The Photopolymer Science and Technology Award

The Photopolymer Science and Technology Award No. 201100, the Outstanding Achievement Award 2020 was presented to Dr. Masao Tomikawa for his outstanding achievements in photo definable polyimides science and technology including the photo reaction mechanism of the Ionic-bonded-photosensitive polyimide, and the pioneering development of positive photo definable polyimide by partial esterification of poly(amic acid) for semiconductor stress buffer and for the organic light emitting diode (OLED) displays. In addition, he contributed the Cu compatibility study for the improvement to long time reliability of the polyimide and Cu interconnection.

Dr. Masao Tomikawa is a research fellow at Toray Industries, Inc. in Japan. He became a fellow of The Society of Polymer Science, Japan in 2019. He is a member of the Chemical Society Japan, the Society of Polymer Science Japan, the Society of Fiber Science and Technology Japan, American Chemical Society, and IEEE.

He serves for many years on the Program Committee Member of ICPST (The International Conference of Photopolymer Science and Technology).

He received the technical award from Chemical Society, Japan in 2009, the technical award from the Society of Polymer Science Japan in 1991, and the Japan Institute of Invention for unique Patent in 2010, 2015, 2017, and the Best Paper Award from the Pan Pacific Microelectronics Conference in 2018.

He received BS and MS degrees from the University Tokyo in 1984 and 1986, respectively. In addition, he received Ph.D degree from Tokyo Institute Technology in 2011. He has studied the soluble rigid polyimides in the Institute of Polymer Science at the University of Akron from 1992 to 1994 as a visiting scholar.

Dr. Masao Tomikawa has studied the chemistry and applications of the photo-definable polyimide for long time. One of his important contributions for photo-definable polyimides is a study of the initial-photo reaction of the ionic-bonded-photo-definable polyimide [1], where he showed that the initial reaction is the photo-induced-charge separation in a poly(amic acid) (PAA) chain but the acrylic group in the photo reactive amine did not react mainly. This means that the photo reaction of the ionic-bonded-photo-definable polyimide is related to the charge-transfer-complex formation in poly(amic acid). This clarification of the initial-photo reaction led to the improvement of the photo-definable polyimide.

His most important contribution to the photo-definable polyimides chemistry is that he found the novel partial esterification reaction of PAA by using dimethyl formamide dialyl acetal (DFA) [2]. The dissolution rate of the partial esterified PAA to alkaline solution was controlled precisely by an addition of DFA. He reported that the novel positive-photo-definable polyimide by using the partial-esterified PAA and diazonaphthoquinone
compounds.
In order to obtain high sensitive and precise patterning positive-tone-photo-definable polyimide, he examined the polarity of poly phenol compound of photo-reactive diazonaphthoquinone compounds [3]. He found that the diazonaphthoquinone compound composed of low polar polyphenol was tended to gather in the surface region. Thus the dissolution contrast between exposed area and unexposed area at the surface region is extremely high when using phenol compounds which has the low dipole moment. In addition, he invented the novel-polyimide-back-bone structure for the positive-tone-photo-definable polyimide [4] and commercialized [5]. The developed positive tone photo definable polyimide was applied for semiconductor packages [6]. In addition, he and his co-researchers developed the photosensitive polyimide for the advanced semiconductor-chip-scale packages [7].

He and his co-researchers examined the polyimide structure and composition to design the high elongation stored at high temperature for long time reliability [8].

They studied for the improvement of Cu compatibility with polyimides. Interconnection structure of photo definable polyimide and Cu became much more important for the advanced semiconductor packages. They examined Cu atom and ion diffusion into the polyimide layer, and the void formation between Cu and polyimide mechanism. They found that the void was formed due to the diffusion-rate difference in Cu atom and Cu ion [9]. The study of the Cu-void formation is quite important for the material development. Thus he awarded from the Pan Pacific Microelectronics Conference as a best paper. By using the knowledge, they demonstrated a panel level re-distribution layer on a glass panel substrate for the advanced Fan-Out Packages [10].

To use the photosensitive polyimide in manufacturing production line, he examined the effect of exhaust at the polyimide soft baking and found to show high photo sensitivity when baking under the high exhaust pressure [11].

From the other point of view, he and co-researchers obtained positive polyimide image by using an ionic-bonded-photo-definable polyimide [12]. He and co-researchers found that Tg temperature difference between exposed area and unexposed area. The difference generated the rate difference of imidization.

In addition, he and his group modified that the positive photo definable polyimide for the pixel divided layer of OLED displays to improve long term reliability of OLED displays by minimizing the out-gassing and pixel shrinkage study with development of the slit-die coating process [13]. The photo-definable polyimides for OLED displays are using as a de-facto standard.

From the view point of basic studies, he examined the photo-induced-properties change in the novel soluble rigid polyimides [14]. He found that the anion radical formation in dianhydride moiety in the polyimides, and the reduction viscosity change and solution color change. Those facts are important to understand the photo reaction of aromatic polyimides.

In addition, he studied the adhesive property of polyimides for the epoxy molding compound by examining the visco-elastic properties of various polyimides, and found that the β-relaxation temperature and strength of polyimide were the important factor for adhesion [15]. In addition, he contributed the polyimide molecular design for good adherence to the epoxy molding compounds.

In order to apply polyimide for new fields, he investigated to develop the positive-tone-photo definable polyimide with the high refractive index by dispersing TiO2 nano particles [16]. The high-refractive polyimide pattern is suitable for micro lens of the image sensors. Moreover, he and co-researchers developed the high-thermal-conductive-polyimide sheet which has extremely low interfacial heat resistance [17,18]. They developed low modulus polyimide to adhere well to substrate.

Finally, he reported that the application of an aromatic polyimide using as a binder resin of Li ion battery [19]. AIST researchers obtained stable and high-power-Li-ion battery by using this polyimide binder. The operation temperature range of the battery was from -50 to 125 °C due to good stability for the polyimide binder.

Recently, he focused on the low-dissipation-loss polyimide for 5G and millimeter radar applications from the view point of the molecular motion of the polyimide [20]. This work shows that the polyimide is able to apply at the high frequencies in molecular design. Those works show to enlarge the application fields in polyimides.

He is a pioneer of the photo definable polyimides not only from the view point of the industrial applications but also the basic studies.

His works were far ahead of its time and his contribution and originality are outstanding. With these achievements, the Outstanding Achievement
Award 2020 was presented to Dr. Masao Tomikawa.

References
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