Innovative thermal energy harvesting for future autonomous applications

By S. Monfray
STMicroelectronics

As communicating autonomous systems market is booming, the role of energy harvesting will be a key enabler. As an example, heat is one of the most abundant energy sources that can be converted into electricity in order to power circuits. Harvesting systems that use wasted heat open new ways to power autonomous sensors when the energy consumption is low, or to create systems of power generators when the conversion efficiency is high. The combination of different technologies (low power µ-processors, µ-batteries, radio, sensors...) with new energy harvesters compatible with large varieties of use-cases will allow to address this booming market. Thanks to the conjunction of ultra-low power electronic development, 3D technologies & Systems in Package approaches, the integration of autonomous sensors and electronics with ambient energy harvesting will be achievable. The applications are very wide, from environment and industrial sensors to medical portable applications, and the Internet of things may also represent in the future a several billions units market.

In this presentation, we will address an innovative way of harvesting heat, and present the fabrication of thin modules that work without a heat sink at temperatures close to ambient. The key point of the integration of this technology is the ability to keep a large thermal gradient on a device by intelligent control over the thermal flow. In order to optimize this, 2D thermal simulations are mandatory in order to perfectly understand and maximize the thermal gradient in the prototype. This work is realized thanks to CFD-ACE+ software (ESI Group). Then, to provide an innovative system of conversion of heat into electricity, the concept is based on two key principles: 1-the conversion of a continuous stream of heat into mechanical impulses, 2-the conversion of these mechanical pulses into stored electrical energy. The generated electric power density can be increased by miniaturizing each device, but an optimal working point should be found in order to have high power due to scaling and enough signal so as to overcome the threshold of the harvesting circuit. The miniaturization imposes also a thermal optimization that can be simulated by the ESI Group software. The concept is unique in the sense that it is based on a matrix structure of micro or mini energy nodes which will work together and which do not require the use of radiators, thanks to the controlled thermal resistance. This opens the door to new properties and features of the object, with better performance for low power applications.

Innovative product features planned:
Flexibility, low cost, large area
Dr Stephane Monfray is the Principal Scientist in the Advanced Devices Technology group at STMicroelectronics in Crolles. Since 2008, he is a member of the STMicroelectronics experts staff. He was involved in FP6 and FP7 projects (Nanocmos, Pullnano, Duallogic) and leads since 2012 a national project (FUI) on energy harvesting. He is the author and co-author of more than 70 publications in major conferences and journals, of more than 30 patents, of a book chapter. He was instructor at the SOI conference shortcourse in 2010, and at MIGAS in 2011, and he had multiple participations and paper presentations at the IEDM in 2001, 2002, 2004, 2007 and 2010. He was the co-recipient of the Paul Rappaport Award in 2000, and he is the co-recipient of the 2012 French Electronic Grand Prize “General Ferrié” for his work on thin film devices.