TREND ANALYSIS OF CONTROLLED THIN METALLIZATION FLASHOVER

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Abstract

Tests validating the consistency and repeatability of controlled electrical surface flashover on metallized thin film insulators were performed. The study of electrical surface flashover has been mainly confined to its prevention under various contaminated conditions such as ice. The experiments discussed in this paper have gone in the opposite direction. The focus of the experiments was not to prevent surface flashover, but to enhance it, control its path, and control its intensity. This was achieved by selecting an insulator with an extremely contaminated surface. The insulator chosen was polypropylene film coated with a conducting surface composed of metallized aluminum. The surface of the polypropylene film was put under a pulse capacitive discharge of 2500 V_{dc}. Results have shown that a controlled flashover is achievable and repeatable. The trends discussed in the paper show promise for novel low energy light sources.

I. INTRODUCTION

Surface flashover is a phenomenon in which electrical arcing occurs on the surface of a material. In this particular instance, plasma is being generated on the surface of a metallized polypropylene film strip as seen in Figure 1. Many investigations have been performed to better understand flashover and its mode of propagation on insulating surfaces such as ice, vacuum and air [1]. However, the focus of this research was to control the path and intensity of the flashover on a metallized polypropylene film. “Bottlenecks” were introduced on the metallized surface of the film to control the path of the current through the film and likewise increase the possibilities of generating a surface discharge within the bottleneck region. Photodiodes were used to measure the light intensity within the bottleneck region. Series of tests were conducted to validate the consistency and repeatability of the controlled electric surface flashover. This research will aid in developing a new low energy fuze for the ignition of energetic materials.

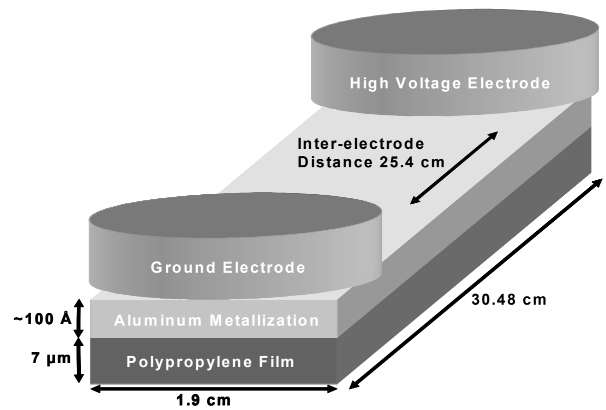

Figure 1. Surface flashover experimental setup

II. EXPERIMENTAL SETUP

The film sample used for these experiments was metallized polypropylene film. The film was approximately 7 microns thick and the aluminum metallization on the film was roughly 85 to 100 angstroms thick. The dimensions of the film samples were ¾” by 12”. Four bottlenecks were created in series on the film sample, running along its length at even intervals as seen in Figure 2. Two photodiodes were used to measure the light intensity in the infrared spectrum at the bottlenecks. The magnitude of the intensity of the photodiodes was a relative measurement and was not representative of actual lumens measured. The power source used was solid state, and utilizes a capacitive discharge through an NMOS controlled thyristor to dump its charge into the sample. The current monitor used was a Pearson type 411. It measures 0.1 Volts/Ampere. The voltage probe used was a Tektronix P6015 with an attenuation ratio of 1000:1 (i.e. 1000V = 1V).

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14. ABSTRACT
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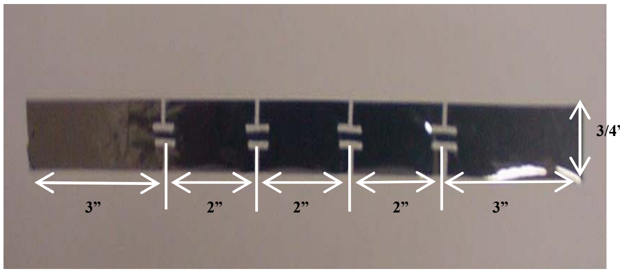

Figure 2. ¾” X 12” polypropylene sample

III. RESULTS

Some factors have been employed to ensure consistency and repeatability of controlled flashover. These include the intensity of the surface flashover in the infrared spectrum, current through the film sample, time duration of the current flow and time duration of the flashover as recorded from the infrared photodiodes.

