Radiation-Induced Graft Copolymerization of Methacrylic Acid onto Polypropylene Fibers. V. Mechanical Properties

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Synopsis

Mechanical properties of polypropylene-*g*-poly(methacrylic acid) fibers, prepared by graft copolymerization of methacrylic acid onto polypropylene fiber using simultaneous gamma ray irradiation technique, were evaluated. In general, an improvement in the mechanical behavior of the polypropylene fiber by grafting was observed. Denier and initial modulus of the fiber showed a linear increase with the percent graft, and elongation showed an opposite trend. The results have been explained in terms of reinforcing effect of poly(methacrylic acid) grafts and reduction in the segmental mobility of the polymeric chains. Tenacity also increases up to certain graft level, beyond which a sharp decrease occurs, probably due to the influence on the compactness of the macromolecular chains with the further grafting.

INTRODUCTION

The physical properties of polypropylene are markedly affected by graft copolymerization of vinyl monomers.[1] However, very little has been reported on the mechanical properties of polypropylene graft copolymers.[2-5] Mechanical properties of a graft copolymer depend, largely on the number, size, location, and compatibility of the grafted moiety with the backbone polymer.[6] Jabloner and Mumma[7] have shown that the grafting of butyl acrylate results in considerable decrease in tensile properties.

The present investigation has been undertaken with the objective to evaluate the effect of the graft copolymerization of methacrylic acid onto polypropylene fiber.

EXPERIMENTAL

Polypropylene fibers with different percent graft were prepared by graft copolymerization of methacrylic acid, using simultaneous irradiation technique by gamma rays as reported earlier.[8,9]

The tensile properties of polypropylene graft copolymer fibers (PP-*g*-PMAA) were determined, using an Instron tensile tester. All the experiments were carried out using following specifications: guage length 4 cm; crosshead speed 10 cm/min; chart speed 50 cm/min; full scale load = 100 g. Fifteen tests were made on each fiber sample, and the average value is reported. From the stress–strain curve, denier, initial modulus, elongation, and tenacity were determined.

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RESULTS AND DISCUSSION

The dependence of denier, elongation, initial modulus, and tenacity on the graft level has been shown in Figures 1 and 2. It may be seen from the results that the mechanical properties of polypropylene fiber are, in general, improved by grafting of methacrylic acid. Initial modulus and denier increase with the increase in the percent graft. However, after reaching a maximum value at 21% graft level, tenacity shows a marked decrease with further grafting (Fig. 1). Denier of the fiber increases linearly with the increase in the graft content, which is essentially due to the increase in add-on percent of grafted PMAA onto original fibers.

Initial modulus of the fiber shows a linear increase with the increasing PMAA content in the fiber, while elongation shows a decreasing trend. Similar behavior has been reported in the polyethylene–styrene graft system.[10] In the present system, it appears that the increase in tensile properties of the fiber is the result of a composite effect of the PMAA grafts with polypropylene backbone and could be explained in terms of the decrease in the free volume and segmental mobility of the amorphous regions.

During grafting, PMAA grafts fill in the regions between the amorphous chains; this necessarily results in a decrease in the available free volume. PMAA, thus, may exert a reinforcing effect by acting as a filler and results in an overall improvement in the tensile properties. Kurilenko et al.[11] have also shown that in polyethylene-*g*-acrylonitrile films, polyacrylonitrile microstructures form a dispersed phase fulfilling the function of an active filler which essentially lowers the molecular mobility of polyethylene and enables the film to maintain its high strength.

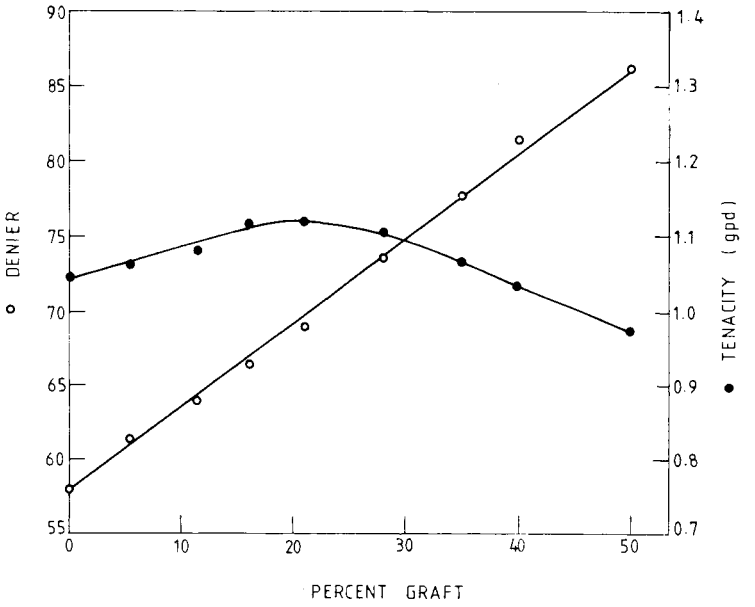

Fig. 1. Variation of denier and tenacity with percent graft in polypropylene-*g*-poly(methacrylic acid) fiber.

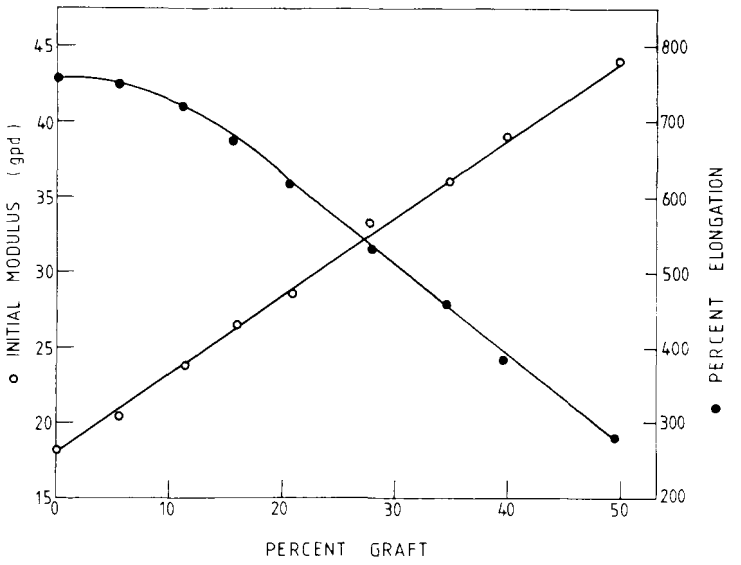

Fig. 2. Variation of initial modulus and elongation with percent graft in polypropylene-*g*-poly(methacrylic acid) fiber.

During graft copolymerization, free radicals are generated onto polypropylene backbone and these primary radicals thus initiate grafting.[8] Hence, the PMAA chains get attached to the polypropylene chains in the amorphous regions. The overall effect is the reduction in the mobility of the polymer chains, thereby resulting in a decrease in elongation, but an increase in the initial modulus of the fiber. Similar approach has also been made by Osipenko et al.[12] for polyethylene–acrylic acid system. An increase in the tensile strength and decrease in breaking elongation by grafting has been attributed to the decrease in the polyethylene segment mobility.

In the present system, tenacity increases only up to 21% graft level, beyond which a decreasing trend is observed. It seems that initially up to 21% graft level, the grafting is followed by compactness of the macromolecular chains. However, with the further grafting, the compactness of the chains is affected, which is evident from the previous studies involving density and diameter[13] and the result is reflected in the decrease in the tenacity despite the reinforcing effect of the grafted component.

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