THERMOELECTRIC THIN-FILMS FOR MICROCOOLERS AND ENERGY SCAVENGING MICROSYSTEMS

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The present work reports on the fabrication and characterization of the first planar Peltier microcooler (Fig. 1) on a flexible substrate. The microcooler was fabricated on flexible Kapton© polyimide substrate, 25 µm in thickness, using Bi_2Te_3 and Sb_2Te_3 thermoelectric elements deposited by thermal co-evaporation.

The cold area of the device (4 mm^2) is cooled using four pair of thermoelectric elements, connected in series with aluminum/nickel contacts (Fig. 3). Flexible substrates add uncommon mechanical properties to the composite film-substrate and enable their integration with many novel types of electronic devices. Kapton was chosen as substrate because of its low thermal conductivity (0.16 $W.m^{-1}.K^{-1}$), thus allowing for higher performance of cooler devices. The value of thermal expansion coefficient of Kapton (12×10^{-6} K^{-1}), which closely matches the thermal expansion coefficient of the telluride films, reduces residual stress and increases adhesion of thermoelectric films. Films were deposited by co-evaporation of Bismuth and Tellurium or Antimony and Tellurium to obtain Bi_2Te_3 or Sb_2Te_3 compounds (Fig. 2), respectively. The performance of thermoelectric devices depends on figure of merit (ZT) of the film, given by $ZT = \alpha^2T/(\kappa\rho)$, where α, T, κ and ρ are the Seebeck coefficient, absolute temperature, thermal conductivity and electrical resistivity, respectively. Optimal growing deposition parameters allow the fabrication of films with ZT = 0.9 and ZT = 0.5 for Bi_2Te_3 and Sb_2Te_3, respectively. These values are comparable with the best published results for the same material, under various fabrication methods (thermal co-evaporation [1], sputtering, MO-CVD, flash-evaporation or electrochemical deposition). A layered structure (superlattice) can increase films performance and a figure of merit of 2.4 can be achieved [2] in a layered Bi_2Te_3/Sb_2Te_3. Seebeck coefficient is increased and thermal conductivity reduced, by controlling the transport of phonons and electrons in the superlattice structure.

Thermoelectric devices were fabricated using photolithography and wet-etching techniques [3,4] with HNO_3 / HCl based etchants The performance of a Peltier microcooler was analyzed by infrared image microscopy, on still-air and under vacuum conditions, and 4 ºC temperature difference between the cold side and the hot side of the device was recorded (Fig. 4).

Acknowledgments:
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References:

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Figures:

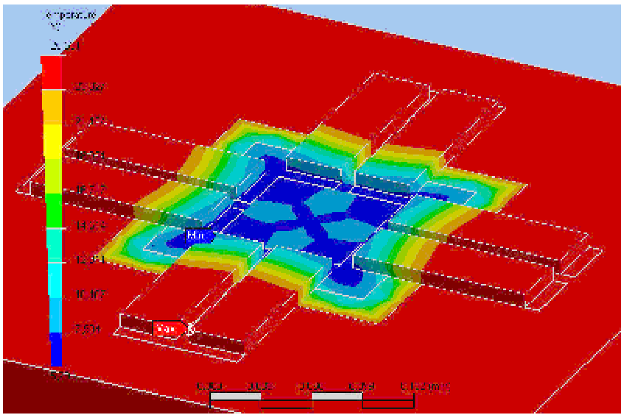

Figure 1: Microcooler simulation shows the possibility to obtain 20ºC of cooling at the center of microcooler.

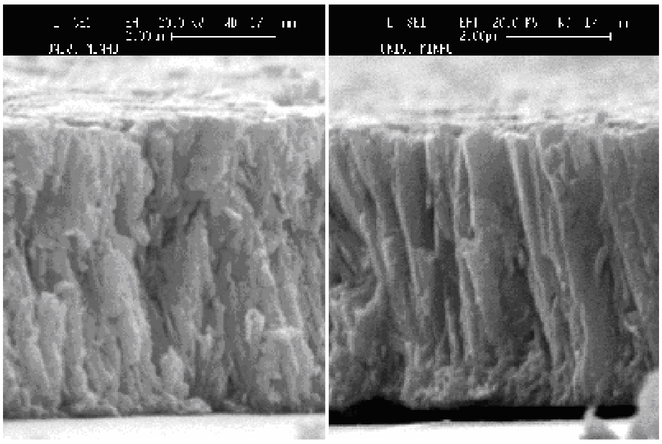

Figure 2: SEM photo of Bi_2Te_3 (left) and Sb_2Te_3 (right) thin films.

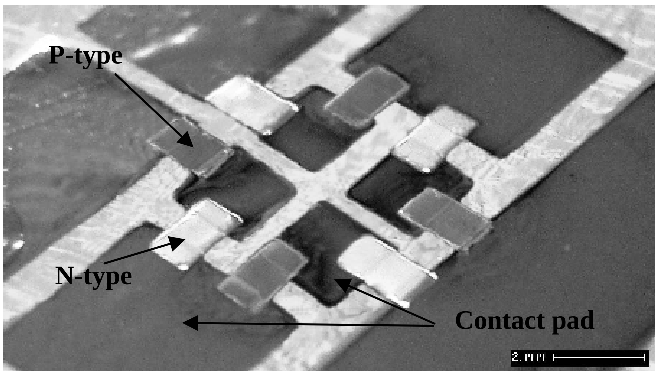

Figure 3: Photo of a microcooler pixel, on top of a polyimide substrate.

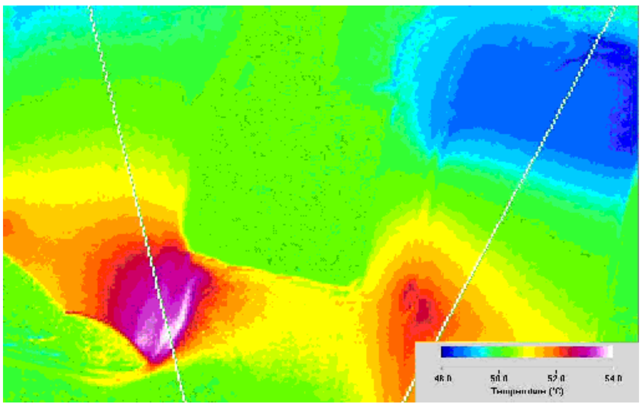

Figure 4: Thermal image of n-type and p-type thermoelectric elements presented on figure 5, powered with 4mA current, under vacuum.