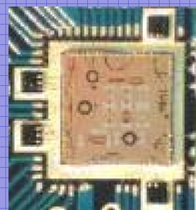
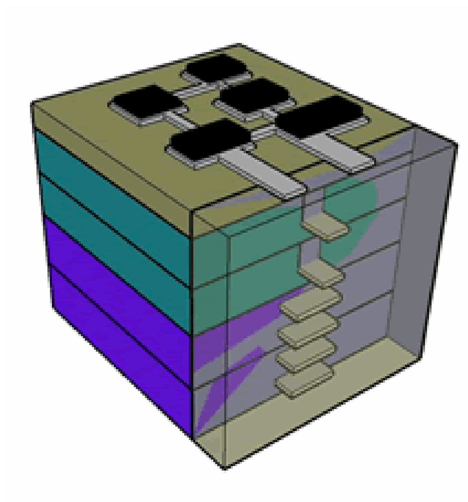
Wireless Sensor Networks

Low Power Radio

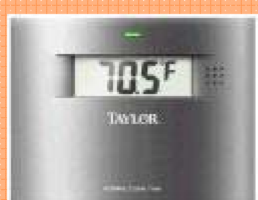


Energy Storage



"Picocube"

Sensor



Renewable Power Supply

Thermoelectric Energy Harvesting

Mike Koplow, Alic Chen, Dan Steingart

Presentation to the DR-TAC

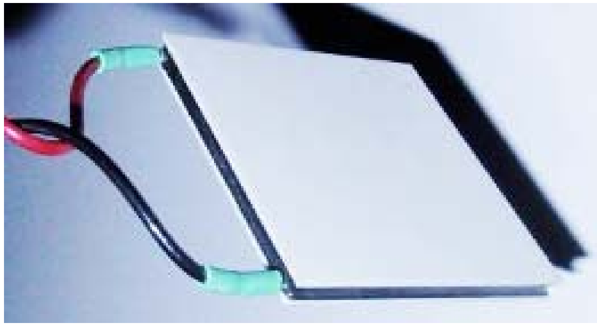
February 19, 2008

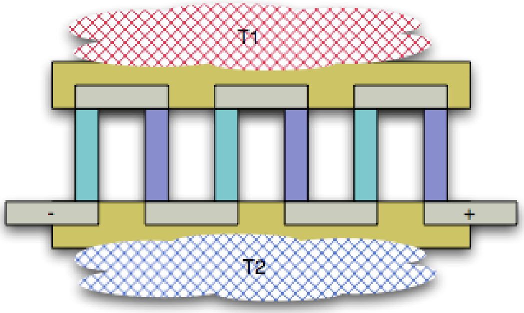
If you remember nothing else…

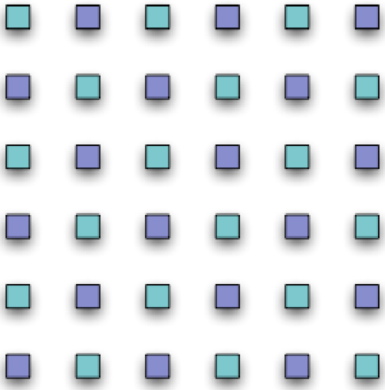
- Thermoelectric devices offer a method to convert waste heat into electrical power for small scale electronics
- Existing bulk processing techniques cannot be scaled
- Novel low cost printing methods are under development to create micro-sized harvesters

Why thermoelectric harvesters?

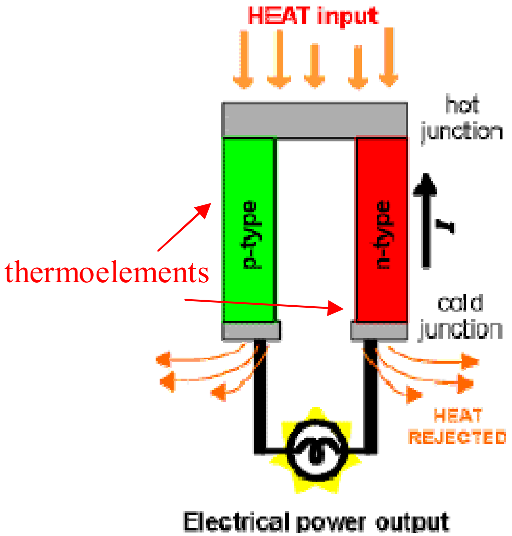
- Thermoelectric devices convert heat gradients into DC electrical power.
- Solid state, no moving parts.
- Scalable



