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HL 49.3

Hybrid Si/Al_2O_3 thin films of the electron crystal – phonon glass type

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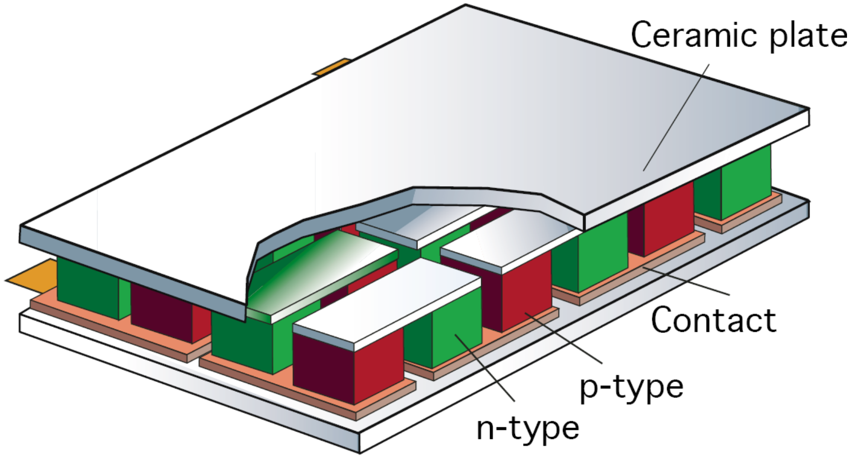
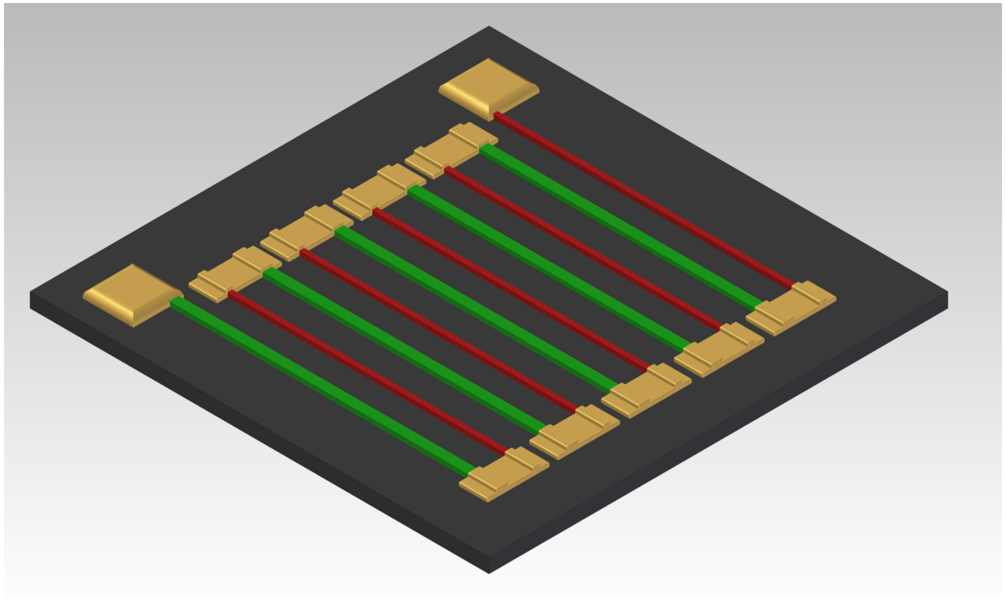
Thermoelectricity
Benefits of Thin Film Thermoelectrics



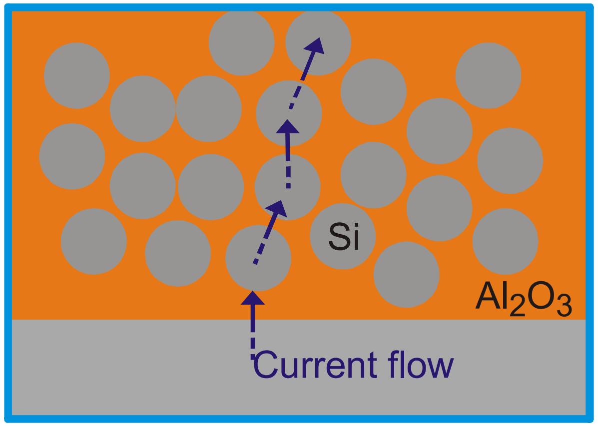
– Expensive in time and money
– Requirement of p- and n-leg

