

# Ultra-rapid and fully integrated active pyrotechnic safety switches integrating nanothermites

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Traditional technologies used to manufacture current pyrotechnic switches are based on synthesis, pressing/casting and injection of macroscopic organic energetic materials (explosive or highly energetic materials), which leads to bulky and dangerous systems. We propose, instead, a nanothermite-based safety switch, which provides a compact circuit breaker, ideally suited to protect against overcurrent, external perturbation and short circuit of a broad range of equipments and systems. This new switch is miniaturized based on the integration of a few mg of nanothermites by additive manufacturing methods directly on electronic circuitry. The concept is simple and adaptable to many applications: two printed board circuit (PCB) are bonded together to form a hermetic cavity of 38 mm<sup>3</sup> in volume. The bottom PCB contains the electronic circuitry and ignitor element to trigger the switching. A second PCB supports the copper connection as part of the circuitry that must be disconnected. Once ignited, the nanothermite generates the high gas pressure burst sufficient to safely terminate the electrical connections of the circuit in less than 2 ms, well before a short-circuit can occur that could lead to an uncontrolled action, i.e. an accident or catastrophe.

We show that the pressure (up to 1.5 MPa) or force level (up to 50 N) and switching time (from 0.9 to 5 ms) can all be controlled by tailoring the nanothermite composition (type and dimension of oxide particles), stoichiometry and compaction rate, so that the response of the actuator can be tuned. Therefore it can be applied in a broad variety of applications, such as electric storage, aerospace manufacturing (rod and bolt pyrotechnic cutters), human safety, demolition, parachute opening, road vehicles, boats and battery powered machines.

We focus our presentation on the vaporization of a 100 μm-thick copper connection to rapidly disconnect a battery unit (in less than milliseconds) regardless of the magnitude of the fault-current. For example, we demonstrate that varying the compaction rate from 3.3 to 7.1 % of the TMD (Theoretical Maximum Density), the switching time decreases from 3 to 1.5 ms. Tuning the Al/CuO stoichiometric ratio also impacts greatly the switching time. The design, fabrication process as well as switching performances will be presented. The proposed concept is innovative and offers unprecedented advantages: (1) harmless manipulation of products of substances and processes for human; (2) an integrated fabrication framework enabling low cost and mass fabrication, reliability, and nanoscale precision; (3) increased environmental protection: only safe and environmental friendly substances and components can now be chosen and combined to produce the energetic layer; and (4) a versatile design that can be applied to a large number of applications.