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ORIGINS OF ACOUSTIC EMISSION IN THE FRACTURE OF GLASS PLATES

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INTRODUCTION

Stress waves are radiated from moving cracks and carry information about the fracture process. In many materials the waves are emitted in bursts and the frequency and amplitude of the bursts is related to the structure of the material [1,2,3,4].

Plate glass is relatively quiet during fracture compared with other ceramic materials. The rate of detection of acoustic pulses ($\dot{N}$) is about two orders of magnitude lower for the same crack velocity in glass as in a ceramic having a more heterogeneous structure [4]. The sources of acoustic emission in fracturing glass plates are at the surfaces. Abraded surfaces produce copious noise while as-manufactured surfaces are quiet.

The present study was undertaken to determine the relation between the size of a surface discontinuity in glass and the acoustic emission that it produced. Artificial two-dimensional microstructures were created on the glass surfaces and the acoustic emission from a crack passing through the microstructure at constant speed was measured.

EXPERIMENTAL PROCEDURE

Soda-lime silicate float glass plates 6 mm thick, were obtained from a local supplier. They were scored and broken into specimens 23 cm x 7.6 cm (9 in x 3 in). The specimens were then notched on one end on a diamond cutting wheel to aid in initiating a crack. They were loaded in the double torsion configuration [1] which has the feature that the crack opens on one face of the plate while the other face acts as a hinge. The artificial microstructure in the form of a series of parallel grooves, i.e., a grating, was scribed or etched upon the opening face of the plate.

An acoustic emission sensor was attached to the end of the plate in the same manner as that used by Evans and Linzer [1] and the ring-down counting method was used to record data [5]. In this method, pulses received by the transducer are amplified and those exceeding one volt are counted. Since the gain in the present experiments was always 95 db, the minimum signal counted was 17.7 μV. However counts obtained by one investigator are not directly comparable to counts obtained by others using different equipment or experimental parameters. Ways of dealing with this problem have been described recently [3].

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RESULTS

Figure 1 shows the total acoustic emission counts as a crack enters and leaves a region that had been abraded with 120 grit silicon carbide powder. By passing the crack from unabraded material through the abraded band and back into unabraded material it is easy to distinguish the effects due to abrasion from the background. The count rate depends upon the severity of the abrasion as shown in Figure 2 which by extrapolation also gives some indication of the acoustic emission from an unabraded surface. The latter is at the threshold of the detection method used.

Figure 1 also showed that when the abraded zone was etched in HF., the count rate was reduced. Microscopic examination revealed that the abraded surface contained many short cracks extending inward. Etching removed or blunted most of these cracks.

More regular gratings were produced by photo-resist etching or by scoring with a thin diamond saw. The first of these two methods had the advantage that no mechanical damage to the glass surface was produced. Figure 3 shows the fracture surface of a sawn grating. Hackle marks indicate the stable positions of the crack front as it passed through the grating. The sequence of events appears to be that the end of the crack is pinned at position A causing the crack to bow-out. It grows stably from A to B and then jumps unstably to the next pinned position at C. There is a small increase in load during the stable portion of growth and a drop in load accompanied by a burst of acoustic emission when the crack jumps ahead. Etching of the sawn gratings removes or blunts all of the cracks at the bottoms of the notches. The propagation of a crack through an etched-sawn grating follows the same sequence of events as in the unetched grating but there is much less acoustic emission as shown in Table 1. Thus the main source of acoustic emission from sawn gratings as from abraded surfaces is the intersection of the main crack with superficial cracks.

The photoresist-etched gratings of 50 μm depth produced significant and reproducible acoustic emission in spite of the absence of superficial cracks. Very shallow gratings (< 15 μm deep) made by this method did not produce acoustic emission. The fractured surface of a photo-resist grating is shown in Figure 4. Hackle marks are less easily seen on this surface but careful examination reveals the fracture sequence to be the same as in the sawn gratings.

DISCUSSION

There appear to be two ways in which acoustic emission can be produced when a crack passes through an elementary microstructure. One is by interaction with microcracks. Presumably these pin the main crack by blunting it. The local stress must increase before breakaway can occur. At breakaway the crack snaps forward locally at greater than the general crack velocity. Since the count rate and amplitude of emitted pulses both increase with increasing crack velocity [4], this could result in a pulse of acoustic emission. The size of the microcrack is of importance as indicated by the dependence of count rate upon the grit size of silicon carbide used in the abrasion. Thus a crack is a strong pinning point but it produces acoustic emission only if it is large enough to pin a significant length of the main crack.

Compared to cracks, the grooves produced by photoresist-etching and etched saw cuts are relatively weak pinning points. They do not oblige the main crack to undergo large changes in radius of curvature. Being large however they do interact with large segments of the crack. The greater acoustic emission resulting from 50 μm deep photoresist gratings than from 300 μm deep etched saw cuts appears to be due to the greater sharpness of the photoresist grating which results in stronger pinning.

CONCLUSIONS

Artificial microstructures can be created on the surface of glass plates. The interaction between these microstructures and moving cracks reveals that acoustic emission results from successive pinning and breakaway of the main crack. Microcracks and sharp grooves in the surface act as pinning points.

