The Photopolymer Science and Technology Award

The Photopolymer Science and Technology Award No. 132200, the Best Paper Award 2013, was presented to Atsushi Asano, Yuta Maeyoshi, Katsuyoshi Takano, Masaaki Omichi, Masaki Sugimoto, Masahito Yoshikawa, Satoshi Tsukuda, Shun-ichiro Tanaka, Akinori Saeki, and Shu Seki, from Osaka University, Japan Atomic Energy Agency, and Tohoku University for their outstanding contribution published in *Journal of Photopolymer Science and Technology* **25(5)**, 685-688 (2012), entitled “Fabrication of Nanowires Based on Polystyrene Derivatives by Single Particle Nano-Fabrication Technique”.

Atsushi Asano

Atsushi Asano received his B.S. degree in Osaka University in 2009, and then received M.S. degree in Osaka University in 2011. He is now a Ph.D. candidate under the direction of Professor Shu Seki at Department of Applied Chemistry, Graduate School of Engineering, Osaka University. His current research fields include polymer chemistry, radiation chemistry, and functional organic materials chemistry.

Yuta Maeyoshi

Yuta Maeyoshi received his B.S. degree in 2010 and M.S. degree in 2012 from Osaka University. He had investigated the formation of fullerene nanowires by using single particle nanofabrication technique and its application to organic photovoltaics. He currently works at Honda Motor Car Co. Ltd.

Katsuyoshi Takano

Katsuyoshi Takano received his B.S. degree in 1993, M.S. degree in 1995, and Ph.D. degree in 2002 from Gunma University. He became a postdoctoral fellow at the university in 2003, and transferred as a postdoctoral fellow at Japan atomic energy agency in 2005. From 2008, he started to develop a nano-microprocessing technique using focused light and heavy ion beams with the kinetic energy from several to hundreds mega electron volts. He joined Osaka University as a postdoctoral fellow in 2011. His current research interest focuses on the nano-materials fabrication by radiation chemical processes.

Masaaki Omichi

Masaaki Omichi received his B.S. degree in 2006, M.S. degree in 2008, and Ph. D. degree in 2011 from Osaka University for the study on physical immobilization of bioactive proteins on polymer surface and application to blood purification system. He became a research associate at the same university in 2011. He has been a research assistant professor at Anan National College of Technology since 2012. His research interests include polymer chemistry, radiation chemistry, and biomaterial. He is a member of the Society of Polymer Science, Japan.

Masaki Sugimoto

Masaki Sugimoto received his B.S., M.S., and Dr. Eng. degrees in Department of Metallurgy and Materials Science, College of Engineering from University of Osaka Prefecture, in 1989, 1991, and 1994. He is currently a deputy principal researcher with Japan Atomic Energy Agency, Takasaki, Japan, and engaged in the research and development of functional ceramic materials using radiation irradiation technique.

Masahito Yoshikawa

Masahito Yoshikawa received his B.S. degree in 1979 from Chiba Institute of Technology, M.S. from Tokyo Institute of Technology in 1981, and Dr. Eng. degree from Saitama University in 2001 for the study on effects of gamma-ray irradiation on electrical characteristics of silicon carbide metal-oxide- semiconductor structures. He is currently a senior principal researcher in Japan Atomic Energy Agency and engaged in the research and development of functional ceramic materials using irradiation techniques.

Satoshi Tsukuda

Satoshi Tsukuda received his B.S. degree from Niigata University in 2002. He received M.S. degree and Ph.D. from Osaka University in 2004 and 2007, respectively. In 2007, he joined Institute of Multidisciplinary Research for Advanced Materials, Tohoku University as an assistant professor. His current interest is formation of hybrid nanowires using high energy ion beam.

