Design, realization and characterization of several types of micro-initiators integrating Al/CuO nanothermite: role of metallic micro-heater and substrate on fire/no fire characteristics

Andréa Nicollet[1,2], Sandrine Souleille[1,2], Ludovic Glavier[1,2], Laurent Mazenq[1,2], Ludovic Salvagnac[1,2], Carole Rossi[1,2]

[1] CNRS; LAAS; 7 avenue du colonel Roche, F-31031 Toulouse, France
[2] Université de Toulouse; UPS, INSA, INP, ISAE, LAAS; F-31077 Toulouse, France

Electro-pyrotechnic initiators used to ignite an explosive, a propellant or any other energetic substances are widely used in many applications including micropropulsion, drug injection, Safe Arming and Firing for missiles, rockets, munitions and airbag inflation …

Our research group has recently reported the integration of nanothermites within MEMS based micro-heater to produce a new type of electro-pyrotechnical initiators. We demonstrated their capacity to ignite the combustion of several energetic compositions, as double base propellants with only 1 A during 12 µs [1]. For practical applications, fundamental challenges associated with electro-pyrotechnic initiators are to ensure a low and reliable firing energy, fast and reproducible pyrotechnical responses while being robust, easy in fabrication. To improve the micro-heater performance, the technological challenge entails the electro-thermal element to be thermally insulated from the substrate while being in intimate contact with the nanothermite layer to be ignited.

This study presents the fabrication of 1.6×2.6 mm² electro-pyrotechnic initiators consisting in 1 µm thick Al/CuO nanothermites sputter deposited on top of a metallic micro-structured resistor (micro-heater): when a current is supplied to the micro-heater, Al/CuO thermite reacts in a self-propagating manner and produces sufficient heat to ignite a pyrotechnic material as a propellant packed close to the nanothermite layer.

In this paper, we first present the fabrication process flow of two different micro-initiator designs: one on glass wafer and a second on low conductive polymeric substrate. Then, we experimentally investigate the influence of the metallic resistance type (Ti, NiCr, Pt) on firing and no firing behaviors and reliability. Firing/no firing measurements are carried out at ambient using two photodetectors built in the shape of microscope objective. The first one detects light signal emitted by the reaction sparkles in the range of 380 nm to 1 100 nm and the second detects light signal in the range of 800 nm to 2 600 nm. In accordance with the blackbody formula, the first photodetector covers the range of temperature ranging from 2 634 K to 7 626 K and the second one from 1 115 K to 3 622 K.

We observe a tremendous dependence of the nanothermite ignition response on the substrate nature and metallic resistance types. For example, unlike Pyrex, on polymeric substrate, firing time (delay between the current input and sparkles generation) ranges from 150 µs to 6 s for constant current ranging from 0.1 A to 1.5 A considering a Ti resistor of 17 Ω. For such micro-initiators, no fire condition is obtained below 0.1 A. In another resistance configuration (3 Ω) on polymeric substrate, firing time ranges from 500 µs to 4 s for constant current ranging from 0.3 A to 1.5 A. For such micro-initiators, no fire condition is obtained below 0.25 A.

[1] G. Taton, D. Lagrange, V. Conedera, L. Renaud, and C. Rossi, "Micro-chip initiator realized by integrating Al/CuO multilayer nanothermite on polymeric membrane," Journal of Micromechanics and Microengineering, vol. 23, pp. 105009, Oct 2013.