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BARRIERS TO FLASHOVER DISCHARGE ARCS ON TEFLON*

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Abstract

The effect of various barriers (empty gap, copper, Mylar, and nickel mesh) on the probability of simultaneous arc discharging of two physically separated pieces of electron-beam-charged Teflon was studied. For the empty gap barrier, it was found that simultaneous discharges rarely occur when the separation between the samples is greater than approximately 0.4 times the length of their common edge when this length is of the order of 1 cm. Evidence suggests that electromagnetic fields play a larger role than electrons in influencing the occurrence of simultaneous arc discharges.

Introduction

Although numerous instances of anomalous spacecraft behaviour have been attributed to surface arc discharging of insulating materials[1], the mechanism by which these arcs initiate and propagate is still poorly understood. It is not yet clear what roles are played by electrons, ions and electromagnetic fields. Even more important from the applications point of view, it is not yet completely clear how arc initiation can be prevented, or once initiated, how the progress of an arc can be stopped by some form of barrier. Some successes in arc reduction have been achieved by applying conductive strips to the dielectric surface[2,3]. Also, it has been observed in our laboratory that arcs have occurred apparently simultaneously on two specimens of electron-irradiated dielectric sheet separated by a gap a few millimetres wide, and other experiments[4,5] on a second-surface mirror array indicated that an arc is not impeded by narrow gaps. This arc coupling indicates some form of "communication" across the gap, the nature of which might be determined by varying the gap width or by placing various selective barriers in the inter-sample gap and observing what type or size of barrier is capable of suppressing the coupling. Such a procedure is described below.

Experimental Procedure

The samples used in this experiment were all cut with the same orientation from a roll of 125 μm thick, silvered, spacecraft-grade Teflon. In preparation, each sample was cut transversely across the centre; the two halves then were wiped with a lens-cleaning tissue wetted with acetone and were placed with a barrier between them in a sample holder as shown in Fig.1. The samples were secured in place by one of two overlaid copper masks with aperture sizes of approximately 0.7 x 5.0 cm and 1.4 x 5.0 cm. Four different barrier types with varying dimensions were employed: empty gap, Mylar film, copper sheet and nickel mesh barriers. The latter three were vertically oriented and were 125, 500 and 30 μm thick respectively. The geometries of the empty gap and copper sheet barriers are shown in Fig.2. The geometry of the Mylar and mesh barriers was similar to the copper except they were not doubled by folding; rather they were bent in an "L" shape and slipped under one sample half and an extra piece of barrier material was placed as a shim under the other sample half. The nickel mesh had been electroformed in a square array measuring 0.1 mm to a side, with a transparency of 60%. For these vertical barriers, the sample halves were butted next to the barrier on either side and only the narrow aperture mask was used. In the case of the empty gap barrier, sample width dependence was checked by using both the narrow and wide aperture sizes.

The Teflon was irradiated in a vacuum of approximately 7 μtorr by a 20 keV electron beam at a current density of 100 nA cm^{-2} $\pm$ 35% (including spatial and temporal variations). The subsequent discharge arcs were observed visually and categorized as occurring on one sample half alone or on both halves "simultaneously" within the time resolution of the observer's eye. In addition some observations were made with optical fibre detectors: it was found that visually simultaneous arcs occurred within a few nanoseconds of each other and that the discharges on either sample half propagated away from the barrier. The latter fact suggests that any particles directed toward the barrier would have to be electrons[6,7]. It is for this reason that, in the discussion to follow, the solid barriers are referred to as screening electrons rather than screening particles in general.

Results

For each sample the number of discharges occurring on both surfaces at once was expressed as a percent of that sample's total number of discharges. This figure, called the % occurrence of coupled arcs, gives a measure of the degree of coupling permitted by the barrier under inspection. The percent occurrences of coupled arcs for the various barriers investigated are shown in Figs.3 to 7 for the narrow aperture gap, the wide aperture gap and the copper, Mylar and nickel mesh barriers respectively. Each round dot is a datum obtained from a single sample which typically discharged 25 times (anywhere from 5 to 170 times), and the squares are the averages of the values represented by dots. The barrier heights are measured with respect to the metallized rear surface of the Teflon samples, i.e., a barrier height of zero corresponds to an empty gap.