+ High power output

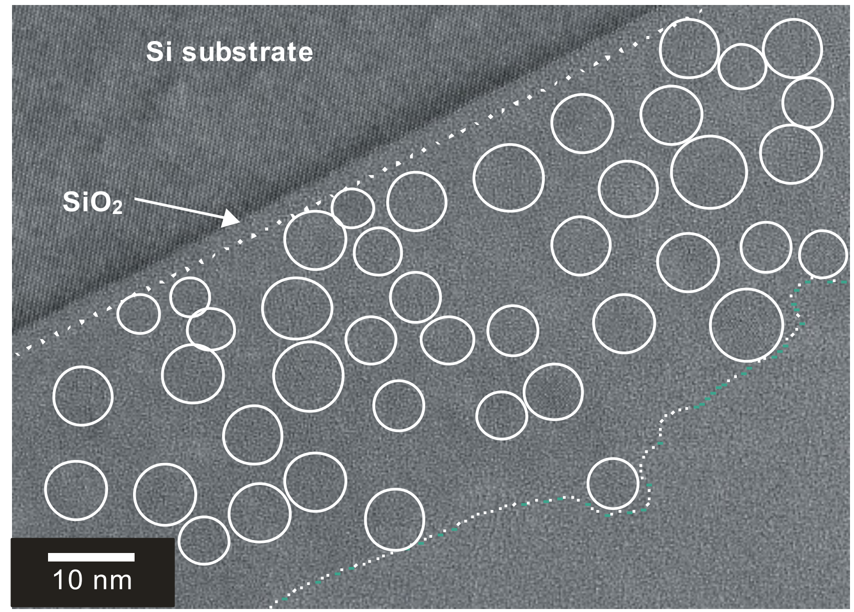


- Assembling by means of lithographic patterning
- wide scope of geometric properties
- In process manufacturing
- Very interesting for sensor applications

Thermoelectricity
Electron Crystal – Phonon Glass



Phonon blocking by Nanoclusters. Electrical current flow is enabled by electron hopping.



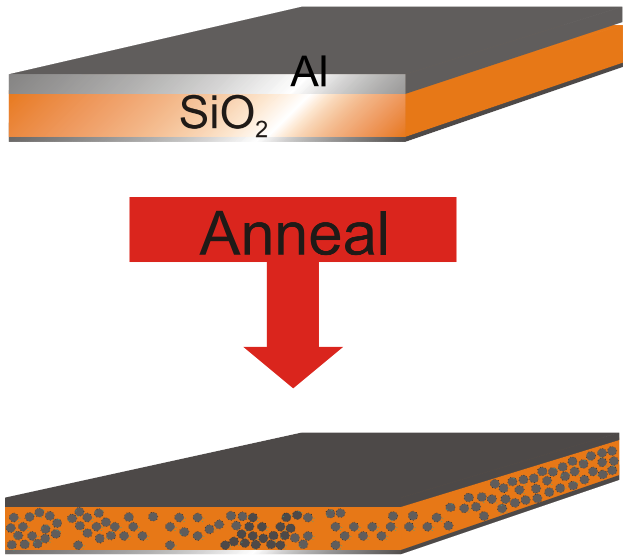
- Thermoelectricity

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

$$\eta_{\max} = \frac{T_h - T_c}{T_h} \frac{\sqrt{Z\overline{T} + 1} - 1}{\sqrt{Z\overline{T} + 1} + T_c / T_h}$$