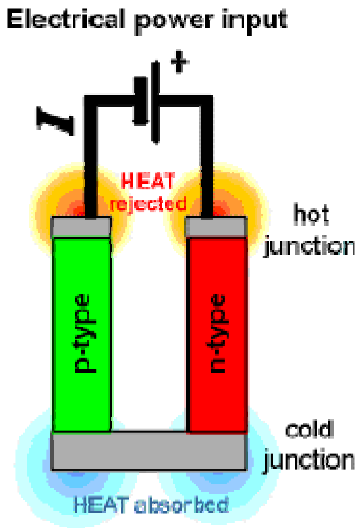




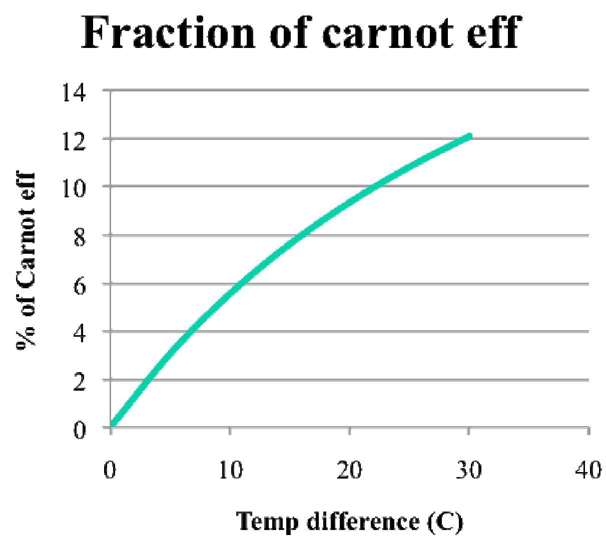
Fundamental Principles

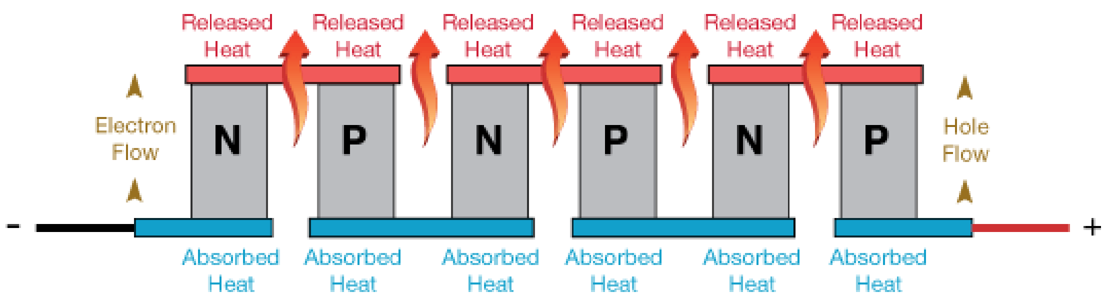


The Seebeck effect

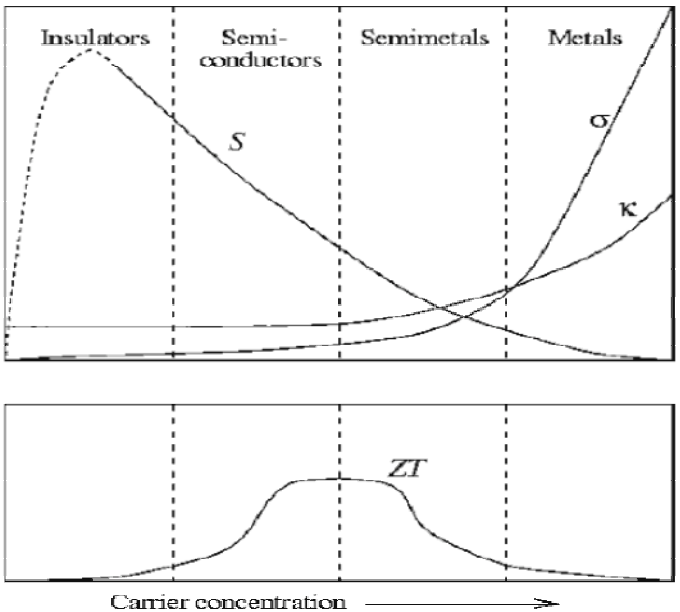


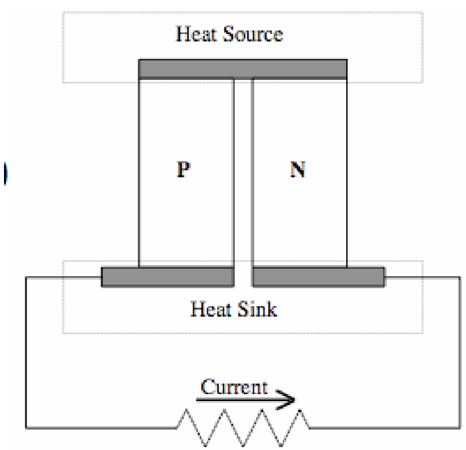
The Peltier effect





Materials





$$Z = \frac{\alpha^2 \sigma}{k}$$

Seebeck coeff

Electrical conductivity

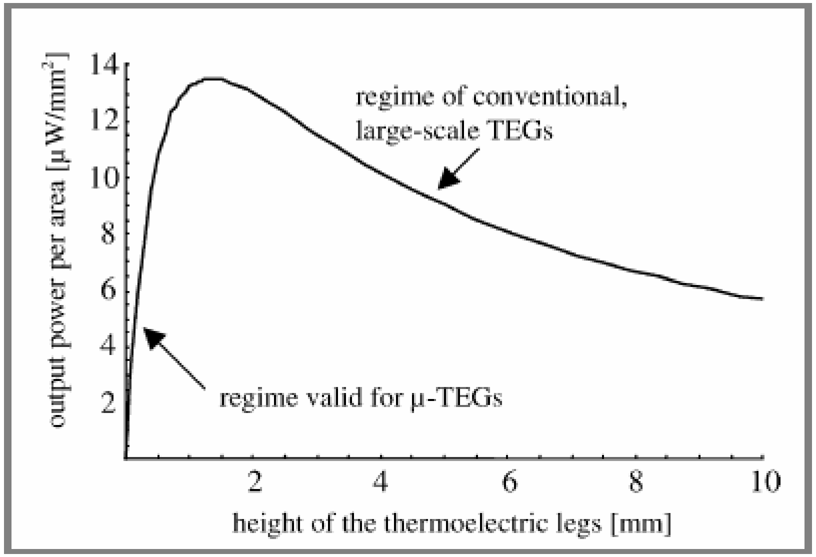
thermal conductivity

- Big EMF=high Seebeck coefficient
- Small internal losses = high electrical cond
- Small heat loss=low thermal cond

