Radiation Application for Synthesis of Advanced Materials and the Related Research on Polymers

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The characteristic of radiation effect on organic materials is the ability to produce the active species for chemical reactions at any conditions, and the species are formed uniformly in the material. The application to polymers using the characteristic has been industrialized in the past two decades such as the curing of wire and cables, processing of polyethylene foam, curing of magnetic tapes and floppy, etc.

For the radiation application to advanced materials and the needs to evaluation of the radiation resistance for space and fusion reactor materials, we have studied the irradiation effects of polymers in the wide temperature range from very low temperature to high temperature under vacuum or oxygen free atmosphere.

The chemical reactions for polymers showed a rather large difference depending on irradiation temperature in quality and/or quantity. The dependence is though to be the difference in molecular motion of polymers during irradiation. The clear difference on irradiation temperature was observed for polytetrafluoroethylene(PTFE) and polystyrene(PS). PTFE has been classified to be the typical chain scission type, but it forms crosslinking by irradiation at high temperature(about 340°C) of the molten state. The radiation crosslinked PTFE showed much improvement in the mechanical properties and also the radiation resistance. So, this processing will be transferred to an industrial plant. For the case of PS, the crosslinking is predominant below the glass transition temperature(Tg), but changes to chain scission above Tg. For other polymers, the irradiation temperature effects are observed, which may be expanding to develop new products.

The newly developed technology in radiation application is the curing of polymer fiber as ceramic fiber precursor. The silicon carbide(SiC) fiber is synthesized from silicon containing polymer of polycarbosilane(PCS) fiber by the pyrolysis at high temperature of 1200°C or more. As the melting temperature of PCS is about 230°C, the fiber must be cured to not melt down during the pyrolysis. The purpose of this work was the radiation crosslinking of PCS fiber without oxygen contamination. The key point was the irradiation technique with exclusion of oxygen to irradiate high doses, because the dose needed for the crosslinking was more than 10MGy. The basic research was carried out using gamma-rays irradiation under vacuum, where the fundamental data were obtained such as the yield of active sites and the reactivity with oxygen and the decomposed gases. For the development of the processing technology, an electron accelerator was applied. The most of work was the development of electron beams(EB) irradiation vessel to irradiate uniformly excluding oxygen. By increasing EB current to shorten the irradiation time, the PCS fiber sample was heated by EB irradiation to result melting. So, the fiber was cooled by Helium gas flow during irradiation. Finally, the 5km long PCS fiber yarn composed of 500 filaments(20μm ϕ) was cured uniformly with exclusion of oxygen. The SiC fiber obtained from the radiation cured PCS fiber has a high tensile strength of 3GPa and high heat-resistance up to 1700°C. The heat resistance of SiC fiber obtained from ordinary processing is about 1200°C. This technology was transferred to a company and the product is supplied to the market. The silicon nitride(Si_3N_4) fiber was also synthesized from radiation cured PCS fiber by the pyrolysis in ammonia gas atmosphere.