 μm were produced by carefully varying embossing load and temperature. Nanoparticles embedded cup-shaped tip nanowires were also produced by utilizing the same mould and further enhancement in surface area-to-volume ratio was observed due to uniform dispersion of nanoparticles through the polystyrene sheet. All kinds of nanowires produced were characterized for light entrapment and a decrease of reflectance from 16.8% to 8.8% (flat tip), 5.58% (cup-shaped tip) and 4.8% (nanoparticles embedded cup-shaped tip) was observed.