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PULSE-SENSITIVE ELECTROEXPLOSIVE DEVICES

Monthly Progress Report for January 1963

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Naval Weapons Laboratory
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PULSE-SENSITIVE ELECTROEXPLOSIVE DEVICES

1. INTRODUCTION

This is the seventh monthly progress report of the program to study the behavior of electrically pulsed metal films on substrates of high thermal conductivity. Phase I is the feasibility and process development study.

2. OBJECT

The object of this program is to investigate the behavior of a metallic film when it is electrically heated and is in physical contact with a heat sink. Specifically, the aim is to study the variable parameters and to develop a manufacturing process or processes for applying a bridge heating element to a ceramic surface with the required thermal contact.

3. WORK PERFORMED DURING JANUARY

3.1 TECHNICAL CONFERENCES

Mr. K. Boyd of the Naval Weapons Laboratory visited Aerojet-General Corporation on 9 January 1963 to observe and discuss program technical progress. The preliminary results of an informative mathematical study of an idealized beryllium oxide (BeO) heat sink-film bridge system was given to Aerojet-General personnel and discussed. This is a mathematical analysis which indicates the effects to be expected when the physical parameters are varied.

3.2 TEST EQUIPMENT

The BeO header units that were ordered have not been delivered. The use of beryllium oxide of high density and purity is relatively new, and difficulty was encountered in locating a vendor to supply headers of this material. The original concept was to make use of BeO transistor heat sink wafers. This was found to be impractical because identical physical

size glass units are necessary for comparative purposes. Delivery of the BeO headers was first expected in the latter part of December. Early in December Aerojet-General was advised that technical problems had arisen and the headers would not be delivered until the middle of January 1963. Further delays have now placed delivery on 19 February 1963.

The tools for explosive loading of the test units are in work. Plans are being made for test firing of explosively loaded BeO units and the protection of personnel from the possible toxicity problem of airborne BeO dust particles.

3.3 FILM DEPOSITION

Gold and aluminum films have been deposited on glass headers during this period. Efforts were made to obtain a deposited film bridge of 0.1 ohm. The problem of film burnout around the edge of the connecting pins has been overcome by depositing more metal in this area.

3.3.1 Gold Films

Sixteen glass header units were cleaned with isopropyl alcohol in an ultrasonic cleaner. On each of these units the central region between the connecting pins was masked by placing a 0.020-in.-diameter aluminum wire across the header. The units were then placed in the vacuum system and a gold film deposited on them. The headers were taken from the vacuum system, the masking wire removed, and they were then returned to receive an additional gold deposit over the whole surface. The first deposit was calculated to have a thickness of about 0.4 micron; the second deposit over the entire surface was half the first, or 0.2 micron. This provided a total deposit of gold on the connecting pins of approximately 0.6 micron thick and a region approximately 0.020 in. wide between pins 0.2 micron thick. The deposit was then cut to form a connecting bar between pins as shown in the microphotographs.

3.3.2 Aluminum Films

Ten additional units were cleaned and given similar deposits of aluminum. A mask with a rectangular hole was used for the aluminum deposits because of the difficulty in removing the aluminum from the glass surface

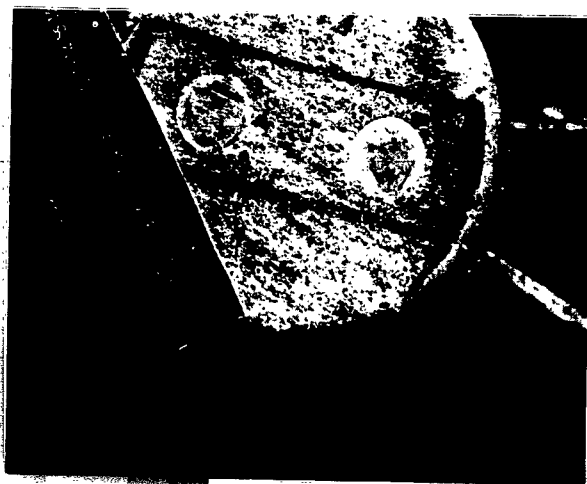
to form the conducting bar between the connecting pins. The calculated deposit thickness for the aluminum is 0.9 micron for both the first and second deposits. Because of the tendency of the molten aluminum to wet and flow on the heated filament boat, an unknown amount of the aluminum flowed over the edge of the evaporating boat and was deposited in the lower portion of the chamber. The metal deposit on the headers is therefore somewhat less than the calculated thickness.

3.4 HEATING TESTS

3.4.1 Pulse Heating

The glass headers with the gold and aluminum films were tested by discharging a 1- μ f capacitor charged to various voltage levels through the film until burnout was obtained. The data on film burnout are presented in Table 1 for gold films and in Table 2 for aluminum films. Table 1 also includes the data for 0.002-in.-diameter gold and for 90/10 platinum/iridium wires. Figures 1 and 2 are microphotographs of gold film samples 5-G and 6-G showing burnout in the central thin film area.

The aluminum films with an original resistance of about 0.1 ohm, when pulsed with a pulse below that required for film burnout, resulted in a drop in the film bridge resistance. When the films were observed in a darkened room while the sublevel pulses were applied, a minute flash or arc could sometimes be observed. The resistance change and observed flashes would indicate that the aluminum film is not continuous and homogeneous. This may be due to the formation of aluminum oxide from the small amount of residual gas in the vacuum chamber or to surface oxidation of the first deposit when the central mask is removed. The aluminum films do adhere extremely well to the glass surface, and it is very difficult to remove all of the aluminum from the surface by scraping with a knife. The small flashes of light (arcing) and change in resistance must be avoided for safety and reliability reasons in electro-explosive devices. This may be overcome with extensive development of films deposited at very high vacuums and with remote control of masks within the vacuum system. Presently, it seems more economically sound to pursue the work with gold films.



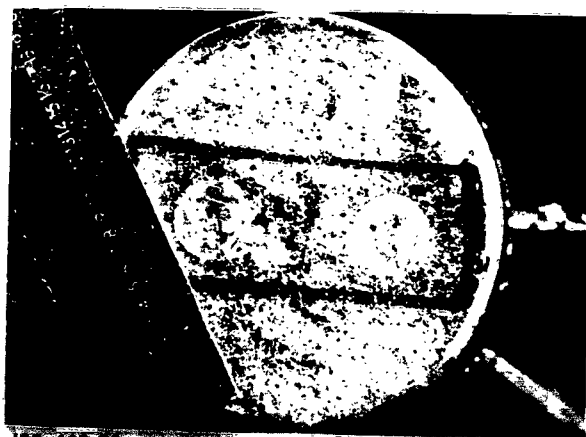
163-405-23

BEFORE PULSE



163-405-25

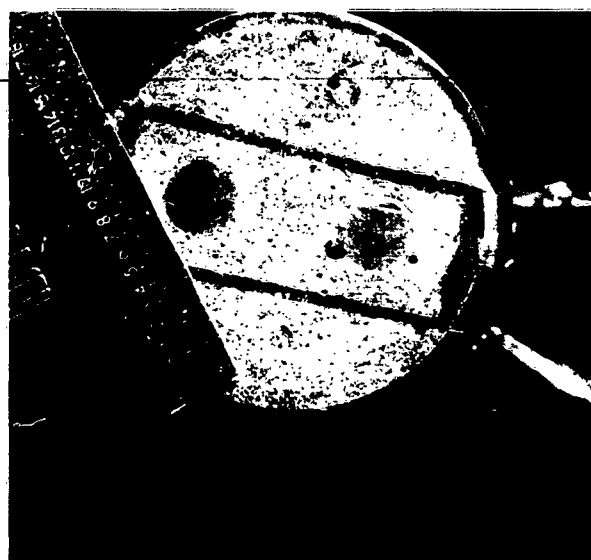
DURING PULSE



163-405-26
2125-7-1-1

AFTER PULSE

Figure 1. Gold Film Sample 5-G (Scale: 5 mils/division).



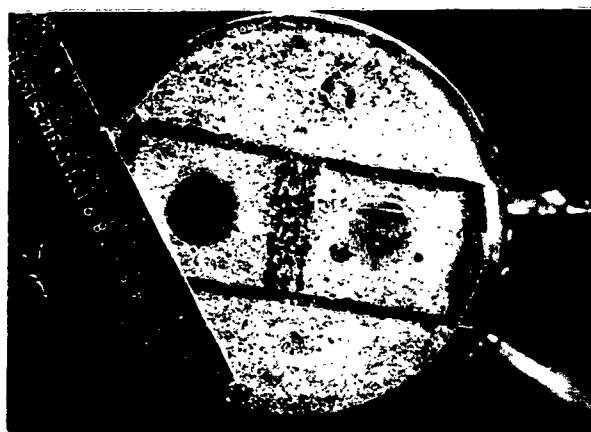
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BEFORE PULSE



163-405-9

DURING PULSE



163-405-10
2129-7-2-1

AFTER PULSE

Figure 2. Gold Film Sample 6-G (Scale: 5 mils/division).

