INTRODUCING NOVEL FUNCTIONAL MATERIALS AND LIQUIDS FOR BREAKING THE LIMIT OF MEMORY DEVICES

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Memory devices with higher performance and higher density are being required to deal with drastically increasing data. However, we are, now, facing the limit of further improvement of memory performance. Related to this, semiconductor technology is facing a miniaturization limit and further increase in the density of memory devices is getting harder and harder. To overcome these issues, introducing novel materials that have unique physical and chemical properties that materials used in conventional silicon technology cannot provide into CMOS process is examined. For example, we hypothesized that the addition of ionic liquids (ILs) to conducting-bridge random access memory (CBRAM) would improve a cycling endurance as well as the switching voltages and data retention of CBRAM [1, 2]. Here, CBRAM has a simple structure of top electrode (TE)/metal oxide (MO)/bottom electrode, in which electrochemically active metals, such as Cu and Ag, are used as one of the two electrodes, which is defined as a TE in this study, and works as a memory device by the connection and disconnection of a CB consisting of the active metal that is eluted electrochemically from the TE. Our hypothesis was based on the expectation that the segregation of the eluted TE metal, which makes the CB too thick to be disconnected again and is a main factor causing a reset failure, could be avoided with the help of high ability of ionic liquids to enhance ionization and diffusion of the TE metal. We actually confirmed that switching voltages and their dispersions decreased by addition of metal containing ILs that were designed for the use in CBRAM. Another example is introducing metal organic frameworks (MOFs) into electric devices. MOFs inherently have periodically and densely aligned nano-scale pores due to self-assembled phenomena. We propose replacing a metal oxide film in CBRAM cell that works as a memory layer with MOF. This is because we expected that the nano-scale pores of MOF enhance ionic diffusion and the directionality of the diffusion along the pores, leading to superior performance including the improvement of the deviations of switching voltages and resistance. We developed a method that enables a selective synthesis of MOF crystal accurately at desired points. Combining the method with conventional microfabrication technic that is familiar with silicon process, CBRAM cells with the diameter less than 100 nm that contain a single MOF crystal each as a memory layer could be fabricated successfully. We observed resistive switching phenomena in theses CBRAM cells, meaning that a single MOF crystal works as CBRAM was achieved as a microfabricated electric device, for the first time. Our examples suggest that introducing novel functional materials and liquids such as MOFs and ionic liquids into electric devices is effective in overcoming the limit of improvement of performances including further miniaturization.

[1] A. Harada *et al*, J. Mater. Chem. C4, 7215 (2016). [2] K. Kinoshita *et al*, Japanese Journal of Applied Physics 56, 04CE13 (2017)