Micro-thermoelectric cooler for the thermal management of photonic devices

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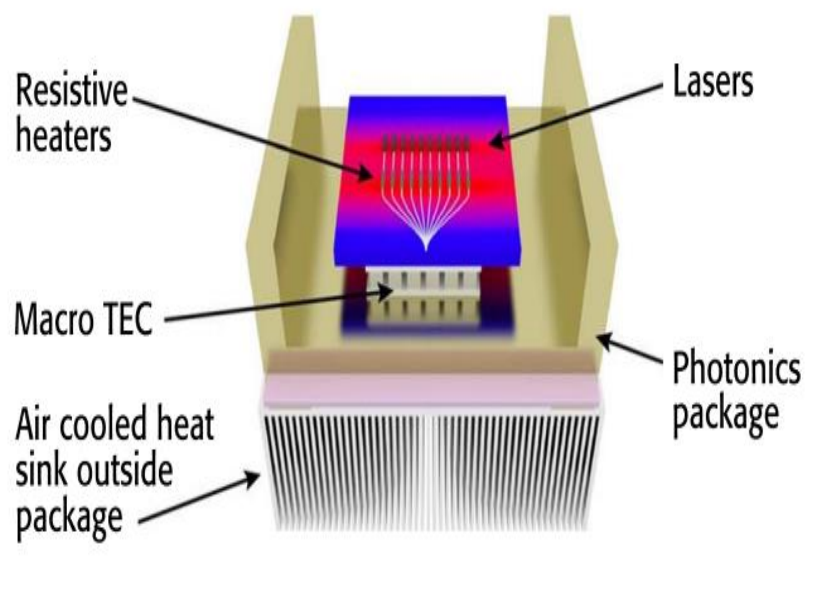
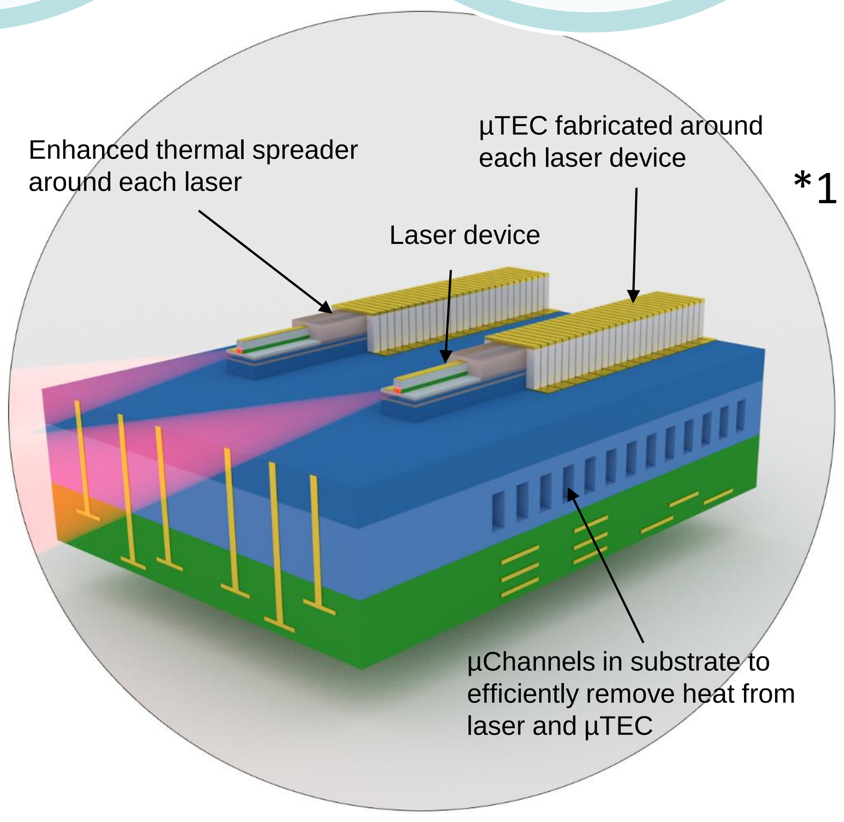
Getting ready to face the future

Data trafficking projected to increase rapidly

For higher efficiencies, performance and reliability, Photonic devices need **to be cooled down**

Photonic devices require a temperature precision better than ±0.1 °C





State-of-the art	TIPS proposed solution
Inefficient cooling	Direct and precise cooling
High power demand	Reduced power demands
High thermal load	Reduced TE material
Bulky design	High density integration