Shun-ichiro Tanaka

Shun-ichiro Tanaka received his B.S. degree in 1973, M.S. degree in 1975, and Ph.D. degree in 1980 from Tohoku University. He joined Toshiba Corporation in 1980 and presided over Project Director of ‘The Tanaka Solid Junction Project’, ERATO, JST (1993-1998). He was promoted as a professor at Nagoya Institute of Technology (2002-2006), and also promoted as a professor at Tohoku University in 2005. His research interests include controlled nano/micro-structure growth in excited reaction fields.

Akinori Saeki

Akinori Saeki received B.S. and M.S. degrees in nuclear engineering from Osaka University in 1999 and 2001, respectively. He received Ph.D. in Applied Chemistry from Osaka University in 2007. He had been an assistant professor at Institute of Scientific and Industrial Research, Osaka University in 2003-2009. From 2009 to 2010, he had been a JST-PRESTO researcher. He is currently an assistant professor (tenure-track) at Osaka University.

Shu Seki

Shu Seki received BS and M.S. from the University of Tokyo in 1991 and 1993, and received a Ph.D. from Osaka University in 2001. Since 2009, he was appointed as a Professor of Chemistry at the Graduate School of Engineering, Osaka University.

Photo-induced reactions in polymers have been the key processes in the miniaturization of materials especially as photo-lithography processes, and well-sophisticated concept and/or design of photo-sensitive organic molecular systems have been widely developed as reported in the *Journal of Photopolymer Science and Technology*. One of the most important criteria for the miniaturization (micro- and nano-lithography systems) is the spatial size of the energy deposited by incident photons or the other radiation sources to focus the reaction into

the small spatial area, leading to the principal resolution of the lithography technique and dimensions of the devices fabricated by the process. To realize the fabrication of semiconductor devices in this conventional schema, a use of “delicate” and “precision” optics is indispensable and has been successfully applied for mass production of the devices, such as immersion lithography techniques.

The key concept of “single particle nanofabrication technique”, reported firstly by the authors of the present paper for the award in

2001 [1], is very unique because the technique is moving far away from the conventional schema. Being free from the “focusing” of particles into the small spatial area, the authors were approaching to the concept that *a particle produces a corresponding 1-dimensional nanostructures* [2-6].

The authors have developed successfully a unique technique to produce 1-dimensional nanostructures with precisely controlled sizes on the basis of chemical reactions induced by high energy “single” particle. Non-homogeneous spatial distribution of deposited energy by incident charged particle was converted effectively into promotion of crosslinks of the polymer backbones, giving beautiful nano-wires with ultra-high aspect ratio reaching up to ~750. Unlikely to conventional “focused” charged particle beams used for the “top-down” nanofabrication discussed above, “single” particle is intrinsically free from dissipation of particles in “focused” beams, leading to an extraordinarily high aspect ratio of nanostructures. The size of nano-wires was perfectly interpreted by well-sophisticated theoretical aspects based on the statistical theory of polymer backbone configurations, suggesting that simple cross-linking reaction of the polymers determine the size and structure of nanowires [7-9].

The crosslinks in the 1-dimensional nano-wires were induced effectively by the charged particles via radical coupling reactions in the pendant adamantane moieties, and distributed densely in the ultra-thin nano-wires. The high density cross-linking provides not only the simple formation of the nano-wires but also the higher mechanical strength of the nano-wires than those reported by the same authors [10-12], suggesting the high feasibility of the present nano-wire systems for practical application utilizing their ultra-large surface areas. The control of the nano-wire alignment was also demonstrated finely in the present paper, and this is also the case of a seamless dimension control of nano-materials from 1-dimensional to 2-dimensional ones.

Carbon nanotubes are the primary choice as functional one-dimensional nano-materials, however, the present technique will give an alternative versatile and powerful approach for multi-functional one-dimensional nano-materials, because the technique provides a variety of

nano-wires based on the widespread range of organic polymer materials [13].

Their important research results have been presented at the Conference of Photopolymer Science and Technology 2012 and the paper has been published in *Journal of Photopolymer Science and Technology*. Their contributions give the fundamental aspects of development of nano-materials.

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