HSQ-Based Fabrication of Magnetic Nanopillars

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Abstract
Hydrogen silsesquioxane (HSQ) has been used as e-beam resist and ion milling mask in the fabrication of spin valve devices. The excellent performance of HSQ in patterning nanometer size features and corresponding procedures such as chemical mechanical polishing (CMP) make the HSQ-based process a reliable and economic way to make nanomagnetic devices.

Summary
The recent discovery of spin current induced magnetization switch [1] and oscillation [2] has opened up a new way to manipulate small magnetic structures. Compared with the traditional magnetic field driven dynamics, spin transfer torque has advantages in the preciseness of control and efficiency, and therefore has a large potential in information storage and as microwave devices. Because of the rich science and the promising applications of these phenomena, they have stimulated a great interest in both academia and industry.

Size plays an important role in determining the dynamics of a nanomagnet. Therefore, in order to get better performance out of magnetic structures, it is crucial to be able to fabricate nanometer size devices in a reliable and efficient way. The present process which utilizes poly(methyl methacrylate) (PMMA) as e-beam resist in our lab has been proven to be an effective way in patterning magnetic pillars of nanometer size. However, because of the relative small etch resistance of PMMA under ion milling, extra steps are required that involve the deposition of extra layers that assist the patterning process and the subsequent removal of these layers in order to get effective selectivity in the patterning. Those steps increase the cost and time of the fabrication and more importantly, reduce the yield and make it prohibitive to make complex structures. As a novel e-beam resist, hydrogen silsesquioxane (HSQ) has many advantages over PMMA, including smaller linewidth fluctuations, which provides a better solution for whole wafer processing [3]. Moreover, since HSQ has a much stronger etch resistance in ion milling and reactive-ion-etching, it is especially suitable for the application of magnetic structure patterning [4].

In our experiment, metal multilayers are deposited using magnetron sputtering. An HSQ thin film is then coated onto the metal surface and processed to drive the hydrogen out of the HSQ, forming a rigid Si-O network. In this process development effort, we have been using photolithography

Figure 1: Ion milling mask of HSQ is removed by CMP.

Figure 2: SEM of the top part of a magnetic pillar after CMP.
to pattern micro-size ellipses rather than e-beam lithography in order to reduce the cost and for the convenience of characterization. Ion milling is used to define the magnetic micropillars. After proper encapsulation with oxide, a brief CMP is utilized to remove the HSQ mask. The top part of metal multilayer is therefore exposed and provides self-alignment contact with the top leads. Experiment shows that CMP provides a clean surface for top lead deposition.

In summary, HSQ has been utilized in making spin-valve structures to study the effect of spin transfer. Compared with present process, the HSQ based process is more efficient and provides ample room for the improvement of performance. In our future study, e-beam lithography will be used to make practical spin valve or tunnel junction devices.

References


