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Characterization of Semiconductor Bridge (SCB) Igniters for Use in Thermal Batteries

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Abstract

Semiconductor bridges (SCB) igniters were evaluated as possible replacements for conventional hot-wire igniters for use in thermal batteries. The all-fire and no-fire characteristics were determined using an up-down scheme; the Neyer/SENSIT program was used to analyze the data. The SCB igniters functioned with a higher no-fire level, relative to a hot-wire igniter, for a given all-fire level. This makes the SCB igniter safer and more reliable than its hot-wire counterpart. The SCB is very resistant to electrostatic discharge and does not require a sensitization mixture for ignition of the primary pyrotechnic charge. These factors, along with its amenability to large-scale production, make the SCB igniter ideally suited for use in thermal batteries.

Introduction

Thermal batteries are activated using either a mechanical signal (percussion primer) or electrical signal. The electrical signal is used to fire an igniter that uses a hot-wire bridge coated with a sensitizing mixture (primary explosive) to ignite the main pyrotechnic charge (i.e., $B/CaCrO_4$, $TiH_x/KClO_4$). It is the requirement for a sensitizing mixture, such as barium styphnate or lead styphnate, that makes igniter fabrication variable and hazardous. In addition, the bridgewire igniter is susceptible to functioning in the presence of high electromagnetic radiation (EMR). The no-fire safety currents for such devices require that they not function during application of a constant current for a specified time. Yet, they must function when a higher design current is applied for a specified time (5-10 ms, for example) during all-fire conditions.

The SCB technology, on the other hand, avoids many of the limitations associated with the hot-wire-bridge technology. It is has a much tighter tolerance for the no-fire and all-fire currents and a much narrower window between these limits. In addition, it is very resistant to EMR effects. This makes the SCB igniter intrinsically safer and more reliable then the bridgewire igniter.

SCB devices are characterized by their low firing energy (<3 mJ in many instances), fast function times (<100 µs), and high no-fire currents (which are device specific).[1] When a current is passed through the bridge, it is vaporized to a plasma and readily ignites conventional pyrotechnics in contact with it, without the need for a sensitizing mixture.[2] This requires less energy and time for ignition than a bridgewire igniter. The large silicon substrate provides a heat sink that accounts for the excellent no-fire characteristics. These intrinsic properties of the SCB igniter mean that smaller capacitive discharge units (CDUs) can be used to function these devices.

In this paper we report on different SCB igniter designs and their characterization with both CDUs and constant-current firing sets using various pyrotechnic charges. Statistical tests were used to determine the all-fire energies and the no-fire current levels.

Experimental

SCB Fabrication - The SCB igniters were n-type silicon (phosphorus doped) formed on a 4"-diameter silicon wafer using standard semiconductor lithography. A typical SCB bridge is illustrated schematically in Figure 1. Each bridge was 82 µm long by 74 µm wide by 2 µm thick. The nominal bridge resistance was 2 Ω. To prevent shorting across the lands, an electrically

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were obtained in 1-3 ms, depending on the size of the Ti particles.[4] Tests with $TiH_{1.65}/KClO_4$ mixtures were equally successful. A SCB device loaded with 25 mg of $TiH_{1.65}/KClO_4$, followed with 50 mg of $Ti/KClO_4$, functioned in <200 μs with an input energy of <10 mJ. The energy input is about one-tenth that for a similar hot-wire-bridge igniter.

Additional tests were then conducted using an existing battery igniter where the hot-wire-bridge was replaced with a SCB. A CDU firing set with a 33 μF capacitor charged to 28 V was used for these tests. (It is desirable to use CDU firing sets because they are smaller in volume than constant current firing sets; however, we wanted to verify that a CDU would operate properly.) When loaded with a $Ti/KClO_4$ mixture, commonly used in thermal battery igniters, the device functioned in about 85 μs. Representative voltage and current traces for a functioning device are shown in Figure 3. The SCB ignited the powder at approximately 27 μs as indicated by the spike in the voltage when the SCB plasma formed.

Recently, 1Ω SCBs have been produced which have 1 A/1 W five minute no-firel levels and a 2.5 A all-fire capability. This is an improvement over the all-fire, no-fire discrimination ratio of hot-wire devices.

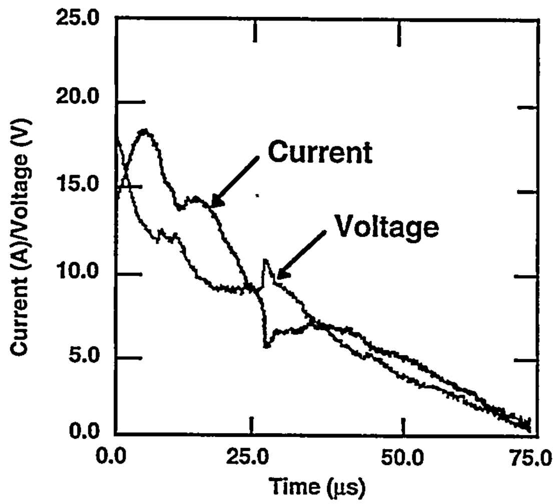

Figure 3. SCB current and voltage waveforms using a CDU firing set.

Conclusions

The performance parameters of SCB igniters were determined using pyrotechnic charges of $TiH_{1.9}/KClO_4$ loaded in the case and header assemblies of conventional hot-wire igniters. The SCB is able to ignite the main pyrotechnic charge directly without the need of sensitizing mixtures, such as styphnates. This makes manufacture of an SCB igniter inherently safer than for a hot-wire device.

The resistance and the design of the SCB bridge can be readily custom tailored for specific applications, thus increasing its versatility. The intrinsic properties of the SCB bridge (e.g. EMR safety, lower all-fire levels with respect to the no-fire level) make it ideally suited for use in igniters for thermal batteries to replace hot-wire devices. Enhanced safety to EMR can be obtained by placing a zener diode in parallel with the SCB. These devices are extremely resistant to HERO (Hazards of Electromagnetic Radiation to Ordnance) environments.[5]

Acknowledgments

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References

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

[2] R. W. Bickes, Jr., "Smart Semiconductor Bridge (SCB) Igniter for Explosives," presented at 3rd Canadian Symp. on Mining Automation, Montreal, Sept. 14-16, 1988.

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

[4] R. W. Bickes, Jr., unpublished data (1992).

[5] R. W. Bickes, Jr., D. Greenway, M. C. Grubelich, W. J. Meyer and J. K. Hartman & C. B. McCampbell, "A HERO Resistant Semiconductor Bridge (SCB) Igniter," JANNAF Interagency Combustion Meeting, Oct. 1992

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