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다층 Co/Pd 나노선 배열의 형성과 자기적 성질
(Formation of multilayerd Co/Pd nano-wire array and its magnetic properties)

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Co/Pd multilayer has been considered as a perpendicular magnetization media in various magneto-electronic devices because of the large magnetic anisotropy and saturation magnetization. In order to use this material system in nm-scale devices, Co/Pd multilayered nano-structure should be formed by the well controlled fabrication procedures, since the nano-structure will govern the resulting magnetism along with the geometry and materials properties. It has been reported that dry etching process of the Co/Pd multilayer is not so straightforward to obtain a controlled micro- and/or nano- structures. In this study, we proposed a unique process of dry etching, from which arrays of multilayered Co/Pd nano-wires are fabricated.

A multilayer of Pd (42 Å, capping layer) / [Co (3 Å)/ Pd (8 Å)]$_{10}$ /Pd (50 Å)/Ta (40 Å, under layer) is sputter-deposited on SiO_2 (1000 Å)/Si substrate. Then, the multilayer film was patterned by electron beam (e-beam) lithography using hydrogen silsesquioxine (HSQ) as a negative e-beam resist. We found that the adhesion property of HSQ on the magnetic multilayer is too weak to form a stable layer. In order to improve the adhesion, we used 300 Å thick amorphous Si intermediate layer, which was sputter-deposited on the multilayer. Then, 300 Å thick HSQ layer was spin-coated on top of this amorphous Si layer. In order to pattern this layer, optimal e-beam dose and developer (tetra-methyl ammonium hydroxide aqueous solution, TMAH) concentration is identified. Electron beam dose was set from 600 to 1000 μC/cm^2 and 25 % TMAH was chosen as a HSQ developer. By using this conditions, multilayerd Co/Pd nanowire arrays with 50 and 100 nm linewidth are fabricated. The morphology, interfacial structures, and magnetic properties of the thin films were characterized by scanning electron microscopy (SEM) and superconducting quantum interference device (SQUID) magnetometry.

For the pattern transfer from the HSQ layer to the Co/Pd multilayer, two-step plasma etching process is used, as in Fig. 1. Firstly, amorphous Si layer is etched with Cl_2 plasma. Etch selectivity of amorphous Si to HSQ greater than 4:1 is achieved. Amorphous Si layer plays an important role as a good hardmask for the plasma etching of magnetic underlayer as well as an adhesion layer between HSQ and substrate. Secondly, Co/Pd multilayer is etched with Ar plasma. Plasma etching with Ar has an advantage over Cl_2 plasma etching in preventing the formation of an unintentional byproduct from the reaction between the metallic layers and Cl_2 gas. Etch selectivity of Co/Pd multilayer to amorphous Si about 2:1 is obtained.

Fig. 2. shows the cross-sectional morphology and magnetization properties of the Co/Pd multilayer. Fig. 2(a) clearly shows that a uniform, continuous multilayer is formed. Fig. 2(b) shows that the magnetization is saturated at 2 and 3 T in out-of-plane and in-plane direction, respectively. This result clearly shows that the Co/Pd multilayer has preferred magnetic anisotropy in out-of-plane direction. Fig. 3 shows the plan-view morphology and magnetization properties of the multilayered Co/Pd nano-wires' arrays with the linewidth of 50 nm and 100 nm, respectively. Fig. 3(a, b) exhibits the well separated nano-wires without residues. Our preliminary results show that the magnetization curve (Fig. 3 (c)) reveals that the out-of-plane and in-plane directions have not so clear distinction: Both curves show the superparamagnetism without remanances and coercivities, in comparison to Fig. 2 (b).

We show that the metallic magnetic multilayered nano-structures with a well controlled geometry, can be fabricated by the proposed two-step patterning process. Detailed discussion on the effect of the interline spacing and interfacial structures on the resulting magnetic properties will be given.

