SHORT COMMUNICATION

Application of the Acoustic Emission Technique to the Investigation of Fracture Processes in Glassy Polymers. II.

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It is well known that several materials produce acoustic sound during tensile testing. Detection of this sound provides information about the deformation and fracture process. The fracture mechanism of glassy polymers has been investigated using the acoustic emission (AE) technique and the microscopic observation in our laboratory. In the previous paper,¹ it was shown that AE could be detected from extruded poly(methyl methacrylate) (PMMA) (Comoglas, Kyowa Gas Chemical Industries Ltd.) immersed in alcohols (methanol and ethanol) when the craze zone grew in stepwise manner but not when it grew smoothly. In this study, we made tensile experiments on extruded PMMA immersed in various alcohols while observing AE and craze behavior, and also examined the fracture surfaces by an optical microscope.

A sheet of PMMA (Comoglas) was cut into tensile strip specimens (150 mm × 30 mm × 1 mm), and each of these was notched on one edge in the center of the strip. The strip was then set on an Instron tensile testing machine and immersed in an alcohol. A few minutes later, tensile strain (0.005 cm/min) was applied in an alcohol immersion condition. Detection of AE signals and observation of the craze zone were simultaneously performed by the use of the apparatus described in the previous paper. All experiments were carried out at room temperature (18—23°C). Alcohols used as the en-

vironmental agents were methanol, ethanol, 1-propanol, 2-propanol, 1-butanol, 1-pentanol, and 1-hexanol.

When the alcohol was changed from methanol to 1-hexanol, the manner of growth of the craze zone and AE behavior were strongly affected by this change. The alcohols used as environmental agents can be divided into two categories: Class A (1-hexanol, 1-pentanol, and methanol) and Class B (ethanol, 1-propanol, and 2-propanol). With alcohols belonging to Class A, the relatively curved craze zone grew smoothly and resulted in the formation of craze bundles (multiple crazing) as shown in Figure 1. It is well known^{2,3} that such a type of craze is produced when the interaction of environmental agents with the polymer is mild. Hence, alcohols belonging to Class A seem to act as mild environmental agents. No AE signals could be detected during the smooth craze zone growth. Finally, catastrophic fracture of the sample took place, accompanied by a very strong AE. Class B alcohols gave a rather sharp, straight craze zone which tended to grow in stepwise manner and produced an environmental crack in the craze zone of the sample. This suggests that Class B alcohols act as severe environmental agents. The craze zone profiles observed with Class B alcohols are shown in Figure 2. Strong AE signals could be recorded along with the stepwise growth of the craze zone.

Figure 1. Profiles of craze zone of PMMA in alcohol (Class A): (a), in methanol; (b), in 1-pentanol; (c), in 1-hexanol.

Figure 2. Profiles of craze zone of PMMA in alcohol (Class B): (a), in ethanol; (b), in 1-propanol; (c), in 2-propanol.

Table I. The results of tensile tests of PMMA in alcohol

	AE ^a	Load at breaking point kg	Maximum load kg	Elongation mm
Methanol	—	32.0	32.0	0.61
Ethanol	+	11.0	15.5	0.37
1-Propanol	+	17.0	21.0	0.49
2-Propanol	+	20.8	24.0	0.54
1-Butanol	+	34.6	34.6	0.68
1-Pentanol	—	49.5	49.5	0.85
1-Hexanol	—	55.2	55.2	1.0

^a +, AE detected; —, no AE detected.

Figure 3. Optical micrograph of surfaces of PMMA broken in alcohol (Class A). Crack propagation direction was left to right.

Figure 4. Optical micrograph of surfaces of PMMA broken in alcohol (Class B). Crack propagation direction was left to right.

Figure 5. Profile of craze zone (a) and fracture surface (b) of PMMA in 1-butanol.

It can also be observed that the load-elongation curves obtained in the experiments with Class B alcohols exhibit peaks, while those obtained in Class

A alcohols do not. The experimental results are summarized in Table I.

A remarkable difference in fracture appearance between Class A and Class B alcohols is observed when the fracture surfaces are examined by an optical microscope. Figure 3 shows rather featureless fracture surfaces in Class A alcohols. In contrast, the fracture surfaces in Class B alcohols have a characteristic shell patterns, as illustrated in

Figure 4. These shell patterns should be formed by a discontinuous growth process which favors AE, although the mechanism for this process is not yet understood.

1-Butanol showed an intermediate character between Class A and Class B alcohols. Tensile experiments with PMMA in 1-butanol produced detectable AE signals but the fracture surfaces had no definite shell-like appearance. The craze zone profile and the fracture surface in 1-butanol are shown in Figure 5.

The above observations show that

(1) Stepwise craze zone growth which produced AE took place in alcohols which act as severe environmental agents.

(2) With alcohols acting as mild environmental agents, the craze zone grew smoothly and AE was not detected.

(3) The fracture surfaces ruptured in alcohols acting as severe environmental agents have a characteristic shell pattern.

(4) The stepwise craze zone growth, the formation of shell pattern, and AE behavior seem to be correlated with each other.

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