Figure of merit *ZT* and improving properties

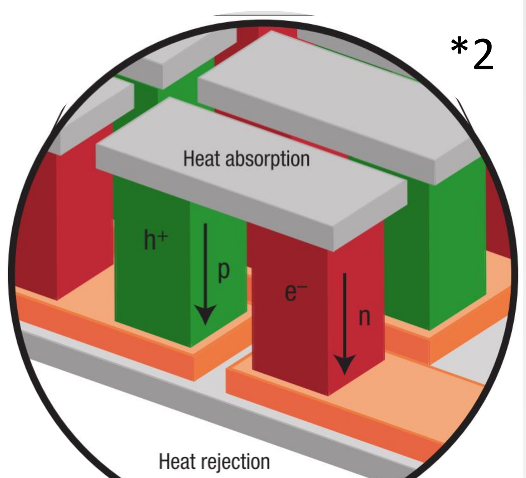
Seebeck coefficient — Electrical conductivity

$$ZT = \frac{S^2\sigma}{\kappa}T$$

Thermal conductivity

$$S = \frac{8\pi^2 k_b^2}{3eh^2}\,.m^*\,T\left(\frac{\pi}{3n}\right)^{2/3} \qquad \frac{1}{\rho} = e\,.n\,.\mu$$

Carrier density — Carrier mobility



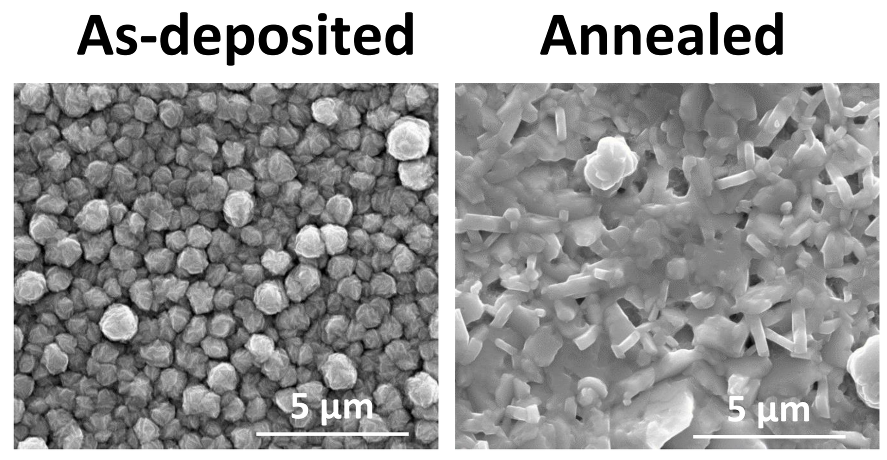
- Electrodeposition method is facile, economical and scalable to mass production (semiconductor fab compatibility).
- Materials: Bi-Te based p and n-type materials (best available material for near room temperature applications).

Improving thermoelectric properties of electroplated films

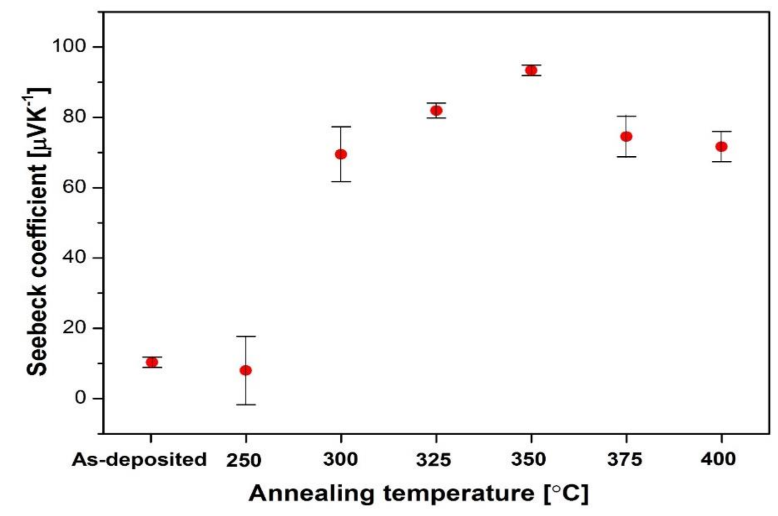
- **Additives**
  - ➢ Surfactant sodium dodecyl sulphate impact on p-type BiSbTe films studied.[3]
- **Annealing**
  - ➢ Enhancing TE properties by annealing of p-type BiSbTe with varying parameters.

References:
[1]Enright et al., Bell Labs. Tech. J., **19**, 31 (2014).
[2]Snyder et al., Nat Mater **7**(2): 105-114 (2008).
[3]S. Lal et al., ECS J. Solid State Sci. Technol., **6**, N3017 (2017).