Best materials:

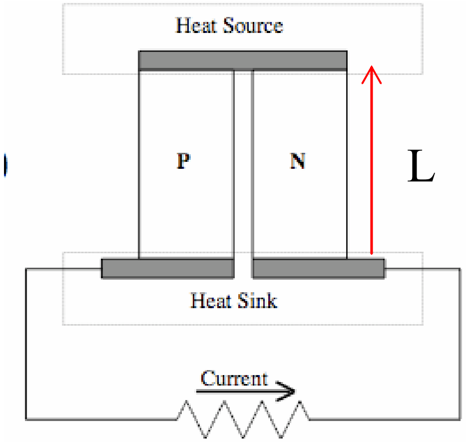
α= 200 microVolts/degree C

Scalability



$$P \propto \frac{A}{L}(\alpha \Delta T)^2$$

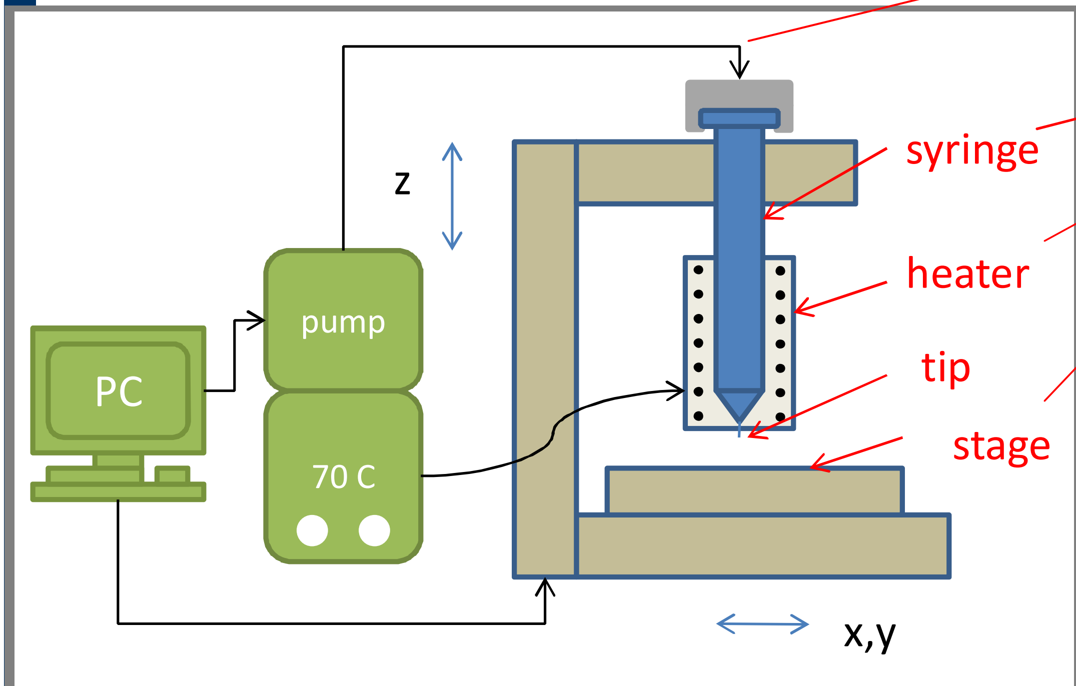
Cross section
Seebeck coeff
Length
Temp difference

