

An Overview of Micro Thermoelectric Technology

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Thermoelectricity has been known since the 1830s. Two functional principles are included under this term: The popular Peltier-Effect describes how electric current flowing through thermoelectric material transports heat, creating a cooling effect. The inverse effect, named after his discoverer Thomas Seebeck, generates an electrical voltage across a material when it is placed between two different temperature levels. Peltier elements have been commercialized for over 50 years in multiple markets from consumer to complex laser metrology applications. The Seebeck Effect just made it to outer space, powering satellites from the heat produced by small nuclear reactors.

A technology leap has occurred recently, which compares to the one from discrete transistors to integrated circuits. Micropelt, based in Germany, leads amongst a few vendors of so-called thin film thermoelectrics. This new approach to thermoelectric technology increases performance levels, particularly power densities, for both Seebeck and Peltier Effects by orders of magnitude. Peltier applications and even more thermal energy harvesting applications can now go to much smaller applications, while still producing very useful results.

The basic building block of all thermoelectric elements, often referred to as thermocouple, is a combination of two thermoelectric 'legs', arranged in an electrical series connection. Thermally, however, they are connected in parallel. The base material is Bismuth-Telluride (Bi_2Te_3), a semiconductor material with best thermoelectric properties between ambient temperature and 200°C . Power generation leveraging the Seebeck-Effect is based on such arrangements of thermocouples. An interesting feature of thermocouples is that the voltage they produce from a given temperature differential is entirely independent of their size. Consequently the microvolts generated by a single thermocouple scale up nicely with hundreds of micro-thermocouples combined in a novel chip sized thermogenerator based on thin film technology.

Thin film thermoelectrics offer nice scaling effects as the production is based on wafer processing and chip making technologies. The idea is straightforward and very similar to the one which led from discrete transistors to integrated circuits on

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Published on Electronic Component News (<http://www.ecnmag.com>)

silicon wafers. A thin layer of TE material is sputtered onto a standard silicon wafer using the same type of equipment as in CMOS fabs. Just the TE material causes a contamination which prevents concurrent use of equipment for both types of product.

Photolithography and dry etching is used to produce the TE leg structures. All obsolete TE material is etched away from the solid thin film, leaving only the required microscopic TE structures. Wafers are produced in pairs, one of which is covered with p-doped material, the other is n-doped. A fully functional TE element is formed by bonding together two correspondingly structured wafer sections with opposite doping. The patented soldering process requires only half as many connections as conventional TE devices with the same number of thermocouples, and a small fraction of their size. Micro thermoelectric elements have been produced with footprints between 0.6 sqmm and 25 sqmm.

Source URL (retrieved on 09/23/2014 - 10:39pm):

http://www.ecnmag.com/articles/2010/07/overview-micro-thermoelectric-technology?qt-most_popular=0