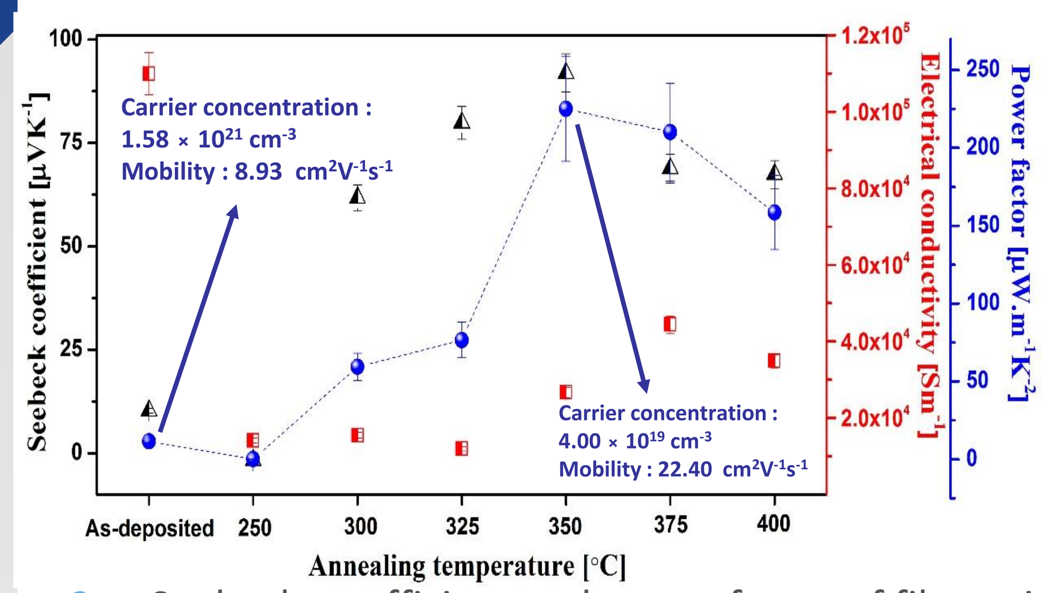
Material improvement by thermal annealing



1. Micrographs of as-deposited and 350 °C annealed films.



2. Seebeck values at different annealing temperatures.



3. Seebeck coefficient and power factor of films with different annealing temperatures

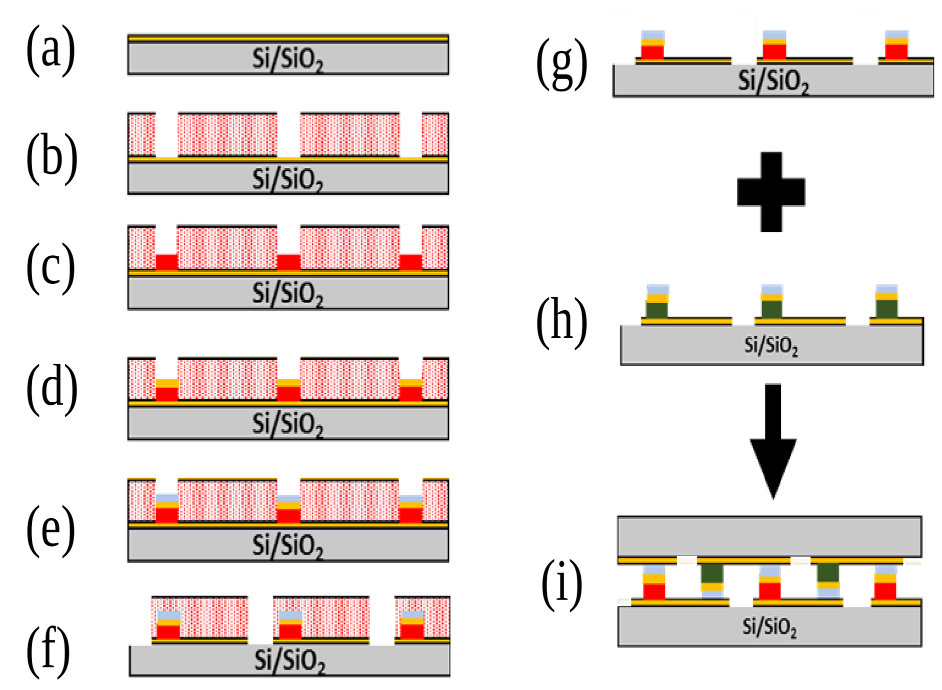
Conclusion I :

- Reduction of carrier concentration
- Improved Seebeck coefficient
- Increase in mobility