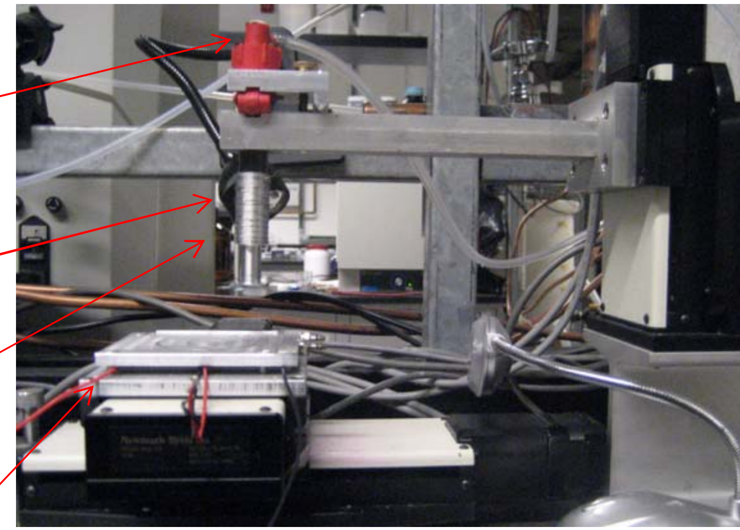


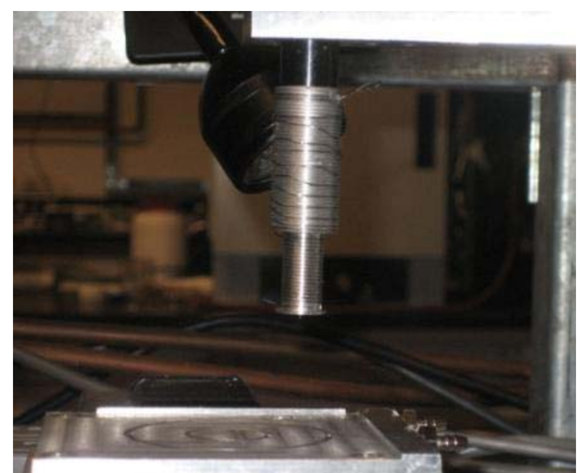
- Conventional bulk elements 1mm² in size (~25 per cm²)
- Optimal size ~0.1 – 0.2 mm long
- We want long thin elements, but how do we fabricate them?

Our approach – print it!

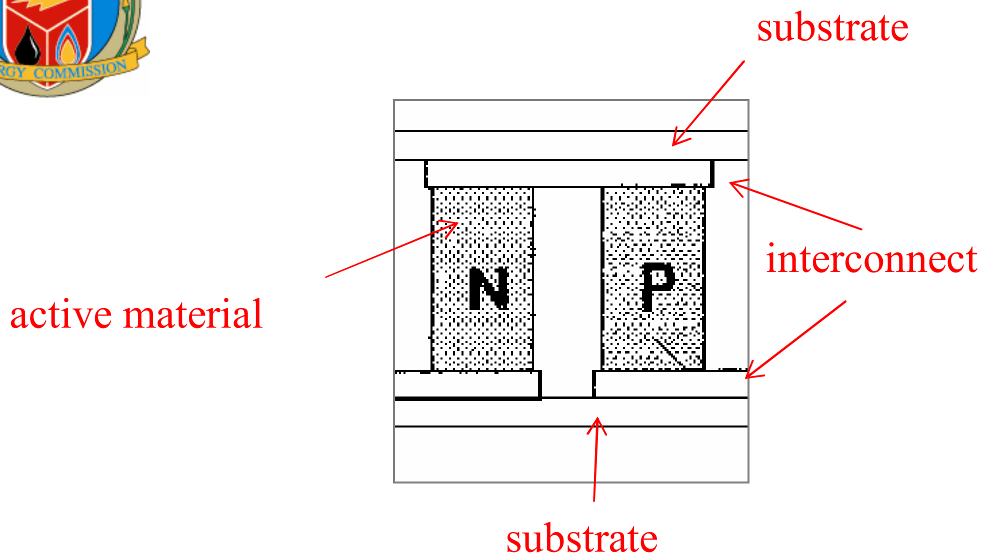
We want to keep the fabrication costs as low as possible:
Use a lost wax method to create molds and print into the molds.

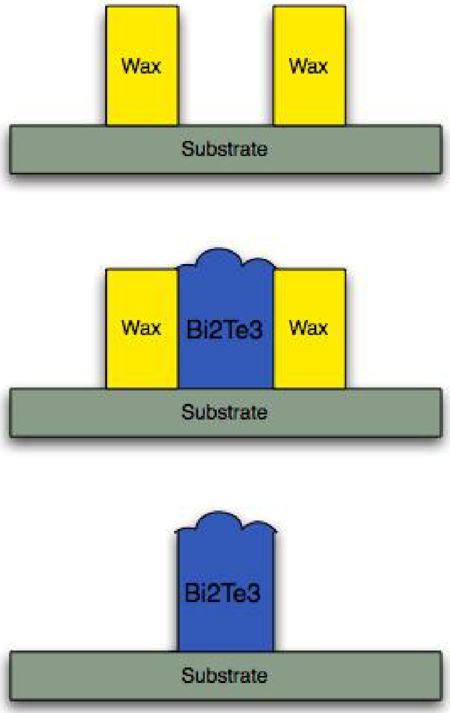






Printing Process flow diagram





Print bottom interconnect → Deposit mold → Print active material →

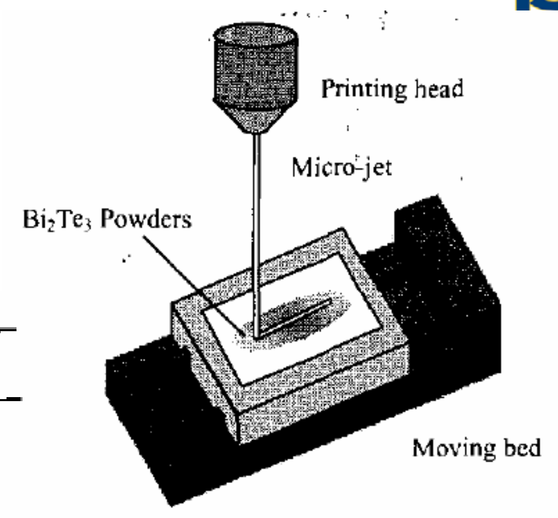
Print top interconnect → Adhere to top substrate → Release mold

