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Carbon Nanotube Array Electrical Interfaces for Thermoelectrics

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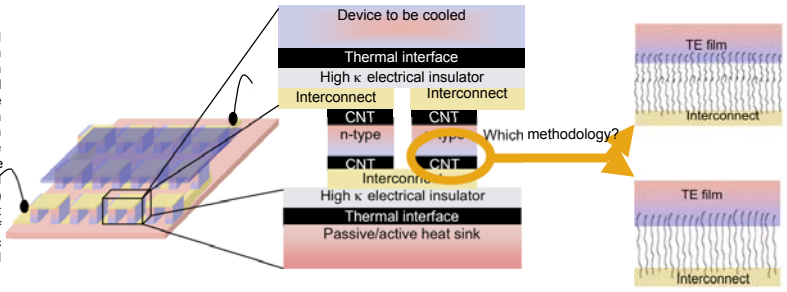
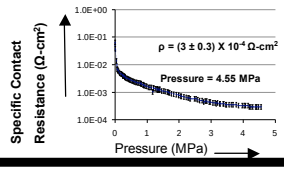
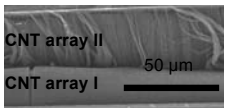
1. Thermomechanical compliance, electrical and thermal contact resistances in miniaturized thermoelectric devices

Miniaturized thermoelectric (TE) heat-pumps seem to be the ideal candidate for localized heat-flux dissipation challenges in microelectronics . It is unfortunate that despite of sustained research in this field, the realization of widespread TE applications in society still remains elusive. Here we report a new strategy to enhance the performance and reliability of TE devices by integrating TE films with carbon nanotube (CNT) arrays by an economical electrodeposition process. We demonstrate significant improvements in the thermomechanical compliance (increase in ΔT_{max} > 200K), and the electrical and thermal contact conductance of the CNT/TE integrated contact over the usual electrodeposited metal-interconnect/TE (M/TE) contacts. Improvements in thermomechanical compliance, and contact conductance at the M/CNT/TE contact will lead to development of various highly efficient and reliable applications like microelectronic cooling, waste heat recovery, precise temperature control and measurement, thermochemistry, etc.



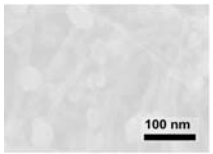
2. CNT-CNT array contact resistance



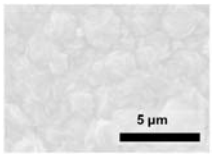


CNT-CNT array interface

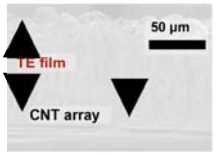
3 Electrodeposition process: Thin films of Bi_2Te_3 were electrodeposited on the as-grown CNT array covered substrates in a standard three-cell potentiostat



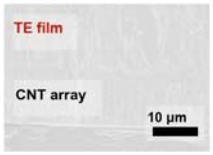
Nucleation of Bi_2Te_3 crystals



Formation of continuous film

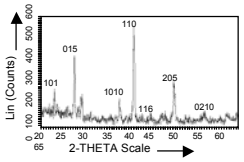


MWCNT array/TE material interface

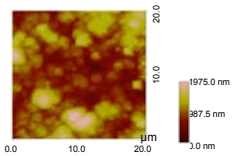


Magnified view MWCNT array/TE material interface

3(b). Polycrystalline Bi_2Te_3 film characterization

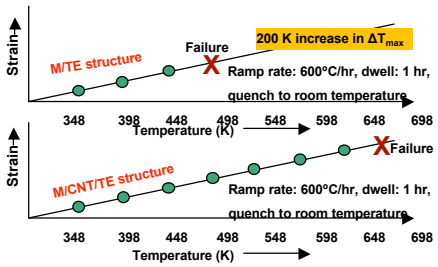


X-ray diffraction pattern for metal/CNT /TE sample

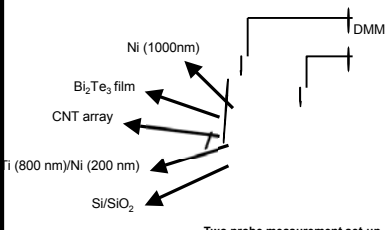


AFM scan of the electrodeposited film surface

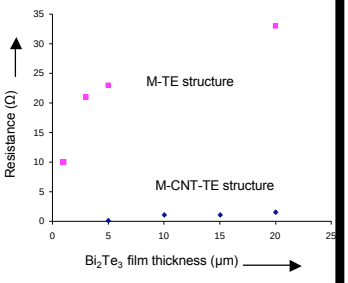
4 (a). Enhancement in thermomechanical compliance:



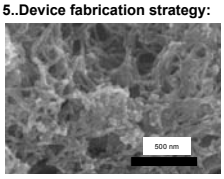
4(b). Effect on electrical contact conductance:



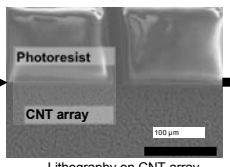
Two probe measurement set-up



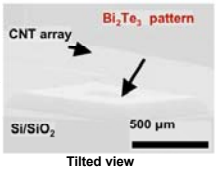
5..Device fabrication strategy:



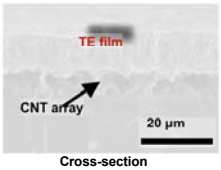
CNT array



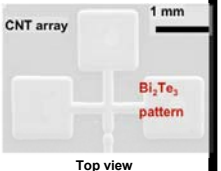
Lithography on CNT array



Tilted view



Cross-section



Top view

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Cooling Technologies Research Center

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