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Improving reliability of thick film initiators for automotive applications based on FE-analyses

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Abstract

Finite element method (FEM) has been proved as a useful tool to design thick film initiators for automotive safety unit applications as well as a method of rapid prototyping of such devices. Besides, it contributes to improve the reliability of the system since potential reasons of failure will be highlighted and as a result suitable remedies can be applied. Parameters like the thermal characteristics of the pyrotechnics, pore inclusions in the explosive, physical properties of the involved thick film materials as well as diffusion effects occurring at the termination ends of the initiator element have to be taken into account during the design process with regard to reliability aspects. Practical ignition tests have been conducted with thick film initiator elements and an explosive composed of $Sb/KMnO_4$ in the order to prove the efficiency of numerical simulation for the design process.

1. Introduction

Electro-pyrotechnic initiator elements, also known as bridge resistors, are resistive elements, which convert electrical energy into heat energy for purpose of initiating an explosion of pyrotechnic material in a controlled energetic reaction. In the last few years the automotive industry has been working on increasing the number of pyrotechnically released safety devices like seat belt pretensioners, side curtain airbags, side bags, inflatable seatbelts, rear seat bags, battery cable cutters etc. to the point where the energy level required to initiate ignition of pyrotechnics has become a very serious cost consideration. Present day initiators operate at energy levels in the area of 1.5 mJ. Consequently, the automotive industry has focused on the development of low energy systems, in the microjoule area, linked by one central intelligent bus system interconnecting the safety units of the vehicles. The realization of reliable low energy detonators utilizing the traditional bridge wire technology would fail. Beyond electro-explosive devices utilizing resistive bridge wires historically demonstrated sensitivity to high frequency electromagnetic interference which is considered as a serious reliability problem for automotive safety units [1].

In contrast, resistive bridge elements realized in semiconductor as well in foil and thin film technology meet the requirements mentioned above and they are therefore considered as practicable alternative to the wire initiator. The performance of such elements is well documented by experimental data and contrasted with that of conventional wire bridge elements [2–5]. A primary object of this study was to provide a concept for

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a metal film bridge initiator realized by application of thick film technology utilizing FEM as a tool for rapid prototyping and improving system reliability. Thick film bridge resistors provide highly producible, pyrotechnical devices with reliable performance at levels less than 150 microjoules with positive effects on over-all cost savings, reliability and manufacturing versatility [21].

2. Construction of initiator elements

Fig. 1a shows the bridge wire construction [2]. A wire, typically Nickel- or Tungsten-based, of about 30 μm diameter is stretched across the terminals and welded at pins. For different resistance values, or energy levels headers with adjusted distances between the pins must be used. Attempts have been also made to fabricate electro-explosive devices using integrated circuit technology. A SCB (semiconductor bridge) is one of those devices fabricated using integrated circuit techniques [3–6]. Fig. 1b shows a semiconductor bridge structure, in which a highly doped silicon film is forming the bridge element with metal lands built up by deposition aluminium or tungsten layers [5]. Impressing a voltage pulse on the SCB device involves melting and vaporization of bridge material.

Fig. 1c shows the thick film replacement for the bridge wire. In this design a resistive film bridge element is realized on a glass ceramic coated alumina substrate is shown. Different resistance values and energy levels are controlled by the pattern etched or laser machined into the metal film. The broad flat surface of the metal film assures maximum contact with the pyrotechnics and the ceramic substrate provides the mechanical rigidity of the initiator element. The lands of the device are solder or conductive epoxy bonded with the pins of the package. In comparison with thick film initiator elements the semiconductor bridge devices with their wire interconnections are delicate structures with only poor mechanical robustness. They are susceptible to fail when the explosive is compacted and pressed against the initiator element in the order to provide an intimate contact required for a low thermal contact resistance and consequently a reliable ignition.

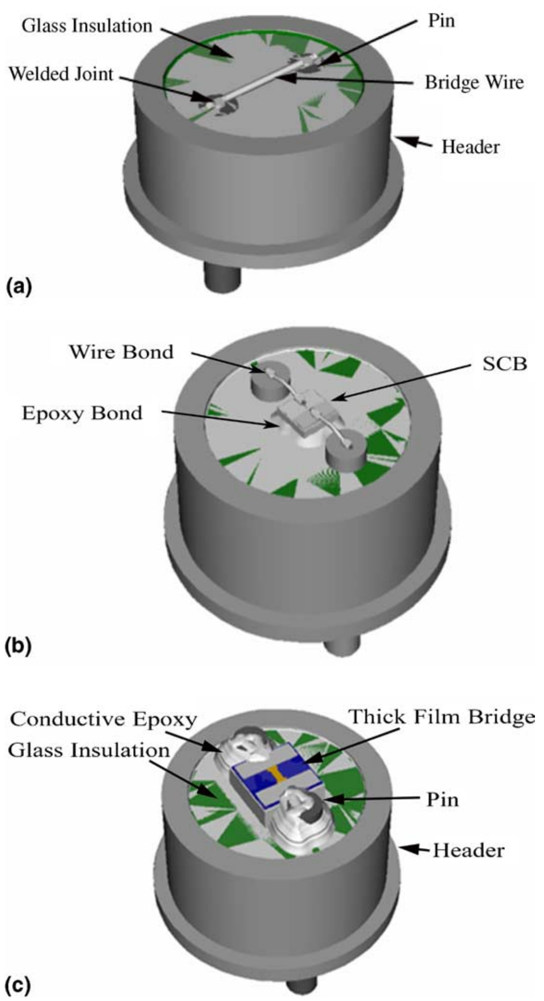

Fig. 1. (a) Bridge wire construction. (b) Wire bonded semiconductor bridge element mounted on a header. (c) Epoxy bonded thick film initiator element mounted on a header.

3. Initiator element-operating principle

Crash sensors in cars induce, in the case of an accident, a current pulse in the resistive initiator element. As the device is heated up to a critical temperature the explosive detonates and consequently the safety unit of the vehicle will be released.

The parameters commonly used for describing an electro explosive device performance are "no-fire"- and "all-fire"-current.

To perform "no-fire"-current test with the bridge element a constant current is applied for a certain period. The resulting bridge temperature has to remain below the critical temperature of the explosive where ignition occurs.

At "all-firing"- current the bridge temperature reaches the ignition temperature of the explosive powder. Ignition occurs and the bridge is either destroyed by the reaction or eventually fused (burned open) by the firing current. Beyond the melting temperature of the bridge element heat transfer is conducted by the vapor of the initiator material penetrating the explosive and finally condensating within or by formation of plasma [5]. All these mechanisms may induce ignition of the explosive.