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X-irradiation and the annealing behaviour of polyethylene

We would like to report the results of an experiment carried out to complement a more extensive study of the mechanisms of crystallite thickening during the annealing of solution-crystallized linear polyethylene (Rigidex 50) [1].

It is generally accepted that the X-ray dose received by a specimen during a typical diffraction exposure is insufficient to produce any evidence of damage in the form of gross structural changes such as a reduction in crystallinity. The principal mechanisms of energy absorption in the 10 kV range are photoelectric and Compton recoil, most of the structural effects being associated with molecular excitation and ionization by photo electrons. There is no evidence for a threshold dose below which no damage occurs [2], although the very small damage levels associated with low doses become difficult to detect. It must therefore be assumed that even the small doses and low dose rates associated with X-ray diffraction will produce some damage. In polyethylene for example such damage can be expected to take the form of a few isolated crosslinks.

We have considered the possibility that molecular mechanisms of chain sliding [3] and unlooping [4] already proposed to explain crystallite thickening might be sensitive to any scattered crosslinks introduced as a result of a diffraction exposure prior to annealing.

In an experiment designed to reveal any such effect the specimens of solution-crystallized polyethylene were irradiated for 8×10^4 sec in an uncollimated beam from a Mo X-ray tube operated at 30 kV 20 mA. The target–specimen distance was 14 cm, and the dose received by the specimen was estimated on the basis of some thermoluminescent dosimetry measurements to be in the region of 0.25 Mrad. This dose is between one and two orders of magnitude larger than that received by a specimen during a typical small angle diffraction exposure. The irradiated specimen was then annealed for 2 h alongside a standard and the

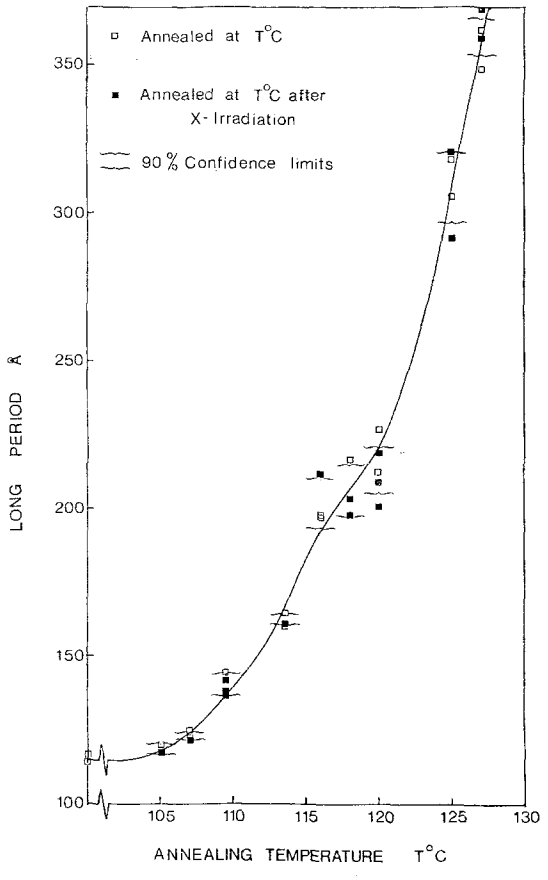

Figure 1 The effect of 2 h anneals on the long period of solution crystallized linear polyethylene specimens some of which had been previously exposed to X-rays.

increase in long period due to the anneal measured for each.

It is apparent from Fig. 1 that the irradiation has no detectable effect on the increase in long period due to annealing. In quantitative terms the ratios of the means of the irradiated and unirradiated long periods at each annealing temperature average out at 1.002.

An interesting feature of the curve is the slight "knee" apparent at a long period of approximately 200 Å. The error bars shown represent 90% confidence limits calculated from values of the standard deviation of the mean for each temperature. It is not possible to draw a curve of continuously increasing slope (i.e. without the "knee") within the bounds of these confidence limits.

The "knee" could be interpreted in terms of a doubling of the thickness of the crystallites associated with the operation of the chain unlooping mechanism.

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Poisson contraction effects in aligned fibre composites

The phenomenon of multiple cracking that is observed under certain conditions in fibre-reinforced brittle matrix composites has generated a great deal of interest in studies of fibre pull-out. The frictional force developed between the fibre and matrix resisting pull-out after debonding results in increased post-cracking strength and multiple fracture. The effect of Poisson contraction of the fibre and matrix before and after matrix cracking has been the subject of a recent letter by Kelly and Zweben [1]. A theoretical treatment considering composite behaviour in three dimensions has been performed in our laboratory and leads to conclusions very different from those of Kelly and Zweben. In this note the results of our investigation will be presented and the differences in the two treatments considered. The results will also be applied to a number of practical examples treated in the earlier paper.

Consider an ideal aligned continuous fibre composite consisting of fibres of radius r_f and Poisson's ratio ν_f arranged in a hexagonal or square array (Fig. 1). Each fibre is surrounded by a cylinder of matrix of radius r_m and Poisson's ratio ν_m. As pointed out by Kelly and Zweben and by Hill [2] in the absence of any matrix shrinkage in speci-

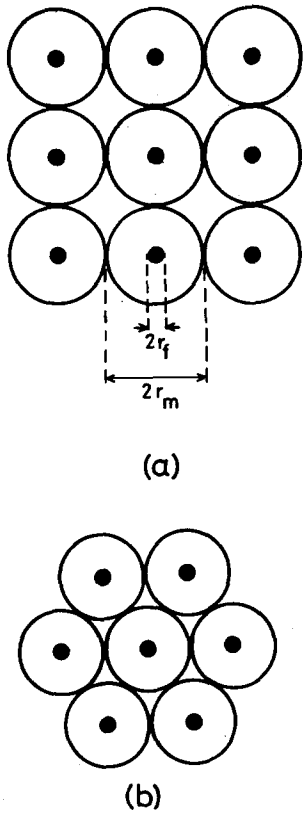

Figure 1 Idealized fibre arrays in composite: (a) square array, (b) hexagonal array. Larger circles (radius r_m) represent imaginary cylinders of matrix associated with each fibre.