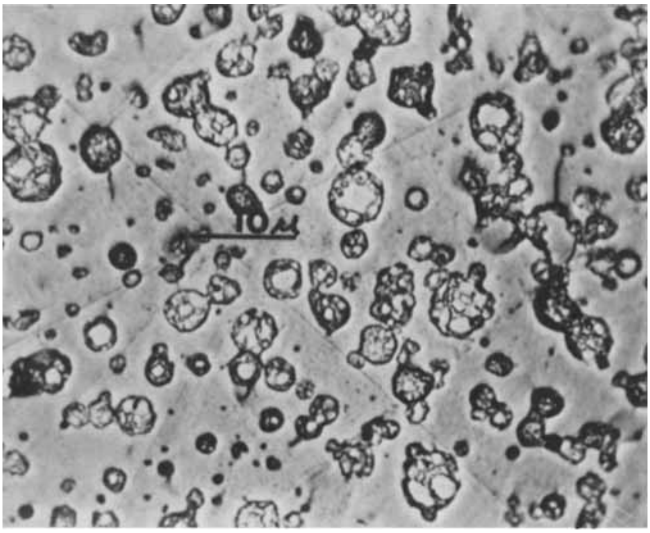
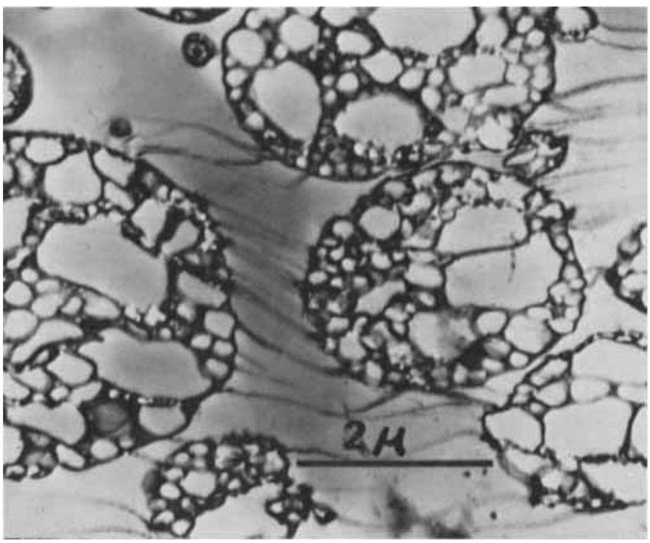
Metallographic Study of Crack Growth in an ABS Polymer

It was reported recently that the microstructure of poly(methyl methacrylate) containing inclusions of natural rubber could be studied by metallography following deposition of a thin layer of a reflecting metal. The technique was recommended for quantitative characterization of microphase structure and for its convenience in studying crack growth.[1] The purpose of the present note is to indicate the wide range of information conveniently obtained from the technique in a study of crack growth in an ABS (acrylonitrile–butadiene–styrene) polymer.



(a)



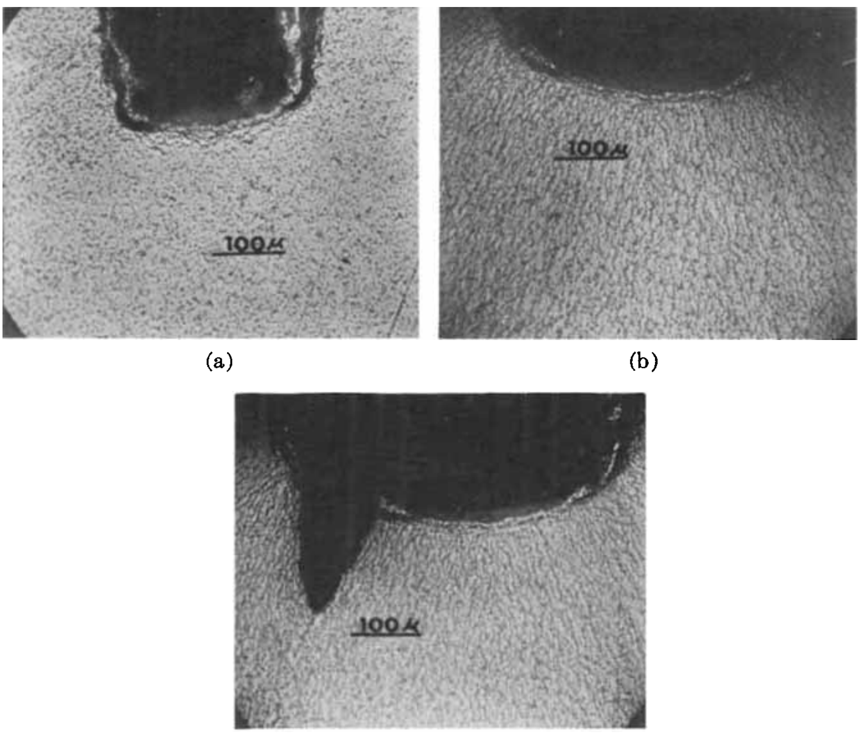
(b)

Fig. 1. Comparison of resolution of microstructure by metallography (a) and transmission electron microscopy (b).