Printed Materials previous results

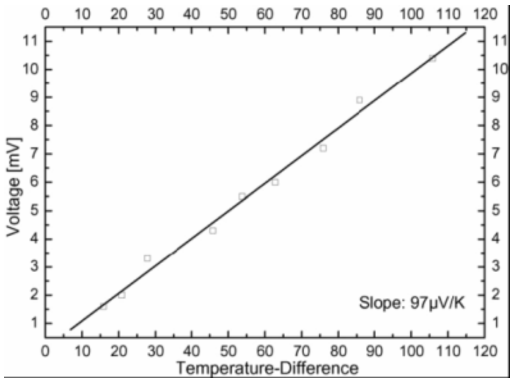
Kyushu Institute of Technology

Beam size: 0.95mm width, 12mm length, and 0.75mm thickness

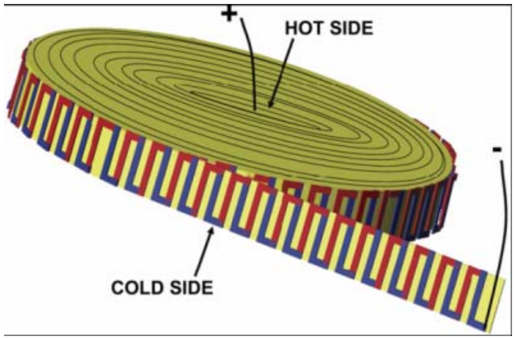
	S [μV/K]	λ [W/mK]	ρ [Ωm]
Single crystal [5]	227	1.73	1.95×10^{-5}
Sintered sample	126	0.36	1.09×10^{-4}



Institut fur Mikrotechnik Mainz (IMM), Germany



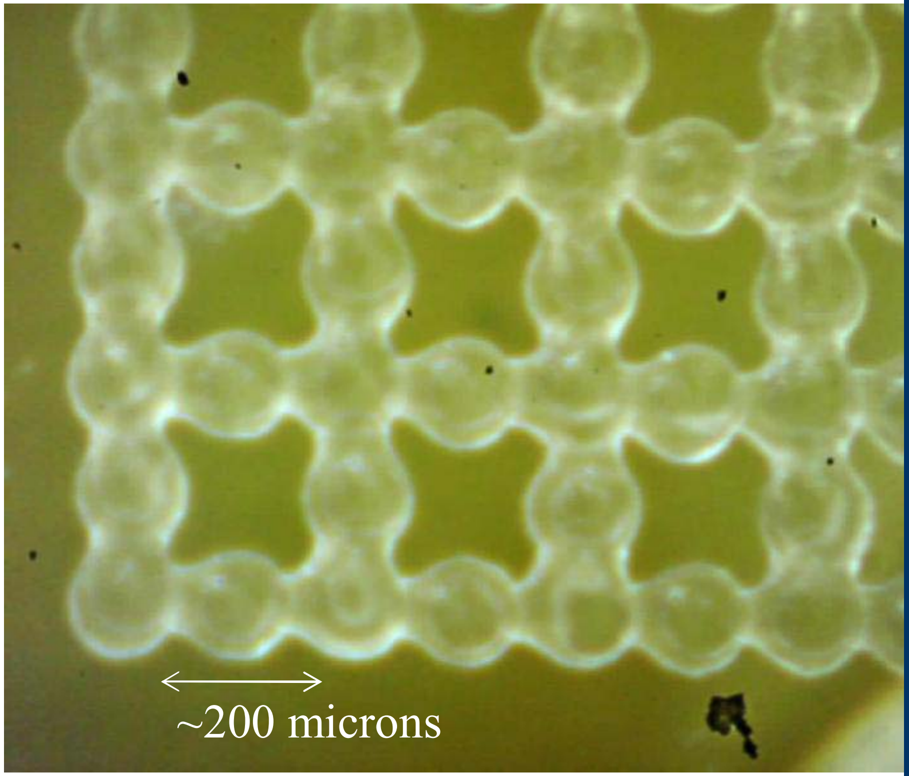
Screen printed micron layers of Bi-Sb

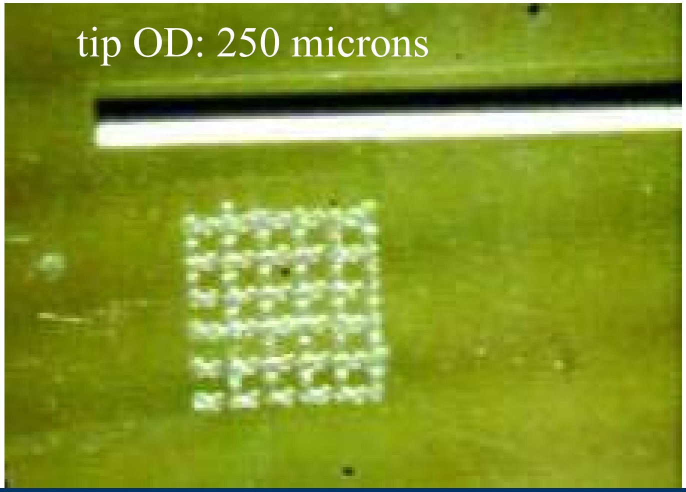


Bulk: 140 microV/K

Top: Miyazaki et al “Micro-fabrication of Bi2Te3 by using Micro-jet,” Proceedings of ICT2003, pp.641-643, (2003).
Bot: Weber et al, “Coin-size coiled-up polymer foil thermoelectric power generator for wearable electronics” Sensors and Actuators A 132 (2006) 325–330

