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Electrical Output from Anodized Aluminium during Shock-wave Loading

WE have observed that a fast rising current pulse can be obtained from a thin layer of anodized aluminium when the layer is subjected to a plane shock wave. This effect has been observed over the pressure range of 5 to 220 kbar. A material which gives such an electrical response to a strong shock wave is of interest from both an experimental and a theoretical viewpoint, so a careful study is now being made of the response of anodized aluminium to strong shock waves.

In order to study the phenomenon, we are performing experiments in which an aluminium–anodize–metal sandwich is subjected to a shock wave from an explosive plane wave lens, and the current output is recorded on an oscilloscope terminated with a 50Ω load resistance. The peak amplitude of the current pulses increases from 0·005 A/cm² at stresses of 5 kbar to 2·5 A/cm² at stresses of 65 kbar in the aluminium substrate. At higher shock stresses the current amplitude decreases, falling to a value of 0·05 A/cm² at 220 kbar. The pulses have rise-times of the order of 10 ns and are approximately 100 ns in duration. The duration is determined by the decay time of the RC circuit rather than by the thickness of the layers. Two different commercially available aluminium alloys containing small amounts of Cu, Fe, Mn, Mg and Cr were anodized in sulphuric, chromic or oxalic acids to form layers 0·0005–0·005 cm thick. Similar electrical outputs were obtained in conditions of shock-wave loading for all samples. Samples of 99·9999 per cent pure aluminium which were anodized in sulphuric acid gave approximately one-third the output of the anodized alloys. This indicates that the electrical response is enhanced by the presence of one or more of the alloying elements.

There are three possible explanations for the electrical output from anodized aluminium. The first involves a migration of charge carriers across the shock-wave front similar to that observed by Ivanov[1]. The voltages observed in his experiments, however, were an order of magnitude smaller than our smallest signals, and therefore this mechanism could not account for the outputs obtained from anodized aluminium. The second explanation is that the electrical output is the result of shock-induced polarization similar to that observed in plastics[2] and alkali halides[3]. To check this possibility we subjected a sample of pure aluminium oxide ceramic 0·05 cm thick to a 65 kbar shock wave and obtained an output of 0·0008 A/cm². If we assume that this output from the

ceramic was the result of shock-induced polarization and therefore is inversely proportional to sample thickness, and if we assume that a polarization signal of the same order of magnitude can be obtained from anodized aluminium even though the structure of the two aluminium oxide materials is different, then we would expect a polarization signal of 0·008 A/cm^2 from a layer comparable in thickness with the anodized layers. This value is, however, almost three orders of magnitude too small to account for the observed outputs from anodized aluminium. The third possibility is that the anodized layers are piezoelectric. A very strong piezoelectric response was detected in the anodized layers with a marginal oscillator using a resonance absorption circuit described by Robinson[4]. In addition, the polarity of the electrical output depends on the direction of shock propagation through the anodized layer as is to be expected from a piezoelectric material. A piezoelectric response was also detected in the anodized powder after it was removed from the aluminium substrate. Al_2O_3 is not customarily considered to be piezoelectric because it lacks the proper symmetry. The large piezoelectric response from the anodized layers indicates that the layers contain an oxide form which is different from ordinary Al_2O_3. Further investigations are being made of the cause of the electrical response of anodized aluminium to strong shock waves.

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