New Frontier of Solid State Ionics: Storage/Conversion of Energy and Information

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Solid state ionics (SSI) is defined as a scientific discipline to cover both basic science and applications of materials that can conduct ions in solid state. To our surprise, phenomena caused by the ion migration and diffusion in solids were already recognized by Michael Faraday as introduced by an excellent historical review on the development of SSI discipline in Europe (K. Funke, Science and Technology of Advanced Materials 14(4): 043502). Japan has been a leading country in global SSI community through its quality and volume contributions in both basic science and applications. One may find the reason in history that the name of our discipline, “solid state ionics,” was defined and proposed in early 70’s by Japanese scientist, late Professor Takehiko Takahashi (Nagoya University) (T. Takahashi and O. Yamamoto, J. Electrochem. Soc., 118 (1971) 1057), who established a small Japanese society, nowadays grown to the Solid State Ionics Society of Japan (SSIJ), as a salon to meet peoples from different backgrounds of physics, chemistry, and metallurgy. In late 70’s, SSIJ contributed to initiate a union of local SSI communities in Europe, Japan, and US to organize biennial international SSI conference, which will celebrate its 20th anniversary (SSI-20) at Keystone Colorado, USA in 2015 following SSI-19 in Kyoto last year.

The ion migration in solids has been attracting scientific curious subject, seemingly due to inconsistent concept of dynamic nature of fast ion migration in solids, where still and static behavior of constituent ions are expected. Later, SSI has attracted by its applications to electrochemical devices for the conversion between chemical and electrical energy, and analog chemical sensors to convert chemical information into electrical signals. While conventional applications were rather simple substitution of liquid electrolytes except for its advantage of usage at high temperatures, new directions of applications today focus on utilization of its unique advantages of SSI, such as being self-standing solid matter, high transference number of single ion, and chemical stability, in all-solid-state batteries, solid oxide rules cells, and so on. Of course, continuing challenge is still necessary to seek for new materials with higher ionic conductivity, hoping to attain comparable one with liquids to overcome suffering disadvantage of low ion mobility.

Further new directions of SSI applications emerge to utilize the ion migration in artificially fabricated nano-space solid at rather low temperatures, in order to control other physical properties, for instance, nano-electronic devices like memristors and nanoionics switching devices. Such new emerging extension of SSI is symbolized by a message at SSI-19: “Today, energies are going to be stored in ions, but in future, all the information will be stored in ions, too.” (S. Williams, Plenary lecture at SSI-19 in Kyoto) Another challenge in SSI subjects is an activation of chemically passivated “ionic hetero-junction (IHJ),” in which depletion of ionic carrier, similar to Schottky barrier in semiconductors, often occurs due to relaxation of the internal potential difference between heterogeneous media by fast ion migration. A synergetic concept of SSI and semiconductor science is necessary to be established, for the control of IHJ properties and its applications, not only to prevent such passivation, but also to enjoy novel chemical and physical functionalities of interface and surface by ion migration.

Ever-expanding discipline of SSI is, by its nature, of interdisciplinary, but, more importantly is of multidisciplinary, which gives rise to vital activity of enthusiasm to seek for new materials and new applications. Therefore, I’d like to send my sincere invitation and warm welcome to anyone who is interested in SSI from different disciplines to explore “a new frontier of solid state ionics.”