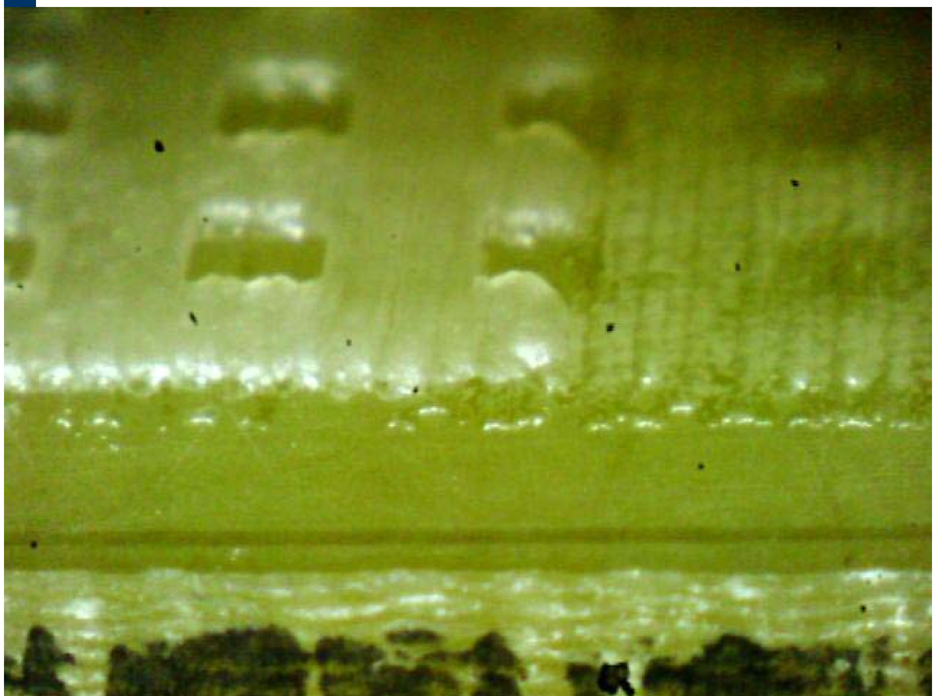
Initial Results

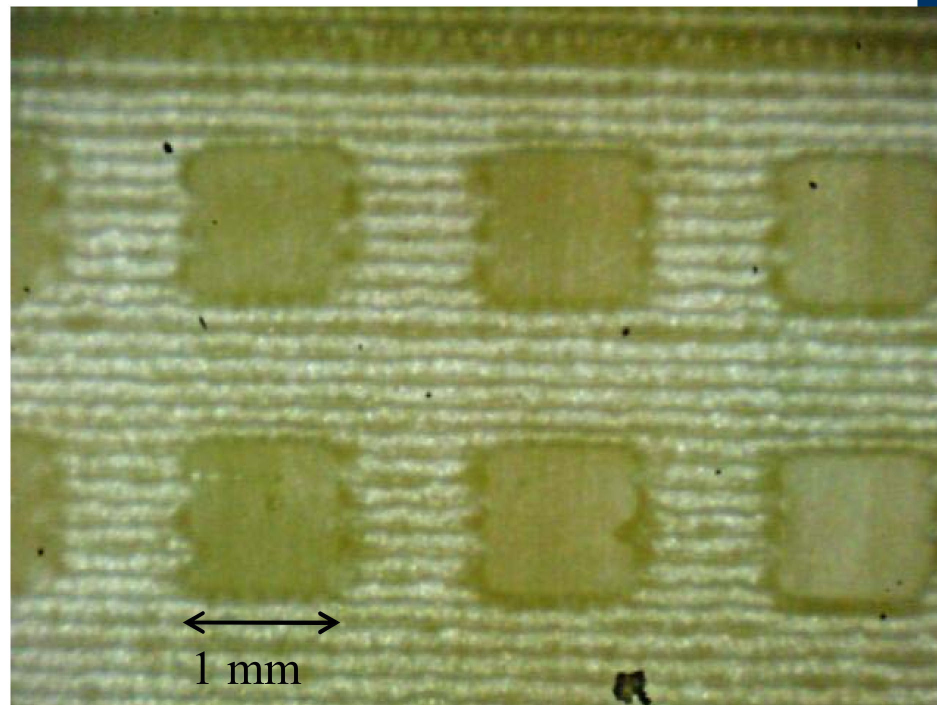




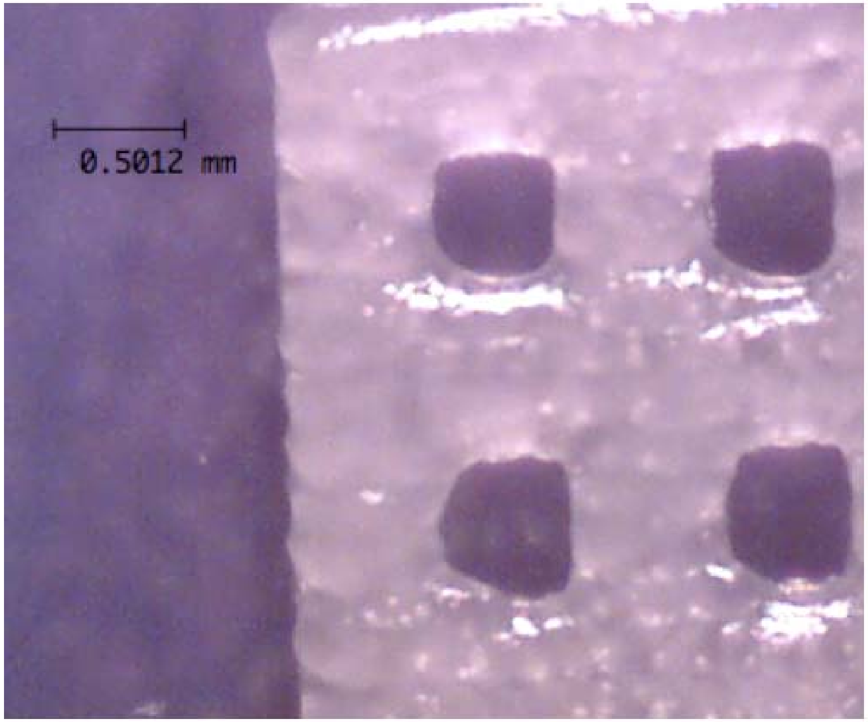
2:51 PM

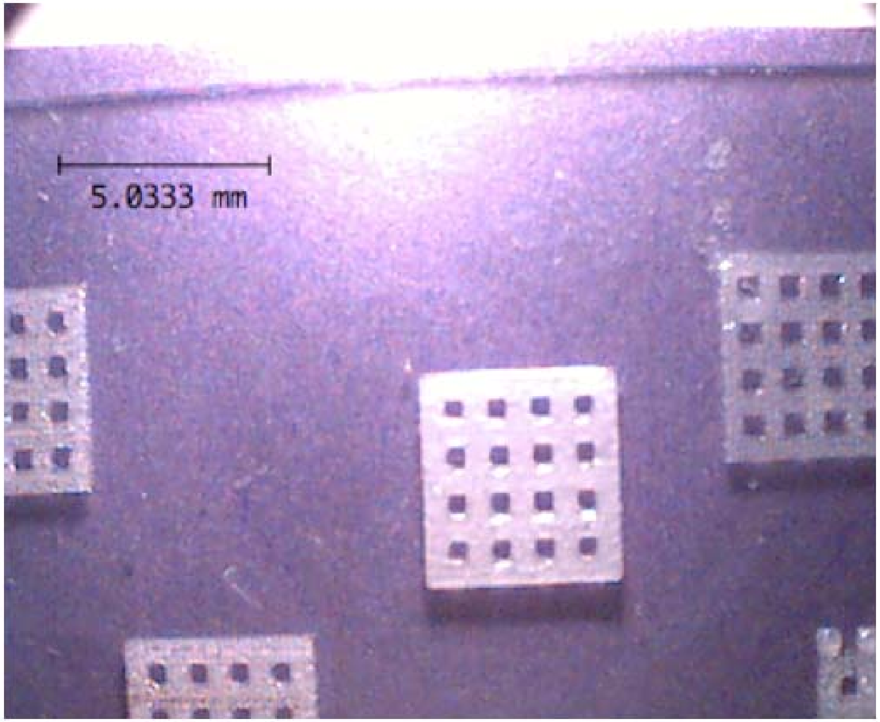
