MEMS-Scale Power Generation for Integrated Microsystems: An Electromagnetic Micro-Turbo-Generator

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Abstract: The recent advancements in microelectronics and nanotechnology led to the development of miniaturized electrical devices with a variety of sensing and actuation mechanisms. However, the energy sources powering these devices have not kept up with this pace of size reduction while maintaining their power density. Equally-compact and high-power units are still the missing piece to realize fully integrated and stand-alone microsystems. The high energy density of hydrocarbons makes them a promising solution for small-scale power generation. To exploit their energy in micro-scale, the development and integration of robust micro-turbo-generators and micro combustion engines are required. This work has been focused on the development of a MEMS electromagnetic micro-turbo-generator capable of converting rotational mechanical energy into electricity in micro-scale.

The device is fabricated using MEMS fabrication technology, and is composed of many components including a turbine rotor, microball bearings, integrated magnetic materials, and thick electroplated stator coils. While the turbine structures allow for pneumatic actuation, the robust nature of microball bearings provides a stable and reliable support mechanism for the rotor at speeds up to 100krpm (kilo rotations per minute). The integration of permanent magnets into the rotating turbine results in a time varying magnetic flux density below rotor surface. To utilize Faraday's law of electromagnetic induction and generate voltage, the device employs a stator with three-phase planar radial coils incorporated in silicon. The initial characterization of the micro-turbo-generator at low speeds (up to 10krpm) and relatively high internal impedance shows an output per-phase power of 10μW that demonstrates excellent agreement with theoretical analysis and simulations. These initial results suggest that watt-level power generation is possible at speeds on the order of 100krpm that is within the stability range of this device. The future integration of this micro-turbo-generator with a same-scale combustion engine will enable the realization of a micropower source that can convert hydrocarbon energy into electricity.

In addition to this technology, there are other architectures for micro-scale power generation such as micro fuel cells, micro batteries, ambient power scavengers, and radioactive materials, each having their own issues. Resolving these problems and further miniaturization is necessary for the development of micro/nano-scale power modules. Monolithic integration of these components with same-scale transducers will lead to fully-integrated and stand-alone microsystems capable of performing in out-of-laboratory environments.

Bio:

Mustafa Ilker Beyaz received his B.S. degree in Electrical and Electronics Engineering from the Middle East Technical University, Ankara, Turkey, in 2005 and his M.S. degree in Electrical and Computer Engineering from the University of Maryland, College Park, MD, USA, in 2008. His research interests are in the fields of MEMS and Nanotechnology with a specific focus on Power MEMS devices with various actuation and control mechanisms for small scale energy conversion. He is a Future Faculty Fellow, and a holder of two doctoral awards from the Clark School of

Engineering and Department of Electrical and Computer Engineering at the University of Maryland, College Park. Mustafa Ilker is currently a Ph.D. candidate in the same institution under the supervision of Professor Reza Ghodssi at the MEMS Sensors and Actuators Laboratory.