A 72-cell magnetic tunnel junction array for locally accessible artificial spin ice

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Artificial spin ice (ASI) [1] consists of an array of small magnetic cells interacted by dipole coupling. The elongated cell shape induces uniaxial shape anisotropy, which give Ising-like character to the cells. The nature of the magnetic interaction and Ising-like character in the array gives rise to frustration, causing emergent properties of ASI such as monopole and phase transition [2]. The exotic character of AST attracts attention also from a viewpoint of application such as physical reservoir computing [3, 4, 5]. Experimentally, magnetizations of the individual cells in ASI were observed by means of imaging techniques such as magnetic force microscopy [1] or photoemission electron microscope with x-ray magnetic circular dichroism [6]. The techniques enable us to investigate wide area of a sample with high resolution, which is essential to fundamental physics. A draw back of the imaging techniques is low speed, several seconds per one image. In the applications, for example, reservoir computing, much faster access speed with compact device size is necessary in. In this context, an electrical means accessible to individual cells is inevitable [5]. In this study, we developed fabrication process of ASI consisting of a magnetic tunnel junction (MTJ) cell array with electrical leads. We can read/write out the magnetization configuration of a cell in the ASI through tunnel magnetoresistance effect [7] and input information to the cell by changing the configuration electrically [8, 9]. The ASIs were microfabricated using lithography and ion beam etching. The cells were 150 nm wide and 400 nm long, arranged in a honeycomb lattice with a distance between the nearest vertexes of from 500 nm to 2 μm. The ASI consists of 72 MTJ cells on a common bottom lead, in which 62 MTJ cells have an electrical top lead. The top leads were prepared by patterning a Ti 5 nm/Au 30 nm film into narrow lines of about 80 nm in width and 120 nm in space in the densest array configuration. We observed the structures by a scanning electron microscope and confirmed that the MTJ cells and electrical leads were well shaped and located.

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