Printed solid structures





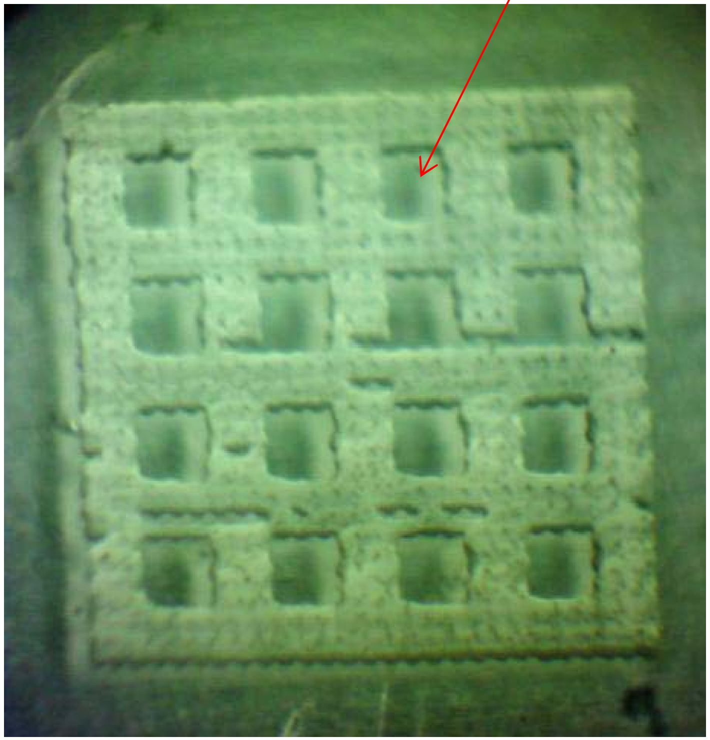
Printed solid structures



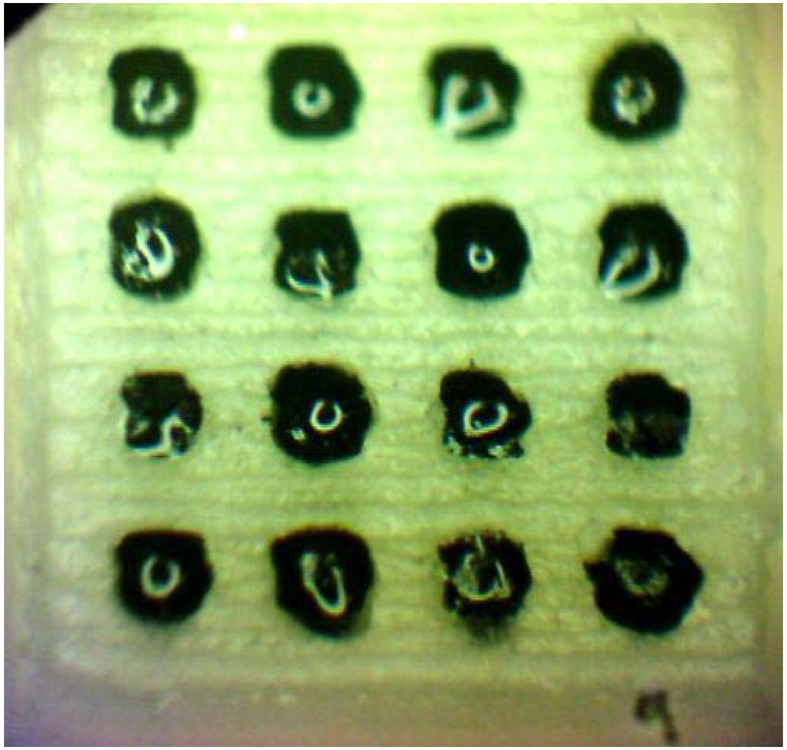


Printed solid structures

Holes are 500 microns in dia, 700 microns tall

