Solid-State, On-demand Gas Generators as *Pneumatic Batteries* for Micro-Electronic Actuators and Fluid Delivery*

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ABSTRACT

Newly developed electrically controlled extinguishable solid propellants (ECESP) are capable of multiple ignitions, extinguishments and throttle/burn-rate control by the application of continuous electrical power [1]. Both burn rate and mass of ECESP combusted is directly proportional to the electrical power input. These propellants are insensitive to ignition by flame and are both non-self sustaining/initiating without the *continuous* application of proper electrical power. Continuous exposure to high temperature flame may eventually over heat the ECESP where low energy combustion/smoldering, however this does not cause the run away high-energy electrical combustion to occur. Typically these ECESPs provide ~1 liter of gas generation per gram of solid propellant. Originally, formulated for use in automobile air bags, the ECESPs *do not* produce highly toxic combustion gases and are low in particulates. One ECESP formulation is a solid solution propellant and is molecularly uniform, having no granular structure once cured; this homogeneity allows direct casting into thin layers and the vacuum casting into complex geometries. The ECESP is also an environmentally/manufacturing friendly as a low hazard material, which can be room temperature mixed, with an extended pot life for casting.

1. TESTING AND DEMONSTRATION

Solid-state ECESP gas generators have been successfully demonstrated with a web thickness from <0.060 to 0.1 inch (radius) and up to 1-inch in length. The ECESP initiates at the upper burning surface, extinguishes on-demand and restarts (figure 1a and 1b). Using minimum excitation power these devices can deliver hundreds of *controlled repeatable pulses* from a 0.125 by 0.50-inch grain (figure 1c). Our testing also demonstrated the importance of not over heating grains, as this leads to ECESP low energy smoldering. Without active direct cooling of the ECESP duty cycles of <20% may be expected.

2. APPLICATIONS

Application of these devices is currently focused on tactical missiles, igniters, thrusters on micro/pico satellites, and on larger spacecraft for controlling vibration on extended booms. Original microchip thrusters were simply clusters of single fire chambers [2]. The modular ECESP devices appear quite compatible with standard electronics manufacturing methods used in making capacitors and batteries. Adoption of *fabless* manufacturing methods and standards from the electronics industry should provide custom, highly reproducible solid-state gas generators at relatively low cost. Using electrical component form factors, should allow these gas generators to be direct mounted on circuit boards and be replaced as easily as common electrical batteries This manufacturing compatibility provides a low cost pathway to important non-space applications as on-demand gas generators for pneumatic actuators or fluid delivery. These solid-state on-demand gas generators should be able serve as “pneumatic batteries” on future circuit boards, potentially enabling new micro pneumatic robotic devices and fluid delivery systems. Movie special effects/FX and smart automotive airbags are also potential areas of application for this technology. Further commercial development is underway to reduce power input requirements and manage thermal feedback.

**Patents Pending*

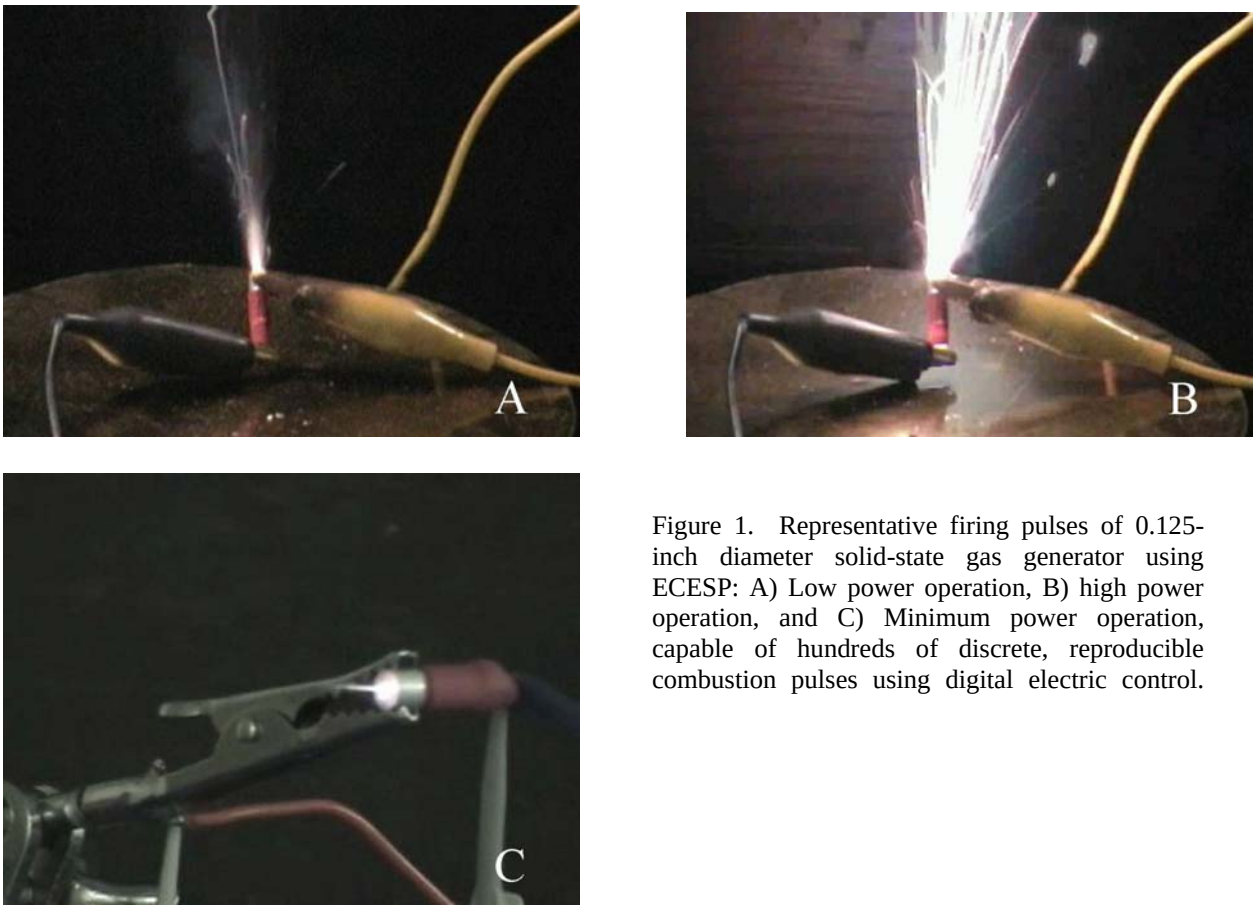

Figure 1. Representative firing pulses of 0.125-inch diameter solid-state gas generator using ECESP: A) Low power operation, B) high power operation, and C) Minimum power operation, capable of hundreds of discrete, reproducible combustion pulses using digital electric control.

References:

1. Sawka, W. N., A. Katzakian and C. Grix, *Solid State Digital Cluster Thrusters for Small Satellites, Using High Performance Electrically Controlled Extinguishable Solid Propellants*. Paper SSC05-XI-3, 19th Annual AIAA/USU Small Satellite Conference 2005.

2. Lewis, D.H., W.J. Siegfried, R.B. Cohen and E.K. Antonsson, "Digital MicroPropulsion", 12th IEEE International, Micro Electro Mechanical Systems Conference (MEMS '99) January, 1999.