Fabrication of arrays of magnetic nanostructures using nanosphere lithography and ion beam etching

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Fabrication techniques like optical lithography, electron beam lithography, and x-ray lithography have been widely used to fabricate low-dimensional nanostructures such as dots[1], ellipse[2], and rings[3-4], to study the shape and size dependence of magnetic, optical, and mechanical properties. Here we present a process of fabricating different types of nanostructures by combining nanosphere lithography and ion beam etching by an electron cyclotron resonance etching system.

Self assembly of polystyrene nanospheres of diameter 500 nm on Si substrates formed hexagonal close packed patterns which were utilized as an etch mask. Etching was performed with Ar and CF_4 gases. Single step etching produced triangular holes between the nanospheres, as shown in Fig 1a. The sidewall angless of the holes (fig 1b and 1c) can be controlled via tilting during the etching process. By suitably combining with an oxygen etch, the size and shape of the holes and hence the resultant nanostructure can be changed.

By performing a two-step etch at different angular directions, the shadow effect of a row of nanospheres on the neighbours allows the triangles to be joined to make dumbbells (Fig 2). By further tuning the process, long zigzag nanowires can be formed.

When extended to a two-layer self assembly process, a unique magnetic ring with a triangular hole can be created. A thin film of NiFe was evaporated on the Si substrate, followed by self assembly of the polystyrene nanospheres. Chlorine assisted ion-beam etching was used to etch triangular patterns in NiFe (see fig 3a) with the nanospheres as an etch mask. Triangular holes in NiFe were formed after the nanospheres were removed. A second layer of nanospheres (fig 3c) deposited sat preferentially on the etched holes because of surface anisotropy created by the etched patterns. A second etch was used to create circular dots using the second layer of polystyrene nanospheres mask. After lift-off, a circular shape with a unique triangular hole is created in the permalloy film (fig 3e-f).

In summary, we will demonstrate the flexibility of the nanosphere lithography process in fabricating multiple types of nanostructures and present the properties of these magnetic nanostructures.

References

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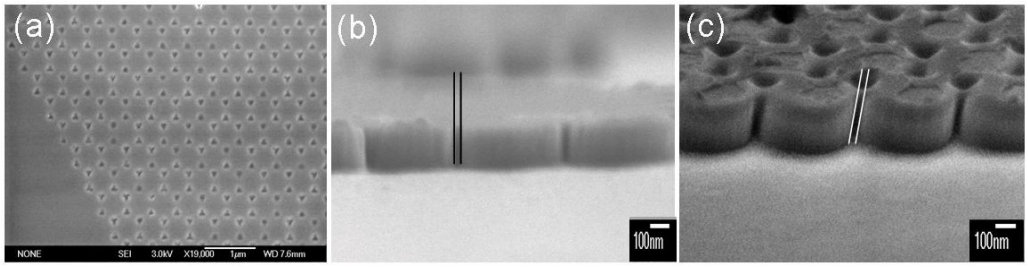

Fig 1 (a) Triangular holes in Si; (b) perpendicular sidewalls; (c) tilted sidewalls

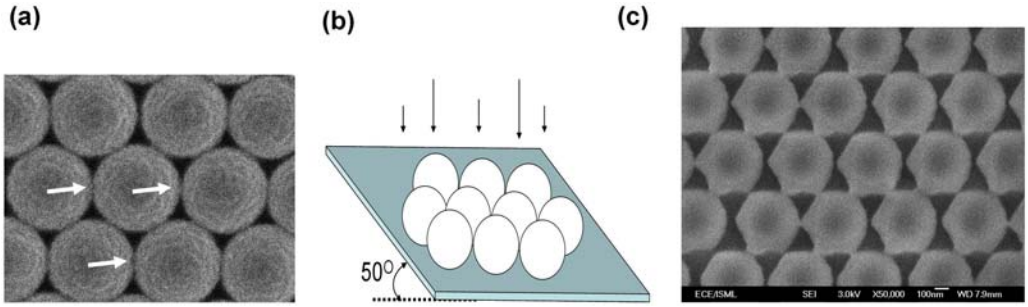

Fig 2 (a) Etching direction; (b) tilt angle during etching; (c) dumbbell elements formed

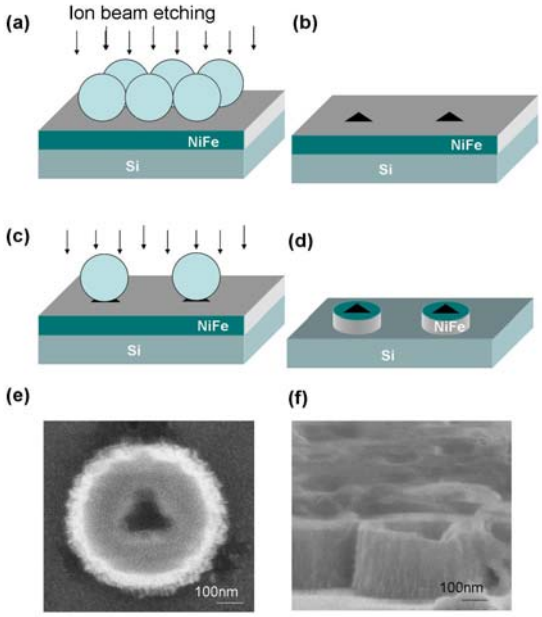

Fig 3 Schematics of two-step deposition and etch to form ring with triangular hole