The Photopolymer Science and Technology Award

The photopolymer Science and Technology Award No. 122200, the Best Paper Award 2012, was presented to Masuhiro Kogoma, Kazuo Takahashi and Kunihito Tanaka, (Sophia University) for their outstanding contribution published in Journal of Photopolymer Science and Technology, 24 (2011) 441, entitled “Improvement of Adhesive Strength of Polytetrafluoroethylene by Defluorination Treatment with Combination of Atmospheric Pressure Glow Plasma Treatment and Chemical Transport Method”

Masuhiro Kogoma is Professor of Department of Materials and Life Sciences, Faculty of Science and Technology, Sophia University. He received the B.Eng. in Tokyo Denki University in 1967 and M. Eng. degree in Sophia University in 1972. He received his Ph.D of Eng. from Sophia University in 1977. His major is plasma technology in material science. Currently, his research activity is focused in the atmospheric pressure glow discharge and that of the application to the surface treatment of the solid films and the powder. He has published over 60 peer-reviewed articles, book chapters, and holds more than 100 patents in this research area.

Kunihito Tanaka is Associate Professor of Department of Materials and Life Sciences, Faculty of Science and Technology, Sophia University. He received B.E., M.E., and Ph.D. degrees from Sophia University in 1993, 1995 and 2004, respectively. He is interested in Plasma Chemistry with the Atmospheric Pressure Glow Plasma technique using for many kinds of surface treatments and thin film depositions. He has published over 60 scientific papers and ten books, and holds 6 patents in this research area.

Kazuo Takahashi is Associate Professor of Department of Materials and Life Sciences, Faculty of Science and Technology, Sophia University. He received B.E., M.E., and Ph.D. degrees in Applied Chemistry (Industrial Physical Chemistry) from Sophia University in 1984, 1986, and 1989, respectively. He worked at Japan Atomic Energy Research Institute (JAERI) from 1989 to 1991. He stayed at the University of Duisburg, Germany as a Humboldt Scholarship Researcher between 1998 and 2000. He is interested in the kinetics and dynamics of fast gas-phase reactions in the high-energy fields such as plasma and combustion.
Fluorinated polymers have many unique characteristics: for example, high chemical resistance, high dielectric constant, high heat resistance and low coefficient of friction. They have already established a position as indispensable engineering plastics. Nevertheless, they suffer from a big problem: the difficulty of adhesion. Some agents, which contain metal sodium, are usually used for surface treatment to improve the adhesion. However, this treatment needs a large amount of cleaning water to eliminate the toxic materials and thus demands the disposal of much waste fluid. Moreover, the treated surfaces become blackish. Thus, a new dry process instead of the wet treatments had been desired. Several studies of fluorinated polymer surface treatment with low-pressure glow plasma were reported [1-2]. However, this method has not been widely used for industry because it is difficult to insert it into an assembly line.

The atmospheric pressure glow (APG) plasma technique was established by M. Kogoma and S. Okazaki in 1988[3]. It can generate spatially uniform plasma even at atmospheric pressure if only one uses a high frequency generator of more than 1 kHz, electrodes whose surfaces are covered with dielectric plates and a sample gas diluted with a large amount of helium gas [4-5]. The APG plasma discharge treatment was able to improve the adhesion strength between some kinds of the fluorinated polymer films and an epoxy glue[6-8]. But still we could not attain a peel strength value between (tetrafluoroethylene) (PTFE) and the epoxy glue that was high enough to meet industry requests. Because the strong chemical bond, the carbon atoms and fluorine atoms in the polymer chain cannot break by simple plasma treatment such as oxidation or Ar-CASING plasma[9]. So we needed a new idea to eliminate fluorine atom from the surface. We considered that the fluorine atoms generated through the dissociation of C-F bonds by the plasma needed to be changed into a gaseous compound by reacting with some reactants, and that the gaseous compound had to be removed from the polymer surface as fully as possible. Boron trifluoride (BF$_3$) is one of the gaseous fluorine compounds at room temperature; indeed, the bond enthalpy of fluorine with boron (757 kJ mol$^{-1}$) is bigger than that of fluorine with hydrogen or carbon (570 or 552 kJ mol$^{-1}$) [10]. In the plasma system, diborane (B$_2$H$_6$) should be the best boron source, since it is very easy to ignite and toxic gas. So we tried to examine the defluorination of PTFE by the combination of the diborane generation in H$_2$/He first plasma zone using boron metal electrode and the boron deposition on the PTFE surface in the second plasma zone. The two plasma zones are directly jointed. It is a kind of the Plasma Chemical Transport Method realized in the unique plasma system. After the de-fluorination treatment, the F/C of the PTFE surface was significantly decreased in the XPS spectrum and the high wettability was found on the treated surface [11]. Finally, by using this plasma system, we succeeded to produce a very high peeling force between treated PTFE surface and the glue, higher than 900 Nm$^{-1}$ which is much higher than the value requested in the industry[12].

As described above, Prof.M. Kogoma and his group has conducted fundamental research on the development of APG plasma and the applications to the plasma surface treatment. In particular, they succeeded in clearing the adhesion mechanism of the fluorinated polymers through their long-time research.

References

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