3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

High-energy Negative Ions in Sputtering Plasma - Energy Distribution and Its Spatial Variation -

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Negative ions often appears in various plasma sources, when electronegative gases or materials are introduced in the plasma source. The well-known production process of the negative ion is gas phase production processes such as dissociative attachment of electronegative molecules or electron attachment. H^- production through two-step gas phase reaction is also well-known, i.e., production of vibrationally-excited H_2* in high-T_e plasma followed by dissociative attachment of H_2* into H^- in low-T_e plasma. Gas-phase produced negative ions are also very common in processing plasmas because various electronegative molecules such as O_2, Cl_2, C_xF_y molecules are commonly used in various etching processes to produce volatile molecules from solid materials. In contrast to the gas-phase production of negative ions, surface production of negative ions are also important. In the nuclear fusion research, H^- production on the surface with the aid of Cs coated surface is now indispensable technology for high-power neutral beam injector.

Surface-produced negative ion is also very important in the case of industrial application of the plasma. In modern electronics-decive fabrications, oxide materials play very important role. For example, transparent conductive films (TCO) made from indium-oxide (ZnO), Indium-tin-oxide (ITO) or indium-galium-zinc-oxide (IGZO) are indispensable in display devices, touch panels, solar cells and so on. Oxide films such as MgO is also important as the core material of magnetic random acess memory (MRAM), which is now intensively investigated as one of the future memory device replacing the flash memory. In the process of these oxide film deposition, magnetron sputtering using oxide target materials is very common because of its beneficial points such as high-throughput, low-cost and low process temperatures. In this process, however, surface-produced negative ions produces severe issues, because negative ions are easily produced on the surface of negatively-biased target and are accelerated by the high-voltage sheaths up to a few hundred eVs. Such high energy ions travelling through the gas phase to the film-depositing surface destroys lattice structure of the film or removing oxygens from the surface to change the stoicheometry. From this viewpoint, understanding of the negative ion behavior in magnetron plasmas is important to control film qualities.

In the talk, high-energy negative ions in magnetron plasmas are discussed. Impact of negative ions on the deposited film is breifly survayed.[1,2] As an example, degredation of the electrical conductivity or crystal phase variations induced by high-energy negative ions are introduced. After introduction of previously-reported diagnostic results related to high-energy oxygen negative iosn, [3,4] systematic study of high-energy negative ions by our group is introduced. In a DC magnetron plasma, O^- energy distribution[5] and O^- flux measurement using a carorimetry method[6] is presented as a radial dependence of the magnetron plasma. In the RF magnetron plasma using insulating material as a target, high-energy O^- shows quite different behavior. O^- energy distribution shows that lower O^- kinetic energy in the vicinity of the magnetron plasma ring, indicating contast bahavior of O^- fulx and O^- kinetic energy. Furthermore, very interesting energy distribution is observed in the case of the RF magnetron plasma, i.e., very complicated fine structure of O^- energy distribution.[7] From detailed measurement of the O^- energy distribution in radial and axial positions in the ring-shaped magnetron plasma, the origin of the fine-structure of the O^- energy distribution is discussed. A few method to control high-energy O^- energy is also mentioned.[8,9]

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