Plasma Etching of Unconventional Materials: Is There Any Systematic Approach?
Prof. Satoshi Hamaguchi and Kazuhiro Karahashi – Osaka University

As the sizes of semiconductor devices continue to diminish and are now approaching atomic scales, the downsizing of transistors following Moore's law is bound to end in the near future. However, the continuing market demand for higher performance and lower energy consumption of large-scale integrated (LSI) circuits has driven invention of new device technologies such as three-dimensional (3D) device structures and devices based on non-silicon materials. Manufacturing of such non-conventional devices poses new challenges for processing technologies. For example, there is essentially no reactive ion etching (RIE) processes for magnetic materials used for magnetoresistive random-access memories (MRAMs) with sufficiently high anisotropy, high selectivity against other materials, and low surface damages. The limited capability of low-damage RIE processes for magnetic materials hinders higher integration of MRAM devices. The dwindling sizes of modern microelectronic devices also require atomic level precision of their manufacturing processes. For example, atomic layer deposition (ALD) processes have been widely used in the industry for conformal thin film deposition for various microelectronic devices while isotropic and anisotropic atomic layer etching (ALE) processes may soon become standard etching processes in the industry. When such new processes are developed with the use of many possible options of surface etching reactions, the key for efficient development is a fundamental understanding of the surface reactions used in the processes. Especially when materials that were not used much in the semiconductor industry in the past, i.e., unconventional materials, need to be processed, it would help the process developer if there were a guidance or systematic approach for the process development based on the chemical properties of the materials to be processed. Currently there is little such guidance and the development of new processes still needs to heavily rely on experience-based approaches. In this study, we shall review our recent work on analyses of etching selectivity and surface chemical reactions for magnetic materials, metal oxides, Si-based materials as well as damage formation mechanisms due to ion bombardment during RIE processes. In our analyses, we use multi-beam injection experiments and molecular dynamics (MD) simulations to emulate elementary processes of plasma-surface interactions that take place in RIE processes. Based on these results, we shall propose a potential methodology to systematically develop etching processes for unconventional materials.

Organized by: