Conf-940245--1

SAND93-1734C

1994 NASA PYROTECHNIC SYSTEMS WORKSHOP

A LOW COST IGNITER UTILIZING AN SCB AND TITANIUM SUB-HYDRIDE POTASSIUM PERCHLORATE PYROTECHNIC

R. W. Bickes, Jr. and M. C. Grubelich
Sandia National Laboratories
Albuquerque, NM 87185-0326

J. K. Hartman and C. B. McCampbell
SCB Technologies, Inc.
Albuquerque, NM 87106

J. K. Churchill
Quantic-Holex
Hollister, CA

ABSTRACT

A conventional NSI (NASA Standard Initiator) normally employs a hot-wire ignition element to ignite ZPP (zirconium potassium perchlorate). With minor modifications to the interior of a header similar to an NSI device to accommodate an SCB (semiconductor bridge), a low cost initiator was obtained. In addition, the ZPP was replaced with THKP (titanium subhydride potassium perchlorate) to obtain increased overall gas production and reduced static-charge sensitivity. This paper reports on the all-fire and no-fire levels obtained and on a dual mix device that uses THKP as the igniter mix and a thermite as the output mix.

1. INTRODUCTION

The Explosive Components Department at Sandia National laboratories was assigned the task of designing actuators for several different functions for a Department of Energy (DOE) program. The actuators will be exposed to personnel as well as to a wide variety of mechanical, temperature and electromagnetic environments. In addition, required outputs vary from a high pressure gas pulse for piston actuation to a high temperature thermal output for propellant ignition. In order to minimize complexity, the firing sets for all the actuators must be the same, and the firing signal must be transmitted via a cable over lengths as long as thirty feet.

Our solution was to modify an existing Quantic-Holex component (similar to a conventional NSI device) with a semiconductor bridge, SCB. Our prototype device used titanium subhydride potassium perchlorate (THKP) as the pyrotechnic. Our second (dual mix) design used THKP as the igniter mix and CuO/Al thermite as the output charge. The low firing energy requirements of the SCB substantially reduced the demands on the firing system; indeed, the present firing system design could not accommodate conventional hot-wire devices. The reduced static sensitivity of THKP[1] helped mitigate the electromagnetic environment requirements for exposure to radio frequency

*This work performed at Sandia National Laboratories is supported by the U. S. Department of Energy under contract DE-AC04-76DP00789. Approved for public release; distribution unlimited.

(RF) signals and human-body electrostatic discharges (ESD).

2. SCB DESCRIPTION

An SCB is a heavily doped polysilicon volume approximately 100 µm long by 380 µm wide and 2 µm thick with a nominal resistance of 1 Ω. It is formed out of the polysilicon layer on a polysilicon-on-silicon wafer. Aluminum lands are defined over the doped polysilicon; wires are bonded onto the lands connecting the lands to the electrical feed-throughs of the explosive header. The firing signal is a short (30 µs) current pulse that flows from land-to-land through the bridge. The current melts and vaporizes the bridge producing a bright plasma discharge that quickly ignites the THKP pressed against the bridge.[2]

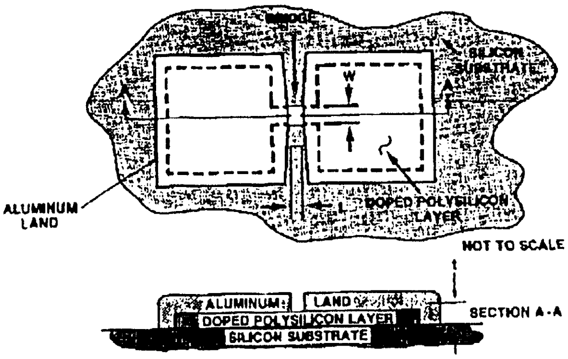

Figure 1. Simplified sketch of an SCB.

The main advantages of an SCB igniter versus conventional hot-wire igniters are that (1) the input energy required to obtain powder ignition is a decade less than for hot wires; (2) the no-fire levels are improved due to the large heat sinking of the silicon substrate; and (3) the function times (i.e. the time from the onset of the firing pulse to the explosive output of the devices) are only a few tens of microseconds or less.[3]

3. IGNITER DESIGN

Our SCB igniter is similar to the NSI device. It consists of a metal body containing a glass header, charge holder and pyrotechnic material. 3/8-24 UNF threads allow the device to be installed into test hardware and an O-ring under the hexagonal head provides the gas seal. The internal charge cavity was reduced to a diameter of 0.156 by utilizing a threaded fiber glass composite (G10) charge holder. The threads help prevent separation of the powder from the bridge due to mechanical shock. The pins are hermetically sealed by glass-to-metal seals and extend approximately 0.020 past the header base into the charge holder. The SCB chip is bonded to the header base between the pins with a thermally conductive epoxy. Aluminum wires, 0.005 in diameter, are thermalsonically bonded to the header pins and the aluminum lands on the chip. For the prototype device, a charge of 85 mg of THKP is pressed at 12,500 psi into the charge holder. A G10 disk, 0.156 diameter and 0.010 thick, is placed on top of the pressed powder, followed by an RTV disk, 0.150 diameter and 0.016 thick. A G10 plug, 0.065 thick, is then pressed on top of the RTV at a pressure sufficient to compress the RTV pad to half its thickness, which maintains a pressure of approximately 5,000 psi on top of the THKP column. A high temperature epoxy seals the interference fit G10 plug in place.

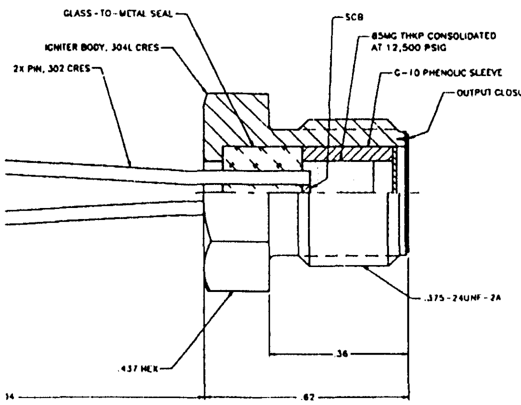

Figure 2. The SCB igniter outline.

4. FIRING SET DESCRIPTION

The firing set for our application is low voltage capacitor discharge unit (CDU) with a 50 F capacitor charged to 28 V (nominal).[4] Because the SCB dynamic impedance changes significantly during the process that produces the plasma discharge, two FET switches in parallel are required to discharge the 35 A current pulse into the SCB. In addition a test current pulse is included that passes a 10 mA pulse through the bridge to verify igniter integrity.

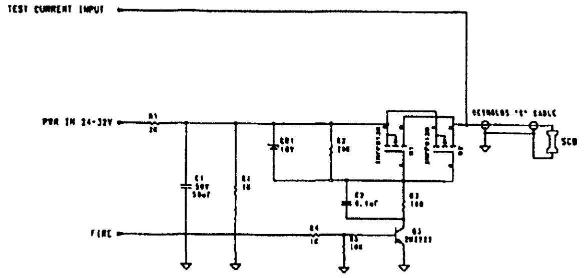

Figure 3. Wiring schematic for the SCB low voltage CDU firing set.

As noted in section 1., some of the igniters may be located as far as thirty feet from the firing set. The use of either large diameter wire pairs or ordinary BNC cable reduced the transmitted current pulses to levels below threshold for ignition. However, Reynolds Industries ɜC cable was able to transmit the current pulse with only a small attenuation of the peak current.

5. PROTOTYPE TESTS

Figure 4. shows the voltage, current and

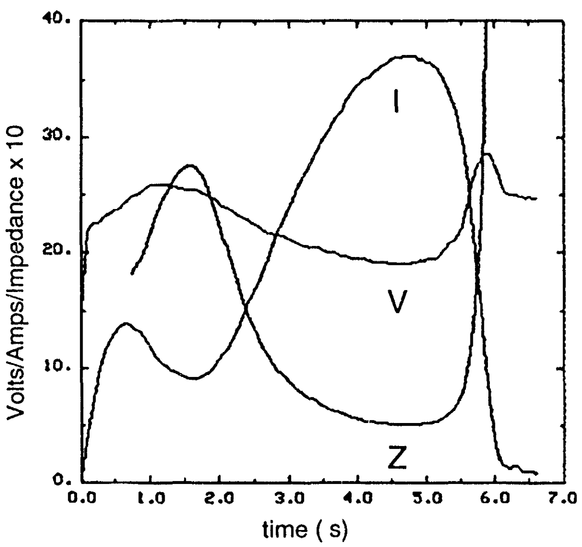

Figure 4. Current (I), voltage (V) and impedance (Z) wave forms across the SCB. At 4.8 s the peak current was 37.4 A, the corresponding voltage was 19.1 V and the impedance 0.5 .

impedance wave forms across a device fired when connected to the firing set through 30 feet of ɜC cable. At ambient conditions, the device functioned in 83 s (determined by a photomultiplier tube looking at the end of the device thorough a fiber optic cable).

Ten units were tested using the NEYER/SENSIT scheme.[5] The units were fired at ambient and connected to the firing set with 30 feet of ɜC cable. An ASENT[6] analysis of the data indicated a mean all-fire voltage of 17.8 V 0.2 V; confidence limits on the mean were 17.7 to 19.2 V at a 95% confidence level and a probability of function of 0.999. See table I for a listing of the data in the shot order prescribed by SENSIT.

TABLE I: ALL-FIRE DATA

Cap Voltage (V)	Go/Nogo (X/O)	Energy (mJ)
18.0	X	5.01
17.0	O	4.36
17.5	O	4.63
18.2	X	4.63
17.7	X	4.77
17.2	O	4.54
17.9	O	4.90
17.3	O	4.54
18.2	X	5.08
17.4	O	4.66

All Fire: 17.8 0.2 V, 4.8 0.1 mJ

Six THKP units underwent 3 temperature cycles over a twenty-four hour period. Each cycle consisted of 4 hours a 74C and 4 hours at -54C. The devices were fired as soon as possible after the cold cycle at approximately -15C. All of the units function when fired using the firing set without the 30 foot cable.

We subjected a THKP unit to a 1 A current for 5 minutes. There was no indication of device degradation and the unit functioned properly when tested. Based on the no-fire tests in Ref. 3, which used the same bridge as tested in this paper, we are confident that these units will have similar no-fire levels similar to those reported in Ref. 3 (1.39 0.03A).

6. DUAL MIX DEVICE

Because composite propellants require a relatively large amplitude long duration thermal input for reliable ignition, we developed an SCB igniter employing two discrete pyrotechnic compositions. First, 25 mg of THKP is pressed at 12.5 kpsi against the SCB and is used as a starter mix to pyrotechnically amplify the low energy SCB signal. The THKP in turn ignites and ejects 150 mg of a high density thermite composition composed of CuO and Al pressed onto the THKP.

We briefly describe the advantages of this device over a device composed of only a single load of THKP or CuO/Al. THKP has excellent and well known interface, ignition and pyrotechnic propagation properties. It also is an excellent gas producer providing zero volume pressures greater than 150 kpsi. Unfortunately, the short, high pressure output pulse of THKP is not ideally suited for the ignition of a composite propellant. CuO/Al on the other hand is an ideal material for the ignition of composite propellants. Hot copper vapor condensing and molten copper impacting on the surface of the propellant provides an excellent source of thermal energy for ignition. Furthermore, copper and copper oxides catalytically enhance the ignition and combustion of ammonium perchlorate. Unfortunately, CuO/Al thermites exhibit poor ignition characteristics at high density and are sensitive to header and charge holder thermal losses. Thus, CuO/Al at high density requires large input energies for ignition and the reaction once started can be quenched as a result of radial heat losses. The THKP ignition charge eliminates both of these problems by providing an overwhelming thermal input to the CuO/Al. Although the CuO/Al is itself a poor gas producer (the copper vapor rapidly condenses), the THKP produces a sufficient gas pulse for this device to be used to operate small, lightly loaded, piston type actuators. In addition, the thermal output of the CuO/Al helps to maintain the temperature of the gases produced by the THKP. We have tested both piston actuator and propellant loaded gas generators with this dual mix device with good results.

7. SUMMARY

We have developed two SCB igniters housed in an assembly with an outline similar to the standard NSI component. Our prototype design utilized THKP to provide for a pressure output static-insensitive device. Our second design used a THKP and thermite mix to provide an output sufficient for piston actuators as well as propellant loaded gas generators. All-fire voltage using a 50 F CDU firing set was 17.8 V; the 5 minute no-fire level is estimated to be greater than 1 A with no device degradation. Future research will examine the tolerance of this device to mechanical shock and electromagnetic environments.

8. ACKNOWLEDGMENT

The testing expertise of Dave Wackerbarth, Sandia National Labs, is acknowledged with grateful thanks.

9. REFERENCES

[1]E. A. Kjelgaard, ɜDevelopment of a Spark Insensitive Actuator/Igniter, Fifth International Pyrotechnics Seminar, Vail Colorado (July 1976).

[2]See for example, D. A. Benson, M. E. Larson, A. M. Renlund, W. M. Trott and R. W. Bickes, Jr., ɜSemiconductor Bridge (SCB): A Plasma Generator for the Ignition of Explosives, Journ. Appl. Phys. 62, 1622(1987)

[3]R. W. Bickes, Jr., S. L. Schlobohm and D. W. Ewick, ɜSemiconductor Bridge (SCB) Igniter Studies: I. Comparison of SCB and Hot-Wire Pyrotechnic Actuators, Thirteenth International Pyrotechnic Seminar, Grand Junction Colorado (July 1988).

[4]Firing set designed by J. H. Weinlein of the Firing Set and Mechanical Design Department, Sandia National Laboratories.

[5]B. T. Neyer, ɜMore Efficient Sensitivity Testing, EG&G Mound Applied Technologies, MLM-3609, (October 20, 1989)

[6]H. E. Anderson, ɜSTATLIB, Sandia National Laboratories, SAND82-1976, (September 1982).

END

DATE
FILMED
3/15/94