Experimental Details
Synthesis

$$3\,SiO_2 + 4\,Al \xrightarrow{\text{temperature}} 3\,Si + 2\,Al_2O_3$$



Steps of producing a hybrid thin film

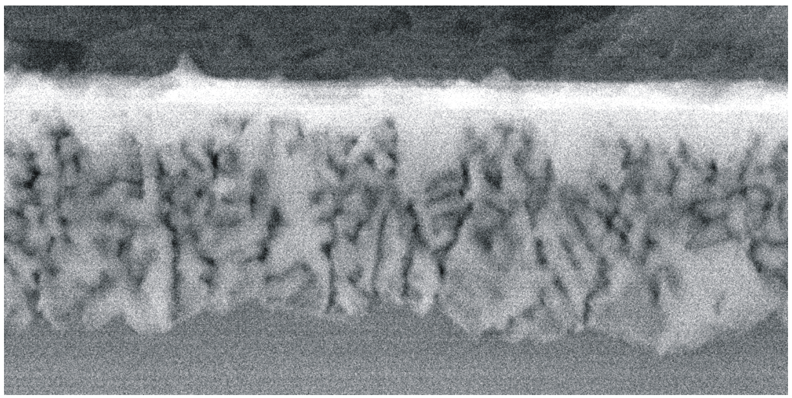
- Cleaning
- Depositing Aluminum on top
- Annealing
- Etching of remaining Al

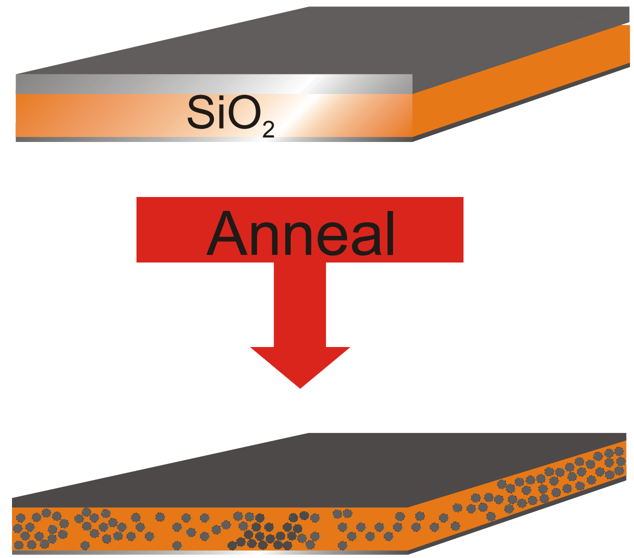
- Physochemical reaction time: approx. 1h / 200 nm