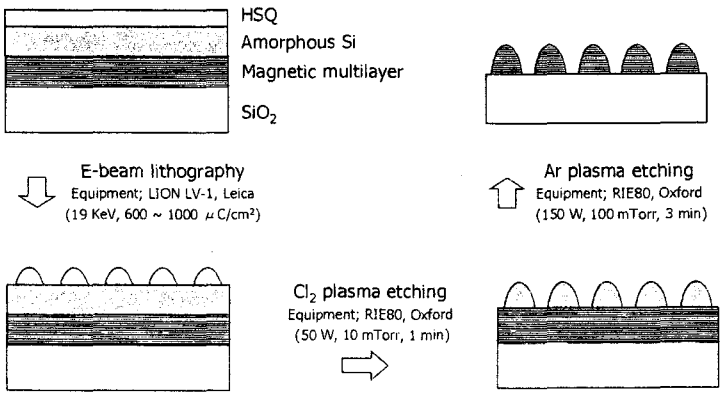

Figure 1. The schematic process flow with a detail process condition and employed equipments.

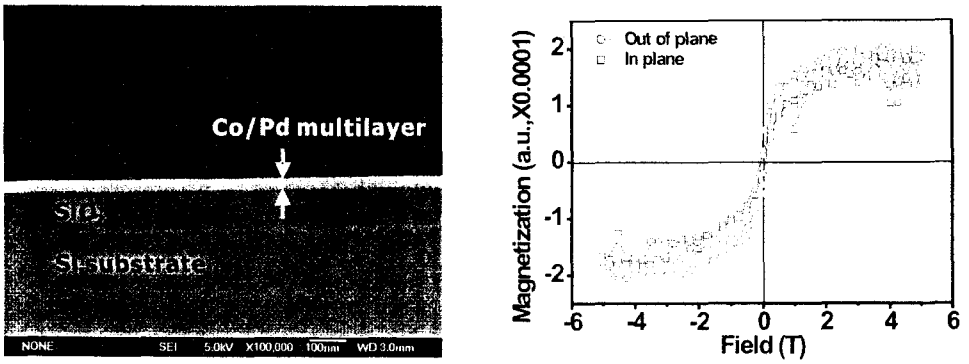

Figure 2. Cross sectional scanning electron microscopy image of multilayerd Co/Pd thin film deposited on SiO_2/Si substrate (a), and its magnetization curves (b).

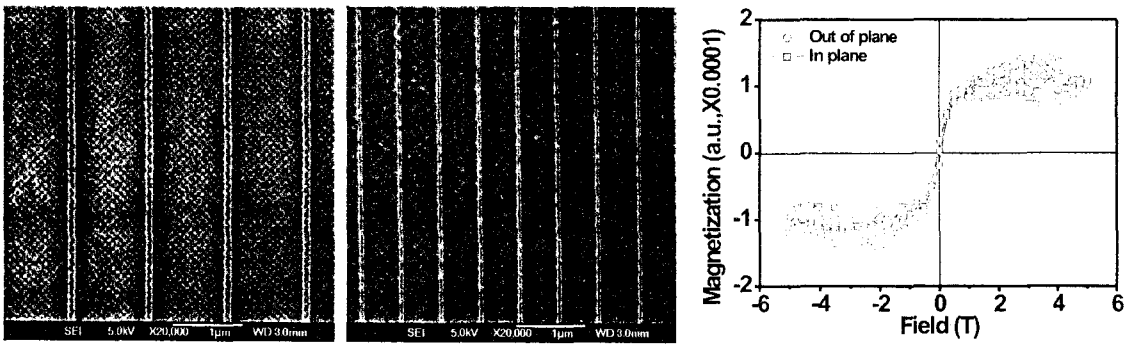

Figure 3. Scanning electron microscopy image of multilayerd Co/Pd nano-wire array with (a) 100 nm, (b) 50 nm linewidth and its magnetization curves (c).