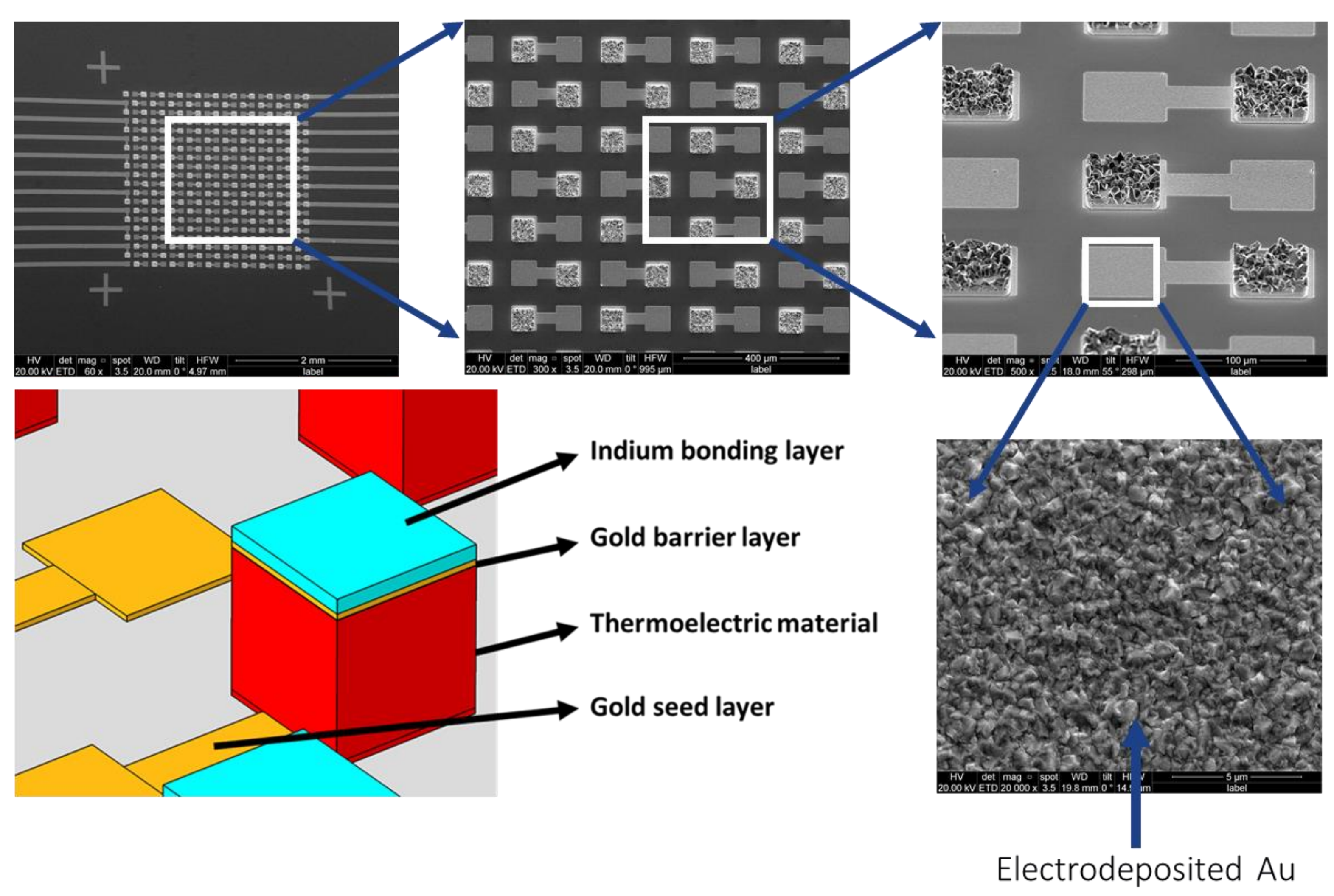
Device fabrication

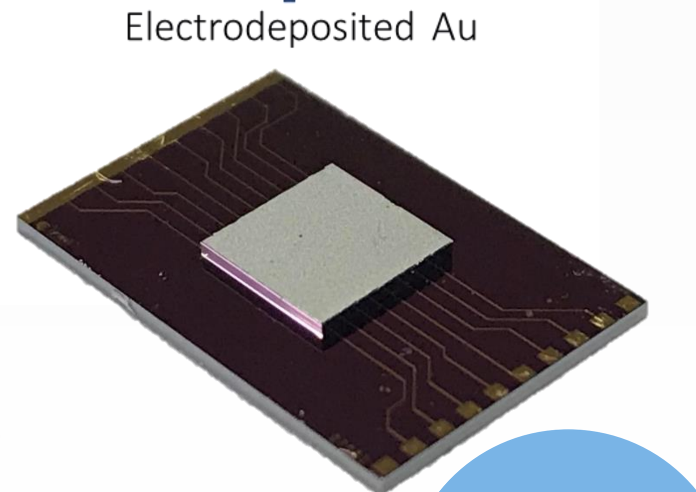
Micro-thermoelectric cooler/harvester

- Cost-effective fabrication
- Two mask process
- Flip-chip bonded device
- Electrodeposited Au and In interconnect and bonding materials respectively



4. Process flow of micro-thermoelectric device





Future work

- Material improvement using doping.
- Characterization of device.

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