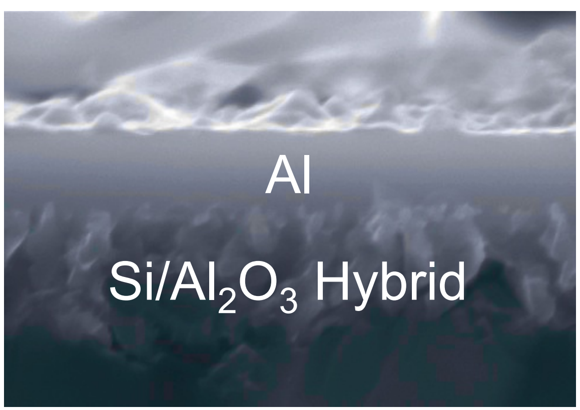
Experimental Details

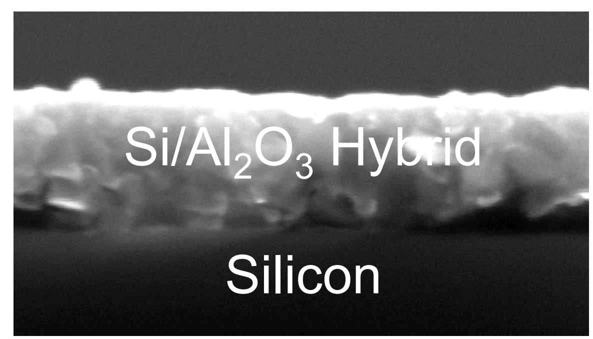
Synthesis

$$3\,SiO_2 + 4\,Al \xrightarrow{\text{temperature}} 3\,Si + 2\,Al_2O_3$$









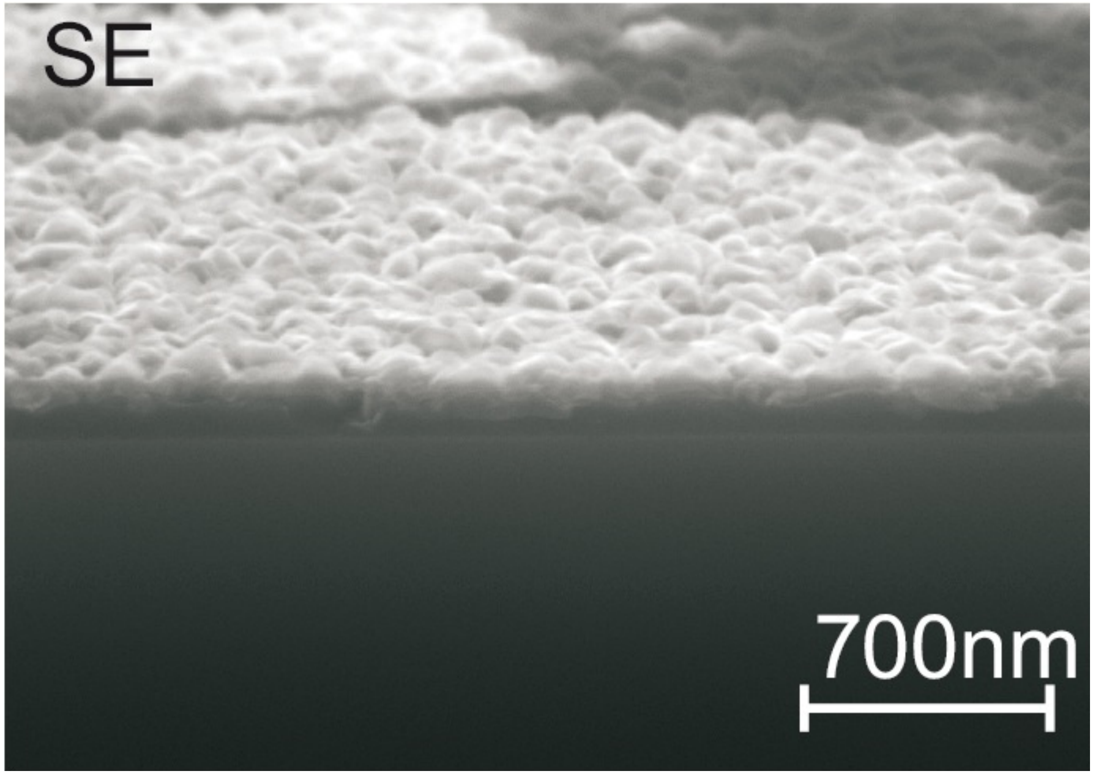
Experimental Details

Subtrates

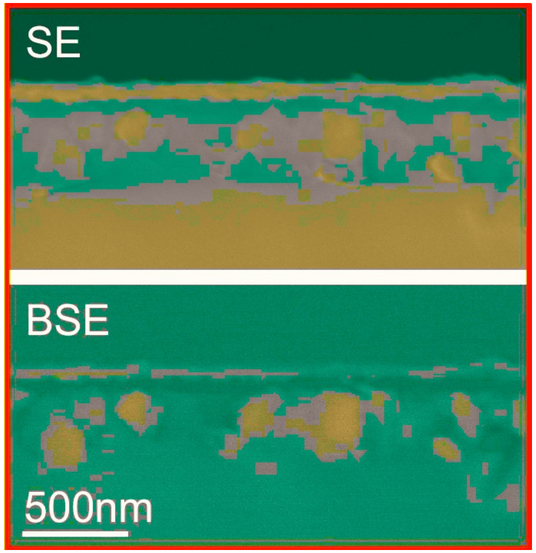
- UV grade fused silica (FS)
- Float glass (FG)
- Thermal oxidized silicon (TDS)
- Thermal evaporated silicon oxide (TES)

