Micro Power

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This lecture discusses the Micro Power Generation Program (MPG) at DARPA and examples of micro rocket technology.

MICRO POWER GENERATION PROGRAM (MPG)

The goal of MPG, which was initiated by Dr. Bill Tang, is to generate power on the micro scale and to enable standalone sensors and actuators with wireless communication. Five DARPA projects will be reviewed, covering micro fuel cells and micro engine.

Prof. Savinell, Case Western Reserve University, is developing a micro hydrogen-air fuel cell with integrated fuel storage for autonomous operation, capable of delivering 10 mW continuous and 100 mW pulse power. The potential application is a wireless sensor with power, sensor, radio, and electronics in one package. Major tasks are to fabricate and test the fuel cell, develop novel polymer electrolytes with higher conductivity at low relative humidity, and investigate both on-board storage of hydrogen (using metal hydrides) and generation of hydrogen (from NaBH4). To date, an integrated device with on-board hydrogen supply based on NaBH4 has been tested with over 67% H2 utilization. A steady-state power output of 2 mW/cm2 and pulse power output of 10 mW/cm2 have been demonstrated. Future goals are to increase power output by improving porosity of substrate and enhance capability to manufacture higher voltage stacks.

Dr. Evans Jones, Battelle, is developing an integrated micro fuel processor and fuel cell. The fuel reformer coverts fuel and water into H2 and CO2 gas using mature catalyst technology and readily available fuels; the fuel cell converts H2 gas into H2O and electricity. Various fuels are being considered, which have the potential to exceed battery performance even at low conversion efficiency. A catalytic reformer system with 10 to 500 mW was fabricated and tested. The reactor volume was less than 5 mm2.

Prof. Fernandez-Pello, University of California, Berkeley, is a developing a MEMS rotary internal combustion engine for miniature-scale power generation using hydrocarbon fuels, which have a fuel specific energy significantly higher than the battery specific energy. Several research issues are being addressed to allow fabrication of micro engines, including combustion, fluid flow, fabrication, and materials. Steady combustion at the micro-scale below the quenching distance was demonstrated. Two generations of mini-engines with

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78 mm3 and 348 mm3 displacement were tested on a dynamometer, and a maximum power of 3.7 W at 9300 rpm was generated. These investigations provide the background for future development of micro engines.

Prof. Ho, UCLA, is developing a high electret generator energized by a MEMS based chemical-thermal reactor. The jet exhaust from a pulsed combustor of 35 mm length is driving a turbine of 20 mm diameter integrated with an electric generator. For the integration a CFDRC developed MEMS software simulation code is used. The pulsed reactor is a multiplayer silicon/ceramic structure.

MIT is developing MEMS heat engines with applications to micro gas turbines, micro rocket engines, and micro blowers. Enabling technologies include MEMS turbo-machinery, micro combustion dynamics, high temperature materials and packaging, gas bearings, and micro electromechanics. The operation of silicon turbine system with 21 mm diameter, 2 grams engine weight, and 1 million rpm has been demonstrated using hydrogen.

MICRO ROCKET TECHNOLOGY

Several organizations are developing micro rocket technologies. One example is the work at Mechatronic, which has developed cold-gas (N2) micro thrusters capable of thrust delivery up to 500μN. They are equipped with micro valves, pressure sensors, and electronics.

An experimental setup for testing the micro propulsion system in space is under development. The experiments will be performed on-board the micro satellite UNISAT-2, in the framework of a cooperation between Università di Roma “La Sapienza”, Mechatronic and INFM. Two pairs of micro thrusters mounted with their thrust direction orthogonal to the spin-axis of the spacecraft will be used to perform spin-up/ spin-down maneuvers.