Interpretation

The trend of the empty gap measurements is that the coupling decreases in an exponential-like fashion with increasing gap width. The gap width at which the coupling falls to 5% is 2.5 and 5.0 mm for the 7 and 14 mm wide samples respectively which suggests that, for samples of this size, the 5% gap width W is directly proportional to the length of the adjacent sample edges L (mask aperture width), such that $W \simeq 0.4$ L.

The metal barriers should act as partial screens against electromagnetic fields in the vicinity of the ends of the sample halves. These fields are thought to be quasi-static because evidence from discharge current pulse shapes[8] suggests that the pulse spectral distributions would have maxima in the 1 to 100 MHz region, meaning that the time scale is slow compared with the propagation time of an electromagnetic wave over distances of the order of the barrier height. In other words, the pertinent wavelengths would be much greater than the barrier dimensions. Of the three vertical

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barriers the solid copper one (Fig.5) is the most effective, eliminating the coupling entirely at a height of 0.7 mm (5 sample thicknesses) and letting past only one discharge out of 44 at 1.1 mm.

Now consider Figs.6 and 7 for Mylar and mesh barriers. At low barrier heights the mesh barrier is more effective than the Mylar barrier. Because the mesh barrier screens fields but not electrons it may be postulated that the fields play a much larger role than do the electrons, in initiating discharges on the adjacent specimen. As the mesh barrier height increases, the % occurrence levels off at 20%, indicating that this small degree of coupling may be caused by electrons passing through the mesh.

At greater heights the Mylar appears to be more effective. The reason is probably that the higher Mylar barriers themselves become charged and so deflect the incident electron beam, thus creating in effect "gap" barriers consisting of narrow uncharged regions on the sample surface on both sides of the barrier.

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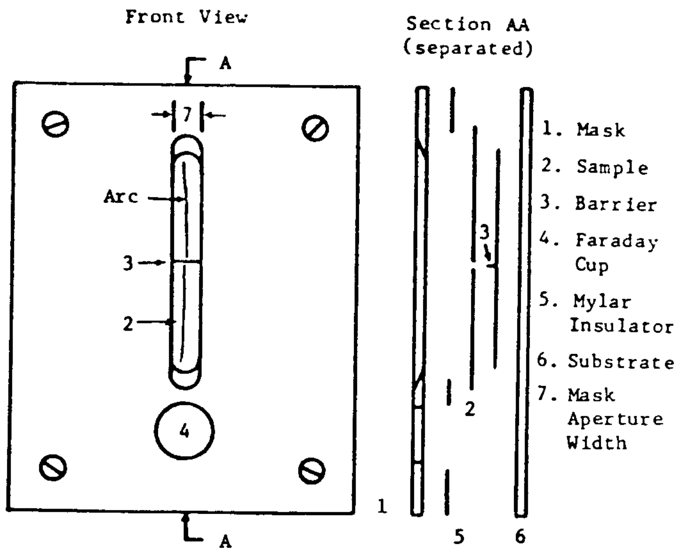

Fig.1 The sample holder showing the mounting of the sample and the barriers.