- High Purity
- Cheap/Mass Production
- IC integration with high purity
- Cheap IC integration and mass production

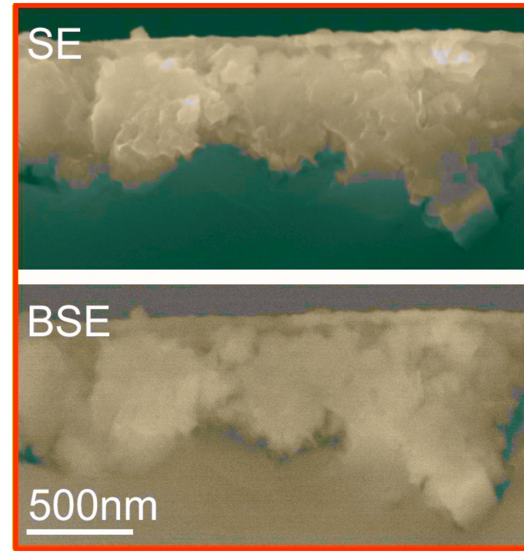
Microstructure
Surface Topology



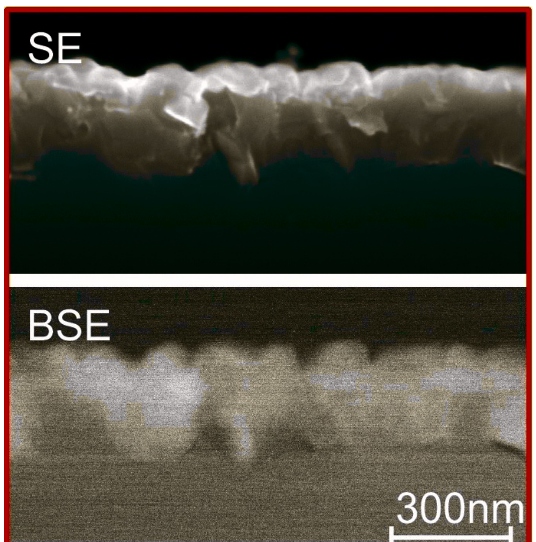
Microstructure
SEM cross sections



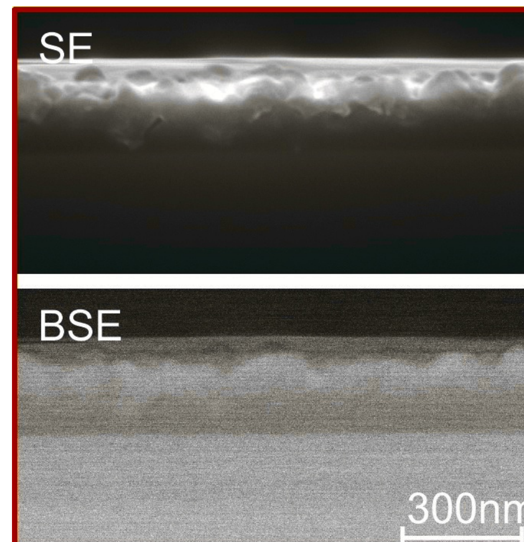
Fused silica



Float glass

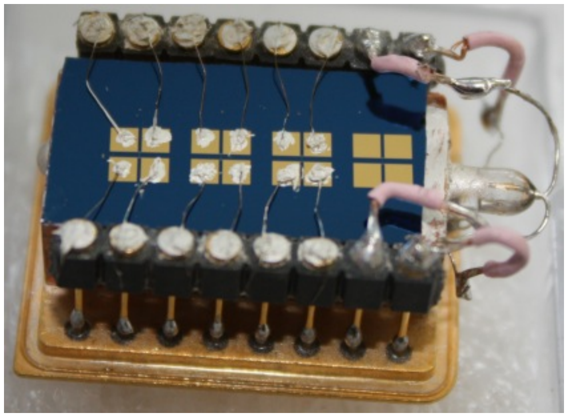


