A CONCEPT AND AN EXPERIMENTAL STUDY ON O⁻ ION SOURCE USING SOLID OXIDE ELECTROLYTES

Yukio Fujiwara, Atsushi Kaimai, Jeong-Oh Hong, Keiji Yashiro, Yutaka Nigara, Tatsuya Kawada, and Junichiro Mizusaki
Institute of Multidisciplinary Research for Advanced Materials
Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai 980-8577, JAPAN

Oxygen ion beams are widely used in engineering fields as well as scientific fields. For instance, oxygen ion beams are used to form SiO2 layers on silicon wafers in the semiconductor industry. It is also known that oxygen-ion-beam implantation improves surface properties of materials. Moreover, oxygen ion beams are used as primary ion beams in Secondary Ion Mass Spectrometry (SIMS). In terms of application, oxygen "negative" ions, O^-, are more useful than oxygen positive ions, O^+. This is because little charge-up of samples occurs, when they are irradiated with negative ion beams. In general, oxygen positive and negative ions are produced using discharge plasmas; however, it is difficult to produce negative ions efficiently.

The concept of Solid Oxide Ion Source (SOIS) is a new one proposed by our group. Figure 1 is a simple illustration showing the principle of the SOIS. The machine on the left is an oxygen pump, introducing oxygen gas into a vacuum chamber. The machine on the right is the SOIS; a short gap exists between the surface of a solid oxide electrolyte and an extraction electrode. Positive high voltage is applied on the extraction electrode, forming an electric field between an air electrode and the extraction electrode. Oxygen negative ions, O^-, emitted from the surface of the electrolyte are accelerated toward the extraction electrode by the electric field. The extraction electrode has holes so that some O^- ions may pass through the electrode; oxygen negative ion beams are produced. Unlike conventional ion sources using plasmas, the SOIS is expected to generate oxygen negative ions efficiently by thermionic emission from the solid surface. We think that the SOIS will have great potential from the viewpoint of ion engineering, opening up a new field in solid-state ionics.

To demonstrate the concept, thermionic emission of oxygen negative ions, O^-, was studied using Yttria-Stabilized Zirconia (YSZ). Figure 2 shows an experimental apparatus for measuring O^- emission. Emission current was investigated at the temperature ranging from 750 to 950 °C under a pressure of about 1×10^{-3} Pa. To clarify the effect of emission-surface condition, gold and platinum coated surfaces were tested in addition to a bare YSZ surface. In all surface conditions, as shown in Fig. 3, negative charged particles proved to be emitted from the surfaces, increasing with temperature and applied voltage. From Arrhenius plots, activation energy of the thermionic emission was estimated to be about 2 eV. In all cases, emission current decreased with time, approaching zero; however, after intervals, the current was found to recover.

On the basis of experimental results, we proposed a model that is based on three key processes occurring on the surface of solid oxide electrolytes: (a) formations of O^- ion by electron capture, (b) accumulation of O^- ions on the surface, and (c) emission of O^- ions existing on the surface, as shown in Fig. 4.

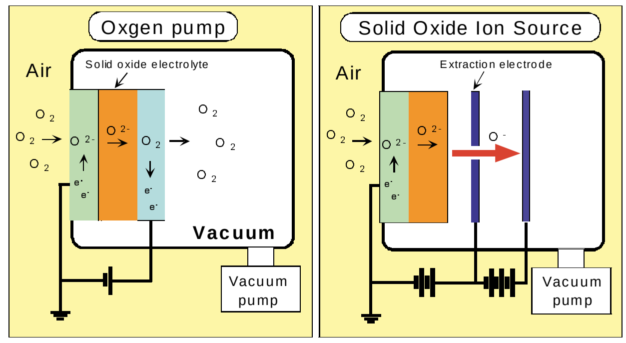

Fig. 1. Comparison between an oxygen pump and the Solid Oxide Ion Source (SOIS)

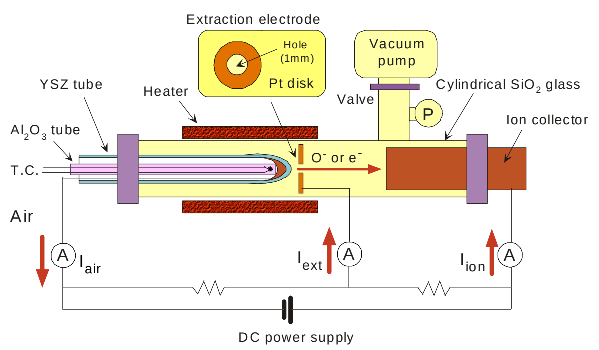

Fig. 2. Schematic diagram of the experimental apparatus for measuring O^- emission.

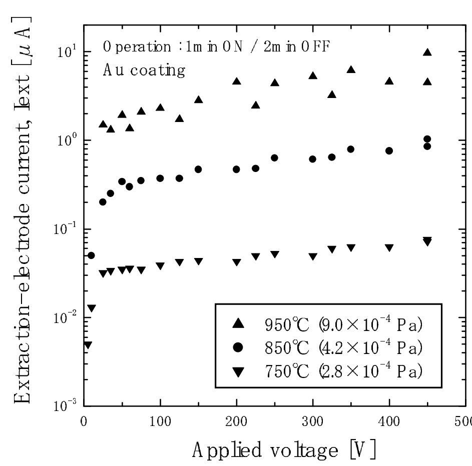

Fig. 3. Applied voltage and temperature dependence of I_{ext} in the case of Au coating.

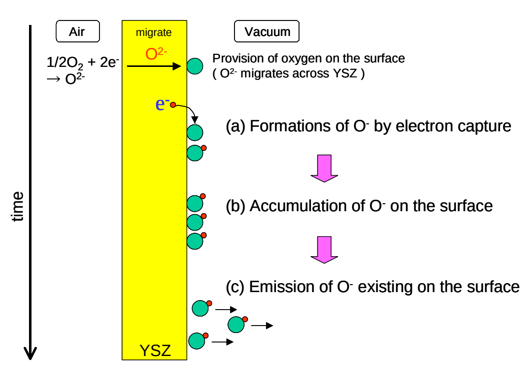

Fig. 4. Schematic diagram illustrating a model for explaining the emission mechanism of O^- ions.