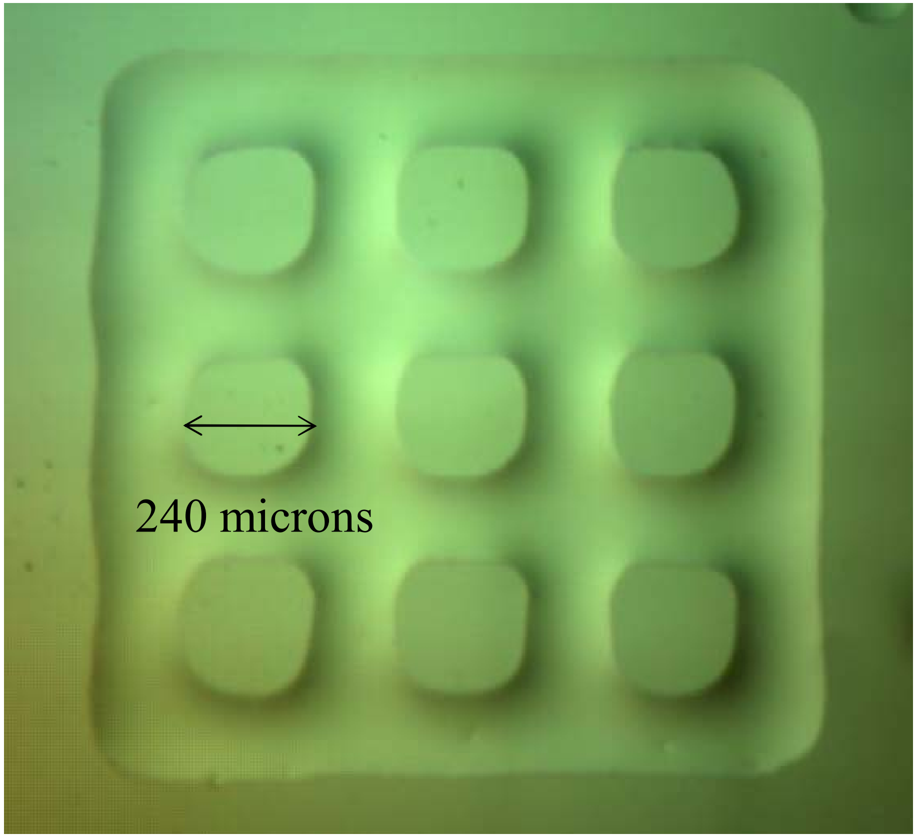


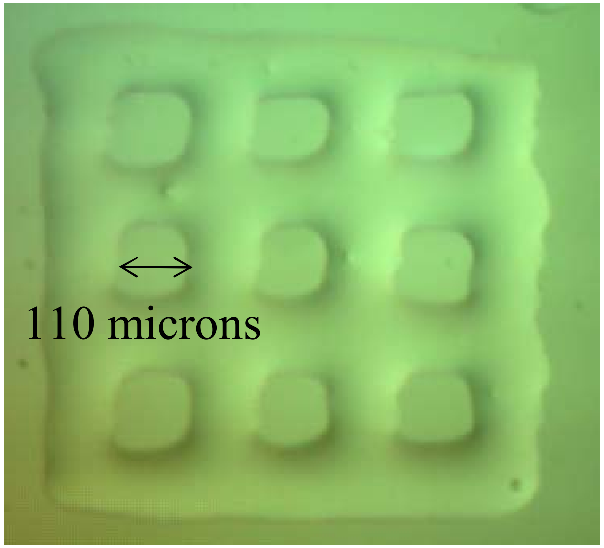
Open cavity



Filled mold

Permanent molds (PDMS)





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