# Magnetic properties of diamond shaped elements and chains fabricated by nanosphere lithography

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Nanosphere lithography has been widely used to fabricate unique low-dimensional nanostructures such as dots, antidots, rods and rings[1-3] for applications such as patterned media and sensors. Previously we reported work on a long chain of diamond elements fabricated by nanosphere lithography.[4] Here we present a detailed study on the magnetic properties of the chain as the number of diamond elements vary. The magnetic domain distributions were studied by magnetic force microscopy and Object Oriented Micromagnetic Framework[5] (OOMMF) simulations were used to understand and explain the domain arrangements and their switching behaviors.

A cubic arrangement of polystyrene nanospheres of diameter 500 nm is used as a self-assembled deposition mask. NiFe was evaporated through the interstitial spaces of polystyrene nanospheres followed by lift-off in a dichloromethane bath.

The magnetic domains of patterned NiFe chains are shown in fig 1. It shows that the magnetic spins are oriented as vortex states in the diamond shaped elements at remanance. As the number of elements in the chain increases, the domain arrangement affects the distribution in its neighbors. Spins are arranged clockwise or anticlockwise depending on the number of neighbors elements in an attempt to minimize the magnetostatic energy [fig 1(b)-(d)]. Fig 2 shows the magnetostatic energy and exchange energy at different field of hysteresis cycles for chains of 1, 2, 3 and 10 diamonds. The magnetostatic energy and exchange energy contribution to total energy varies with number of elements and compete with each other as the number of elements in the wires increases. Fig 2(a) shows that the magnetostatic energy is highest at saturation and lowest at remanance for chain of diamonds compared to individual elements, and because of exchange interaction between them. The switching properties under the application of varying external magnetic field are further studied by magnetic force microscopy and possible application as sensor elements are proposed.

## References

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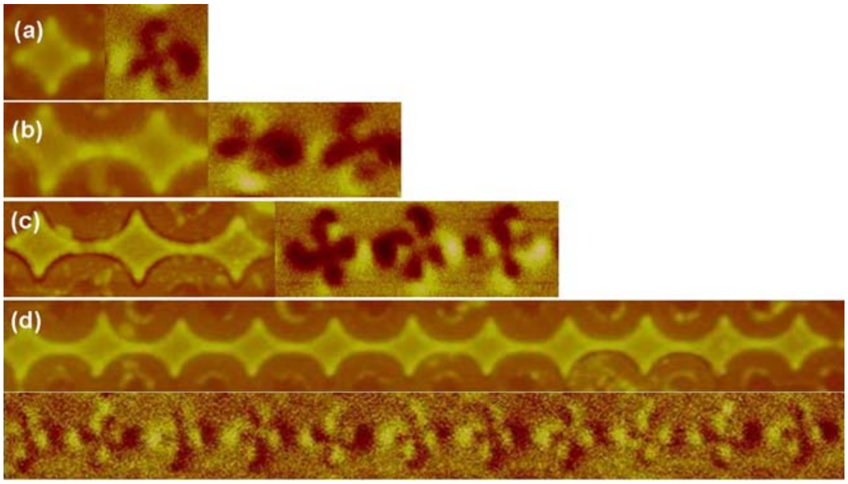


Fig 1 Images showing atomic and magnetic force micrographs taken at remanance before application of any external field (a) a single diamond element (b) a chain of two elements (c) a chain of 3 diamond elements (d) a chain of 11 diamond elements.

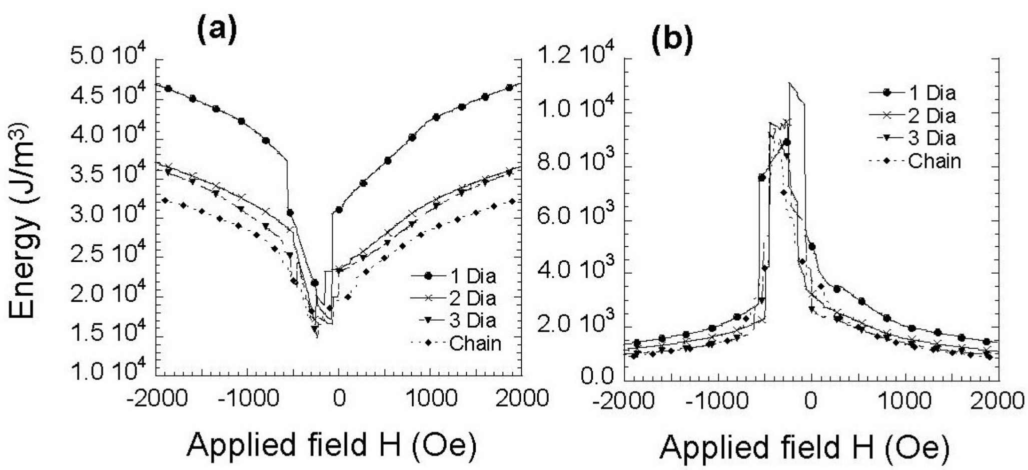


Fig 2 (a) magnetostatic energy and (b) exchange energy variation for permalloy film patterned into a chain of 1, 2, 3 and 10 diamonds.