A powder (ABS 213, Dow Chemical Company) was heated in a mold (diameter, 2.7 cm; thickness, 0.3 cm) at 180°C for 10 min and then pressed under 80 kg/cm^2 for an additional 10 min. The mold was maintained under pressure during cooling, at about 1°C/min, down to 50°C. The molded disc was removed and allowed to cool to room temperature. The surface of the disc was polished and covered with gold, of thickness approximately 200 Å, and viewed by reflected light in a Bausch and Lomb Research Metallograph. Cracks were formed by driving a wedge into a sawcut. Experimental details are given in reference 1. For comparison, electron micrographs were obtained by Kato's method.[2]

An example of the microstructure observed by use of the metallographic technique is shown in Figure 1a. For comparison, a micrograph obtained by transmission electron microscopy is shown in Figure 1b. In this latter figure, the lined features are artifacts (crazes) introduced during the preparation of thin films by microtoming. Electron microscopy is the superior technique for resolution of fine structure, but metallography is convenient for quantitative characterization of the microphase distribution because it provides a wide field of view of a surface. For example, superposition of a grid on a figure such as 1a and a count of the fraction of intersections lying on the microphase particles indicate that the volume fraction of the "rubber phase" particles[3] is 0.29. This estimate follows the convention of including in this fraction regions of styrene–acrylonitrile copolymer within the microphase particles.

A wide field view of the effect of driving a wedge into a sawcut in the material is shown in Figures 2a to 2c. These figures show that extensive crazing precedes crack forma-



(a) (b)

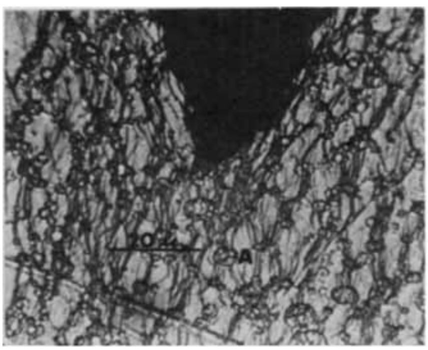
(c)

Fig. 2. View of sample (a) showing incidence of crazing after driving in wedge (b) with eventual crack formation (c).

tion. These observations are similar to ones previously reported for high-impact polystyrenes (HIPS) obtained by transmission optical microscopy studies of thin films during stretching.[4,5]

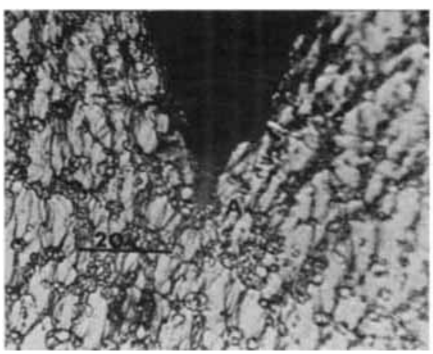
More detailed observations of the course of crack propagation in relation to microstructure are shown at higher magnification (Figs. 3a to 3c). One detail worthy of note is that the particle marked A may be seen to deform from a spherical shape to an elongated particle as it is brought into the stress field near the crack tip. It can also be shown to increase in volume, and hence it may be inferred that the rubber phase supports a considerably stress by resisting triaxial deformation. This observation, which is important in respect to the role of rubber in toughening glassy polymers, confirms previous work on both ABS and HIPS polymers by Matsuo. This author studied surface replicas of stretched samples by electron microscopy.[6]

A second detail of interest is that the crack tip usually cuts through the rubber phase particles transgranularly (Fig. 3c). Previously, intergranular fracture has appeared more common in both ABS and HIPS polymers.[7] Previous evidence for transgranular fracture seems to be limited to one exceptional case reported by Mann, Bird, and Rooney[8] in the course of an electron-microscopic examination of ABS samples fractured at −180°C. In these previous experiments, the polybutadiene starting material had been crosslinked prior to preparation of the ABS polymer. The high level of crosslinking and the low temperature of fracture would both serve to embrittle the rubber phase and so favor transgranular fracture.



(a)

(b)



(c)

Fig. 3. Higher resolution view of crack growth showing successive involvement (a,b,c) of a particle designated A.

In conclusion, evidence has been presented that metallography is a convenient technique for providing information about the relationship between crack propagation and microstructure in an ABS polymer. Other experiments, not reported here, show that the deposition of gold does not introduce artifacts and that similar results are obtained when the metal is deposited after deformation.[9]

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