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BNCP PROTOTYPE DETONATOR STUDIES USING A SEMICONDUCTOR BRIDGE INITIATOR*

D. W. Fyfe & J. W. Fronabarger
Pacific Scientific
Energy Dynamics Division
Goodyear, Arizona, 85338-1295, USA

R. W. Bickes, Jr.
Sandia National Laboratories
Explosive Components Department
Albuquerque, New Mexico, 87185-0326, USA

ABSTRACT

We report on experiments with prototype BNCP detonators incorporating a semiconductor bridge, SCB. We tested two device designs; one for DoD and one for DOE applications. We report tests with the DoD detonator using different firing conditions and two different grain sizes of BNCP. The DOE detonator utilized a 50 μF CDU firing set with a 24 V all-fire condition.

I. Introduction

Customers have asked for the development of small size, fast functioning detonators with low input energies but a 1 ampere no-fire. We have met those requests with the development of semiconductor bridge detonators utilizing the explosive BNCP. These deflagration-to-detonation transition (DDT) devices can function in a few tens of microseconds with input energies of less than 5 mJ.

BNCP[1] is a yellow crystalline powder that can be ignited with a hot wire. It is a coordination compound (tetraamminebis [5-nitro-2H-tetrazolato-N^2]cobalt[III]perchlorate) related to CP[2] (pentaammine[5-cyano-2H-tetrazolato-N^2]cobalt[III]perchlorate). BNCP is currently manufactured in 100 g batches with scale up to 1 kg batches planned. No known carcinogens or toxic gases are used in its manufacture, and the processing media is easy to dispose of with no environmental concerns. The impact sensitivity of BNCP is approximately the same as RDX.

Experiments comparing the characteristics of BNCP versus CP show that BNCP undergoes DDT in shorter distances than CP under similar confinement. At 80% theoretical maximum density (TMD) BNCP produces a dent of 0.026" in a steel witness plate; CP at 76% TMD produces a dent of 0.018". VISAR[3] (velocity interferometer system for any reflector) indicates detonation velocities of

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3.2 mm/μs for BNCP and 2.7 mm/μs for CP at 80% and 76% TMD, respectively. In contrast to CP, BNCP will DDT moderately well under aluminum confinement and, to a lesser extent, under plastic confinement.

The semiconductor bridge[4], SCB, is a heavily doped polysilicon volume formed on a silicon substrate. When a low energy current pulse is passed through the one-ohm bridge it forms a plasma discharge which rapidly ignites the powder pressed against the bridge. But because the SCB is formed on the thermally conductive silicon substrate, the no-fire current levels are as good or better than conventional hot-wire igniters.

We designed and tested two BNCP device designs. Both units were assembled with SCB chips furnished by SCB Technologies, Inc. The first detonator is for a DoD application and was tested under several different firing conditions. The second device is for DOE applications and utilizes a capacitive discharge unit (CDU) firing set with a 50 μF capacitor and a 24 V all-fire voltage.

II. DoD Unit

This unit consists of the body, bottom disk (which holds the SCB), and a 0.005" closure disk; all are 304 stainless steel. The SCB is epoxied to the bottom disk and 1" long nickel ribbon leads are soldered to the SCB lands. The bottom disk is then welded to the body and the unit loaded with 25 mg of BNCP consolidated to 10,000 psi. This device is 0.187" long and 0.245" in diameter. Finally, the closure disk is welded to the end. This unit can initiate PBXN-301 cord across a 0.050" air gap.

Ignition sensitivity tests were made at ambient conditions using two different particle sizes of BNCP, 15 and 25 μm. Using a constant current firing set with a current rise time of 15 μs, the time to ignition of the BNCP (as measured by the formation of the SCB plasma discharge) was approximately 100% longer for the larger particle size BNCP at 3.5 A. In addition, in contrast to the 15 μm BNCP, the large particle size material did not ignite at 1.5 A. Units assembled with the 15 μm material were also tested at -80 °F and functioned for current inputs from 3.5 A to 2.75 A.

The influence of current rise time was tested using the 15 μm powder. Increasing the current rise time to 50 μs resulted in only a slight increase in ignition times compared to the 15 μs tests. We successfully ignited the BNCP with the slow rise time firing set over the temperature range of -65 °F to 160 °F. Tests with the large particle size material at -80 °F, showed that the BNCP was too coarse for use with the 50 μs rise time firing set since two of five units failed to function. In contrast, experiments at -80 °F with the 15 μm BNCP all functioned properly.

III. DOE Unit

In this design the SCB is epoxied to a standard hermetic transistor case which serves as the device header. After aluminum wires are ultrasonically welded to the SCB lands and the feedthroughs of the transistor header, a steel body is welded to the header. The BNCP charge is 49 mg and consolidated to 20,000 psi. A 0.005" thick steel cup is welded over the end of this hermetic unit. This unit is 0.377" long and 0.255" in diameter.

We first carried out VISAR studies to determine if the output of this BNCP device was equivalent to DOE components made using CP. The studies indicated flyer velocities of 2.5 to 2.9 mm/µs, essentially the same as obtained from the CP devices. A ten unit statistical up/down study (Neyer procedure using the SENSIT routine) indicated a mean firing voltage using the 50 µF CDU of 17.6 V ± 1.5 V; the 0.999 firing level with 95% confidence was 22.3 V. The minimum firing voltage from the system is 24 V. While we have not yet carried out no-fire experiments, previous data using CP shows a no fire greater than 1 A. We observed function times for various firing set capacitances and firing voltages. Function times ranged from 55.5 µs for a 470 µF capacitor with a 14 V charge, to 10.4 µs for a 20 µF capacitor charged to 28 V. Units subjected to DOE and DoD electrostatic discharge (ESD) pulses did not initiate and functioned properly when fired with the 50 µF firing set.

IV. Summary

We built and tested BNCP detonators for DoD and DOE customers. The devices meet our customers' needs in terms of performance and cost. BNCP has been shown to be a satisfactory substitute for CP with equivalent or better performance. The SCB igniter permits fast function at low energies, and the SCB devices will meet the explosive safety demands required by our customers.

V. References

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