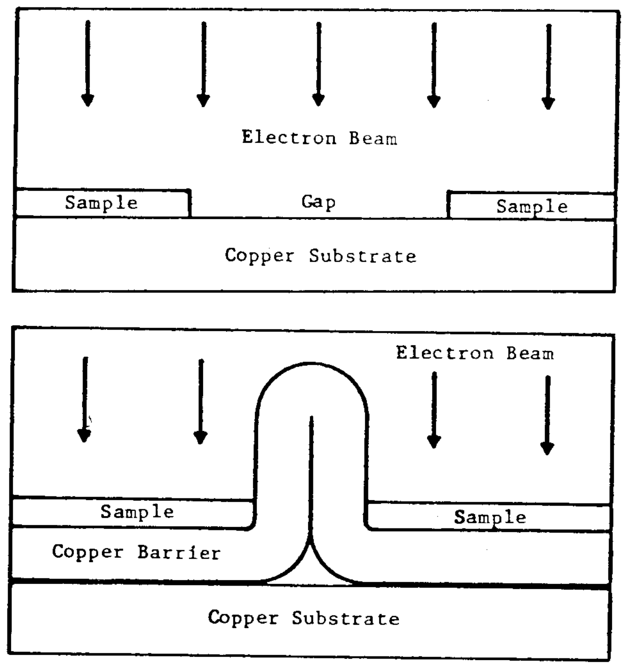

Fig.2 Cross sections (A-A in Fig.1) showing the gap and copper barriers.

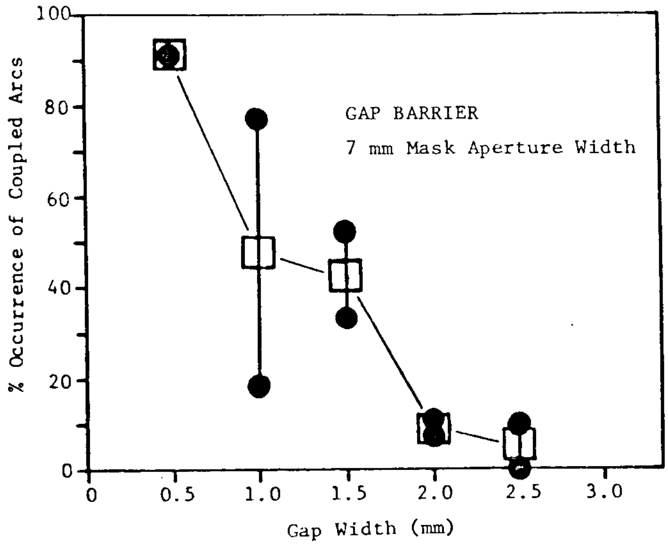

Fig.3 Empty gap barrier effectiveness as measured by the percent occurrence of coupled arcs. The mask aperture width is 7 mm. Note that the gap width at 5% occurrence is about 40% of aperture width.

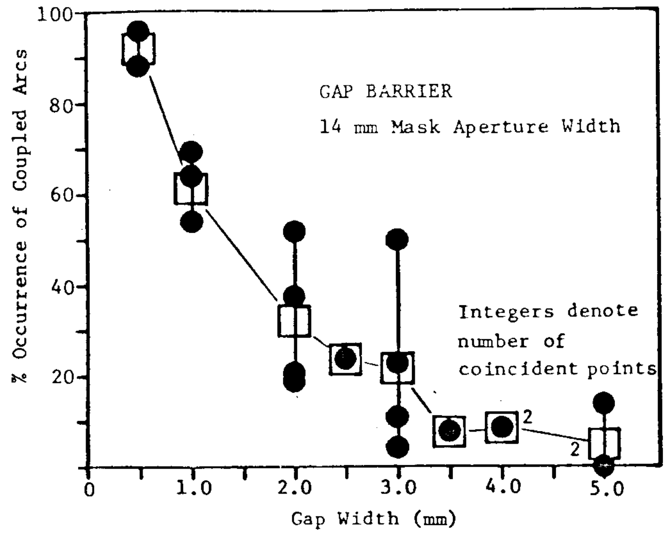

Fig.4 As in Fig.3 with a mask aperture width of 14 mm. Note difference in horizontal scale. Note also that the gap width at 5% occurrence is still about 40% of the aperture width.