REFERENCES

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Table 1

Type of Grating	Depth of Notches μm	Width of Notches μm	Counts per Groove
Sawn	300	300	900
Sawn and Etched	300	300	10
Photoresist-etched	50	225	40
Photoresist-etched	10	80	Nil

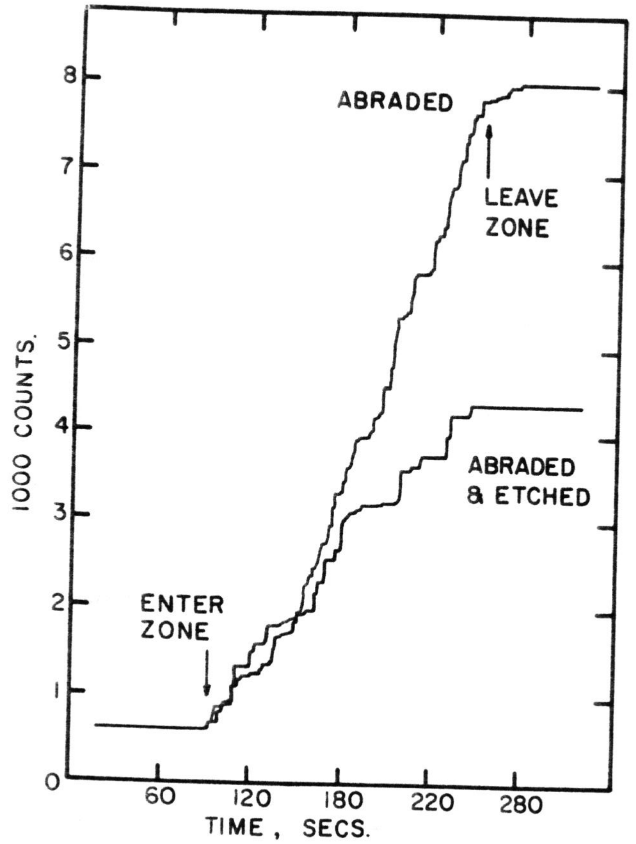

Figure 1 Crack Passes at 1.4 x 10^{-4} ms^{-1} Through SiC Abraded Zone

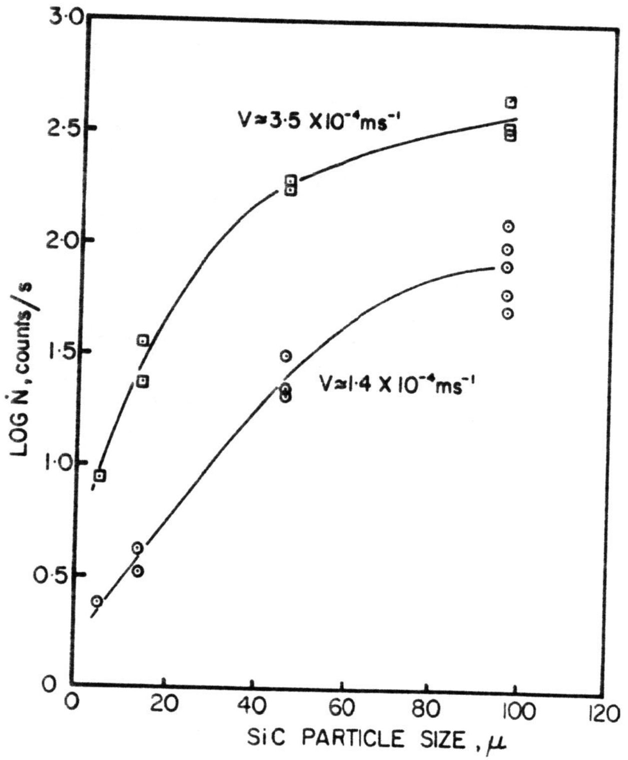

Figure 2 Effect of SiC Particle Size and Crack Velocity on Count Rate

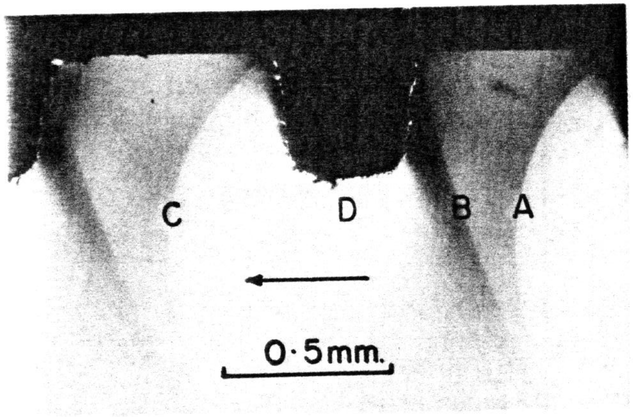

Figure 3 Sawn Grating. A and C are Pinned Positions. Notice Cracks at D.

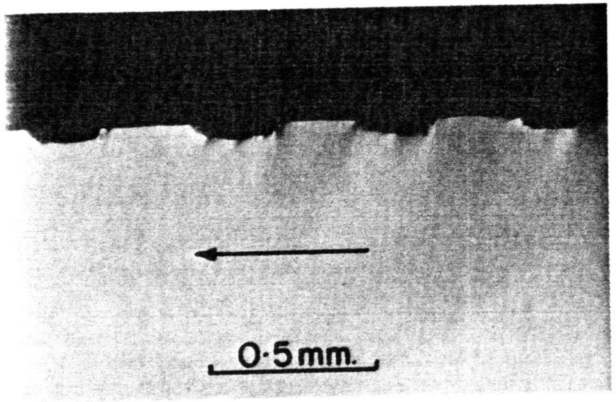

Figure 4 Photoresist Etched Grating.