A. PN junction photodiodes

The intensity of the surface flashover was measured with PN junction photodiodes as seen in Figure 3. The magnitude of the light measurement was on a relative scale and was used in comparing the infrared light intensity between each iteration of the experiment only. The photodiodes serve more as a qualitative measure than quantitative. PN junction photodiodes were used because of their characteristics. They posses a fast intrinsic rise time (approximately 1ns) and wide spectral bandwidths (400nm – 1200nm). They can handle high average optical input powers with excellent linearity, low distortion, and low polarization dependence loss, making them ideal for a transient high speed photometry [2].

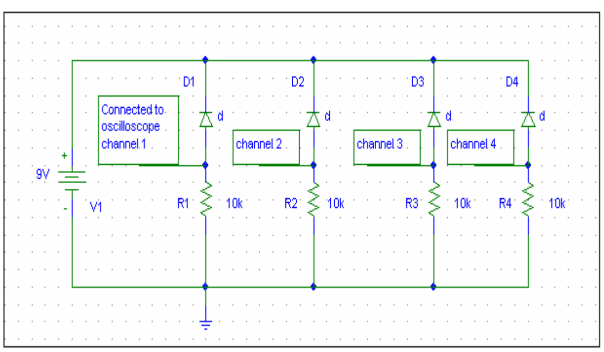

Figure 3. Schematics of PN photodiode configuration

B. Current and time signature

Current signature through film samples in conjunction with their time duration was measured via a Pearson type 411 current monitor and an oscilloscope. This made it possible to compare and contrast current through samples. The average time duration measured was 161.2µs ± 40µs for samples with bottlenecks and 200µs ± 50µs for samples without bottlenecks. The average peak current measured for samples with bottlenecks was 8.45A ± 0.05A and 16.4A ± 0.7A for samples without bottlenecks. Hence, samples with bottlenecks had a shorter event time duration as well as nearly half the magnitude of the current. For all the geometry tested, it was observed that the current was consistent as illustrated in Figure 4.

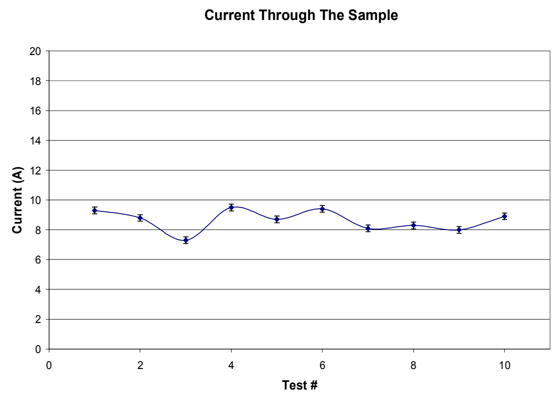

Figure 4. Average current of sample tested

C. Bottleneck size vs. flashover intensity

Provided that the bottleneck widths on the film samples were not always consistent, the correlation between the bottleneck size and flashover intensity was considered. The following was observed after performing several experiments on film samples;

- Photo diode D1 placed over bottleneck with an average gap size of 0.11″ showed average peak voltage of 3.81V.
- Photo diode D2 placed over bottleneck with an average gap size of 0.11″ showed average peak voltage of 2.60V.
- Photo diode D3 placed over bottleneck with an average gap size of 0.10″ showed average peak voltage of 2.02V.
- Photo diode D4 placed over bottleneck with an average gap size of 0.16 inch showed average peak voltage of 1.70V.

As seen in Figure 5, surface discharge that occurred at the bottlenecks closest to the positive electrode have a higher intensity than the surface discharge that occurred at the bottlenecks closest to the negative electrode, regardless of the gap size.

