Magnetic tunnel junction array for physical reservoir

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Physical reservoir computing attracts much attention because of simple learning process and high compatibility with electronic hardware [1-4)]. Magnetic dot array, in which magnetic interaction produces complex magnetization dynamics, is one of the candidates of the physical reservoir. Recently H. Nomura et al. reported by simulation that a reservoir consisting of a dipole-coupled magnetic dot array can perform binary logic functions of AND, OR and XOR. [5)] The magnetic dots are magnetized perpendicular to the film plane. The magnetic interaction was well investigated in in-plane [6, 7)] and perpendicularly [8, 9)] magnetized dots. We also fabricated a pair of closely located magnetic tunnel junctions (MTJs) with in-plane magnetization and observed that magnetic interaction in the MTJs decays with the gap between the MTJs. [10)] In contrast, the effect of the magnetic interaction has not been well investigated experimentally in perpendicularly magnetized MTJs. Usually, perpendicularly magnetized MTJs fabricated is smaller than 100 nm in diameter because of single domain size, resulting in weak interaction between the MTJs. Therefore, it is difficult to investigate the effect of the magnetic interaction over the gap (typically <100 nm) on the magnetization dynamics.

In this study, to develop reservoir using MTJ arrays having sufficient magnetic interaction, we investigated first fabrication process of the MTJ arrays with a small gap. The MTJ films were prepared using a UHV magnetron sputtering system. The film stack was typically a bottom thick lead/buffer layer/Co-Pt based fixed layer/MgO/CoFeB free layer/MgO cap layer/metal cap layer, where CoFeB free layer was basically perpendicularly magnetized. The array consisted of 8 x 8 MTJs. The diameter of the MTJ dot (d) and a gap between the MTJs (g) were set to identical and varied between 40 nm and 100 nm. After deposition of the MTJ films, small hole patterns were prepared using electron beam (EB) lithography with a positive type resist. Then, Ti mask material was deposited by evaporation, followed by lift off. The shape of the Ti mask was transferred to the MTJ film by Ar ion milling. Etched surface was passivated by a 30-nm-thick SiO_2 layer by sputtering. Contact holes on top of the MTJ dots were fabricated using EB lithography and reactive ion etching. Fine patterns of the top electrode leads were prepared using EB lithography, photo lithography and lift off. We will show details of the fabrication process and observed structure of MTJ arrays in the conference. This work is partly supported by the Ministry of Internal Affairs and Communications.

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