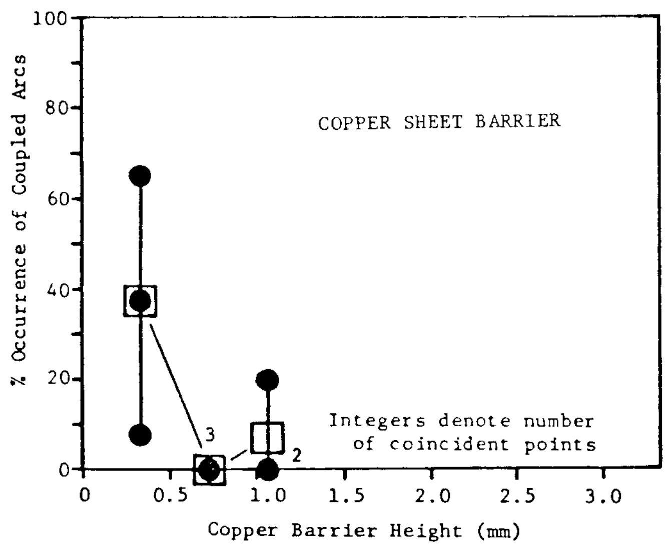

Fig.5 Copper sheet barrier effectiveness as measured by the percent occurrence of coupled arcs.

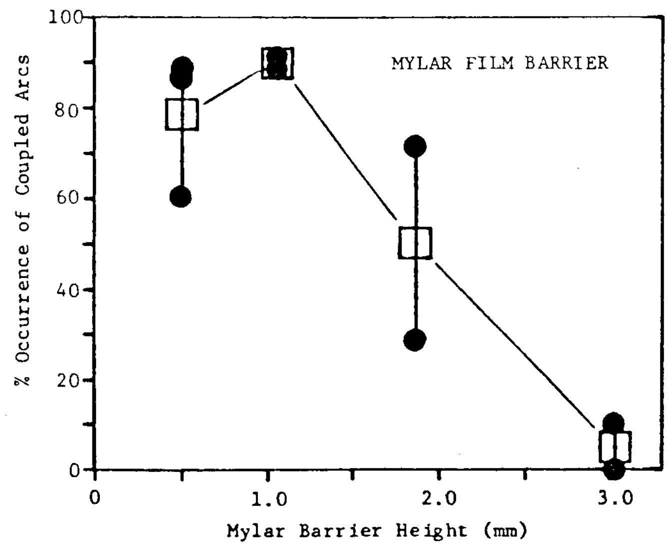

Fig.6 Mylar barrier effectiveness as measured by the percent occurrence of coupled arcs.

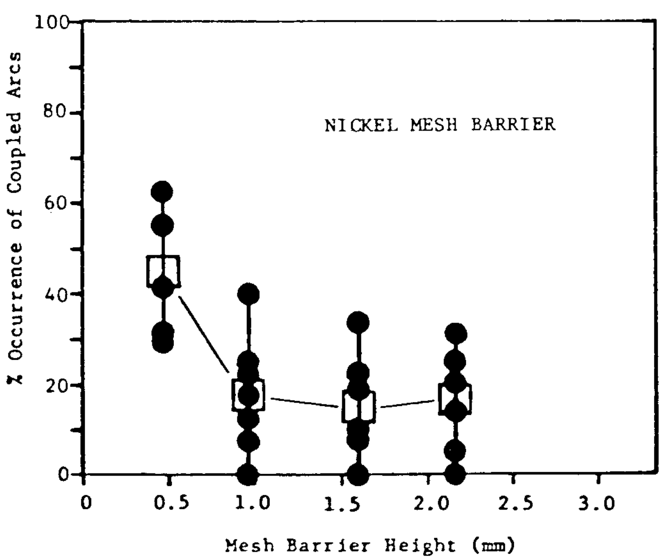

Fig.7 Nickel mesh barrier effectiveness as measured by the percent occurrence of coupled arcs.