Table 1. Gold Films.

<u>Sample</u>	<u>Film Width (mils)</u>	<u>Initial Resistance (ohm)</u>	<u>Capacitor Voltage (v)</u>	<u>Peak Current (amp)</u>	<u>Time to Peak I (μsec)</u>
1-G	61	0.15	72	45	0.7
2-G	70	0.10	95	74	0.8
3-G	62	0.10	95	-	-
4-G	63	0.10	72	50	1.3
5-G	62	0.20	72	38	0.7
6-G	67	0.10	119	90	0.7
Gold Wire	2 dia	0.03	400	500	1.5
Pt/Ir (90/10) Wire	2 dia	0.08	305	300	0.5

Table 2. Aluminum Films.

<u>Sample</u>	<u>Film Width (mils)</u>	<u>Initial Resistance (ohm)</u>	<u>Capacitor Voltage (v)</u>	<u>Peak Current (amp)</u>	<u>Time to Peak I (μsec)</u>
7-A	102	0.1	380	375	1.0
8-A	95	0.1	380	380	0.8
9-A	97	0.13	388	390	1.0
10-A	110	0.1	351	360	1.2
15-A	96	0.15	294	400	1.0

3.4.2 Steady Current Heating

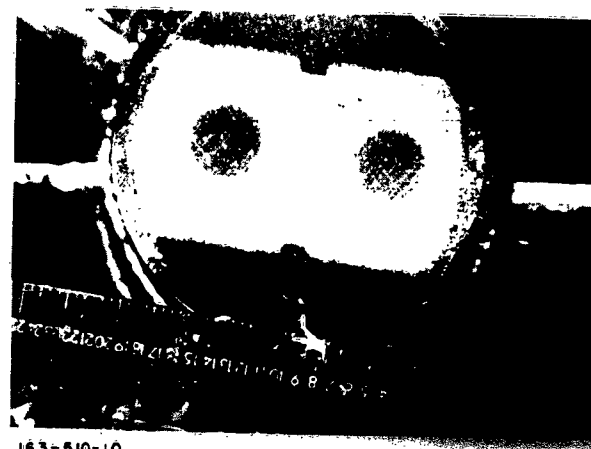
A limited number of tests were performed by gradually increasing the current from a 12-v storage battery through the deposited films. A summary of these tests is presented in Table 3.

Figures 3 and 4 are microphotographs of aluminum film samples 8-A and 9-A, also showing the area of film burnout.

Table 3. Steady Current Tests.

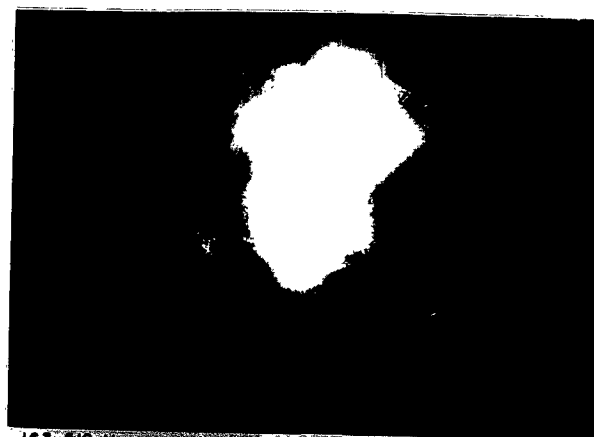
Sample	Type Film	Film Width (mils)	Initial Resistance (ohm)	Resistance at Burnout (ohm)	Current at Burnout (amp)	Heat Sink
11-A	Al	100	0.090	0.130	6.8	Yes
12-A	Al	97	0.187	0.200	6.0	Yes
16-A	Al	102	-	-	4.9	No
7-G	Au	72	0.10	-	3.5	Yes
8-G	Au	65	0.13	-	3.0	Yes

The heat sink consisted of a 1-1/2-in.-wide strip of 1/16-in.-thick aluminum about 12 in. long. The header units were placed in a hole at the center of the strip. The strip was bent into a "U" shape and attached to a camera so as to place the unit at the proper distance and location for the microphotographs of the header surface (Figures 1, 2, 3, and 4). In the limited steady current tests performed, no satisfactory film resistance change measurements were obtained. The entire header with an aluminum film not in a heat sink becomes too hot to touch when a current of 2.5 amp is passed through it for 3 min.