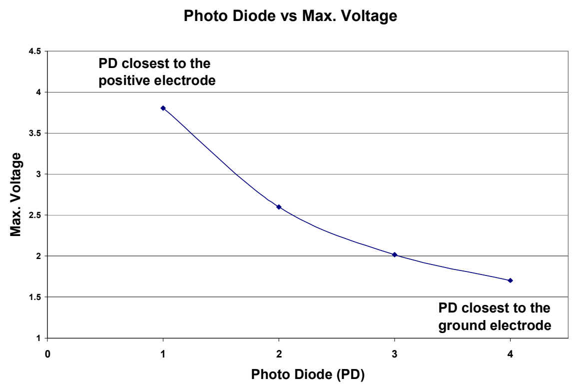

Figure 5. Light intensity at the bottlenecks

D. Ambient light attenuation

To further ensure consistency and repeatability of controlled flashover, hollow plastic tubes were incorporated into the flashover setup (Figure 6 and 7) to attenuate ambient light. The tubes were placed approximately ¼" above the bottlenecks to decrease the field of view of the photodiodes. Several experiments were performed on samples to determine the effect of the tube setup. The results of the tests are tabulated in Table 1, showing a contrast between samples with tube apparatus and non-tube apparatus. The effectiveness of the tube setup is seen in the lowered voltage reading of the photodiode in experiments with the tube apparatus.

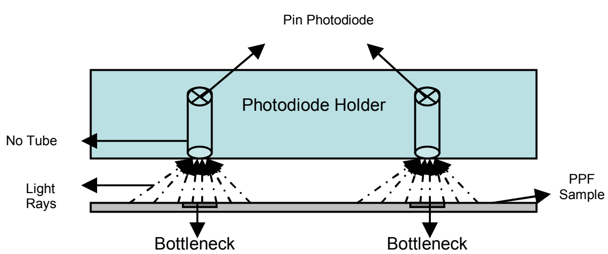

Figure 6. Photodiode setup without tube apparatus

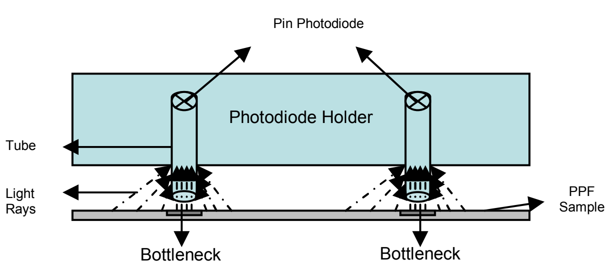

Figure 7. Photodiode setup with tube apparatus

Table 1. Tube vs. non tube test results

	Avg. Diode voltage without tube (V)	Avg. Diode voltage with tube (V)
Negative Electrode	4.68	4.11
Positive Electrode	5.26	4.65

E. Voltage scaling

The input voltage was scaled down to 800V. The average time measured for samples was 40µs ± 30µs and the average peak current measured for 1.12A ± 0.57A. At 800V, flashover only occurred at the bottlenecks. This is significant because it increases control over the precise location where the flashover will occur and where the energy is delivered. Moreover, there is a reduced amount of current and lowered time duration in the system. Energy is the time integral of voltage multiplied by current. As a result, the amount of energy required in the system is reduced which is essential for a low energy fuze for the ignition of energetic materials.

V. CONCLUSION

PN junction photodiodes were used to detect flashover on a metallized film with and without bottlenecks. This creates an avenue to compare infrared intensity between each iteration of experiment. Experiments have shown that samples with bottlenecks have shorter event time duration with nearly half the current flow of a sample with no bottleneck. Flashover intensity at the bottleneck closest to the positive electrode is higher regardless of the size of the bottleneck. Also, the location of the flashover can be localized to the bottlenecks through voltage scaling. As a result, a controlled flashover is achievable and repeatable.

The next consideration is the attempt to completely attenuate ambient light and ensure consistency and repeatability of flashover, using the tube apparatus at 800V.

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