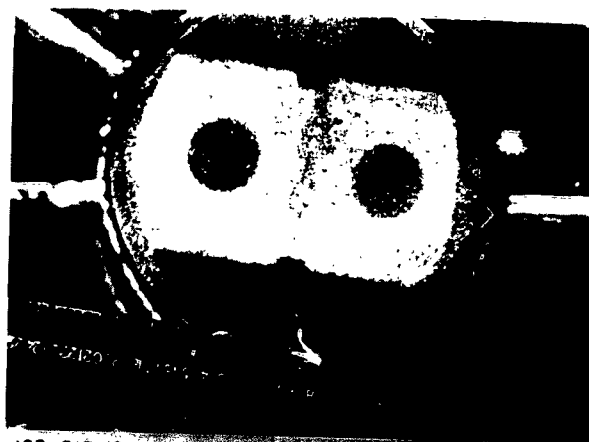
163-510-10

BEFORE PULSE



163-510-11

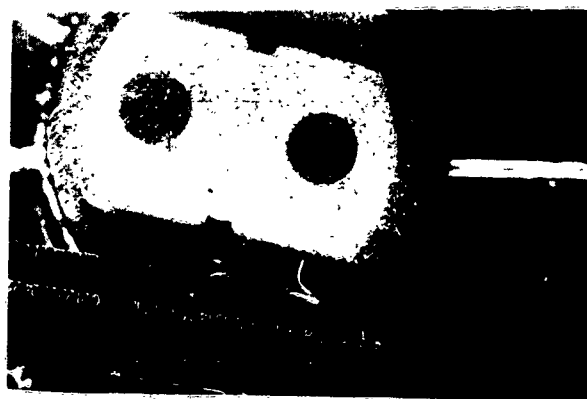
DURING PULSE



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2125-7-3-1

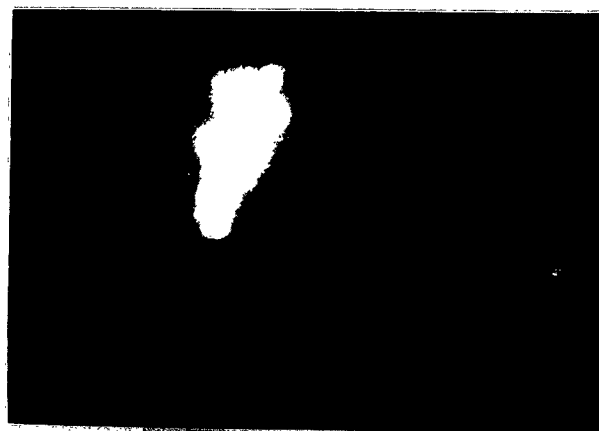
AFTER PULSE

Figure 3. Aluminum Film Sample 8A (Scale: 5 mils/division).



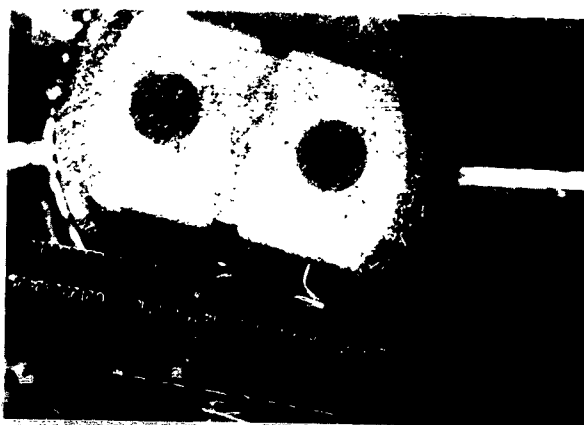
163-510-13

BEFORE PULSE



163-510-14

DURING PULSE



163-510-15
2125-7-4-1

AFTER PULSE

Figure 4. Aluminum Film Sample 9A (Scale: 5 mils/division).

4. WORK PLANNED FOR NEXT PERIOD

- a. Refine and conduct steady current gold film tests.
 - b. Conduct pulse tests and steady current tests with units containing PVA lead azide.
-
- c. Deposit gold films on BeO headers and test with both pulse and steady current.