Thermal oxidized silicon

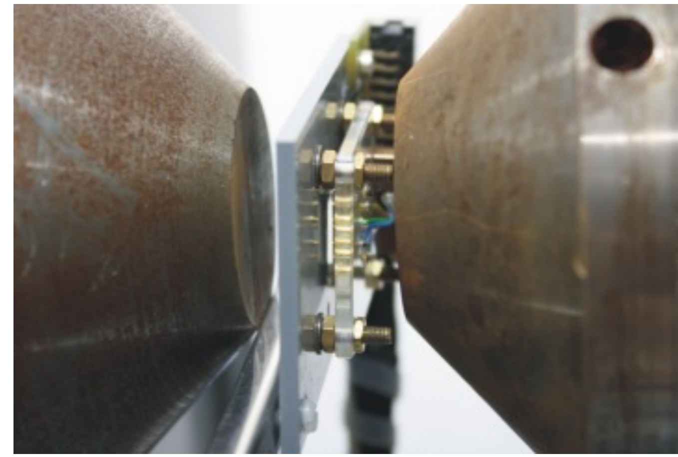


Thermal evaporated silicon oxide

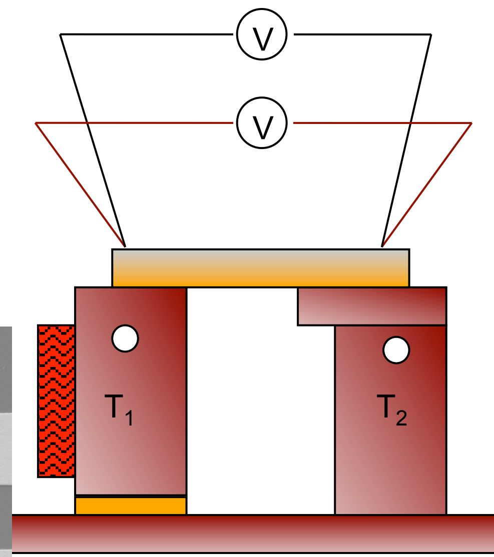
Experimental Details
Characterization Techniques



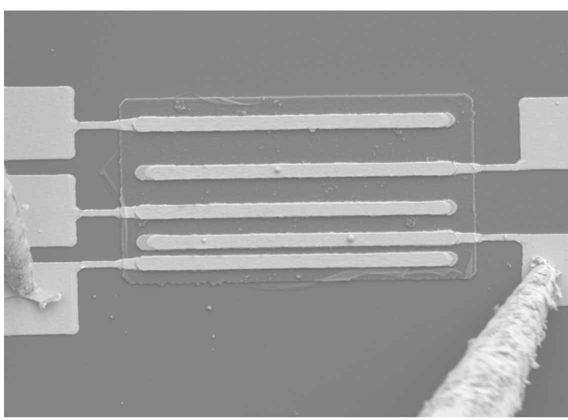
Thermal conductivity
by 3-omega



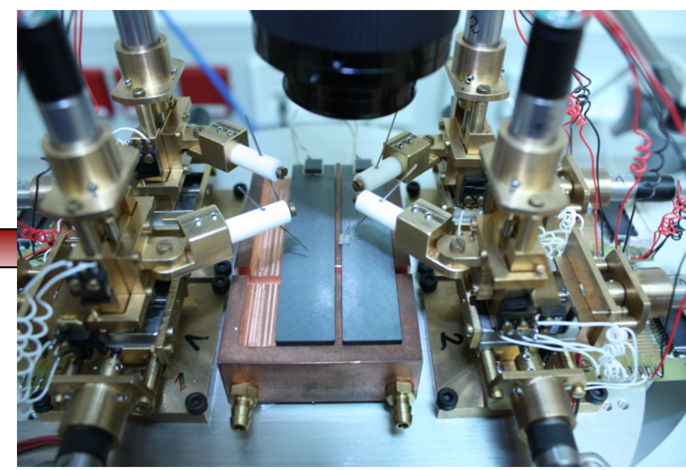
Hall measurements



Seebeck measurements

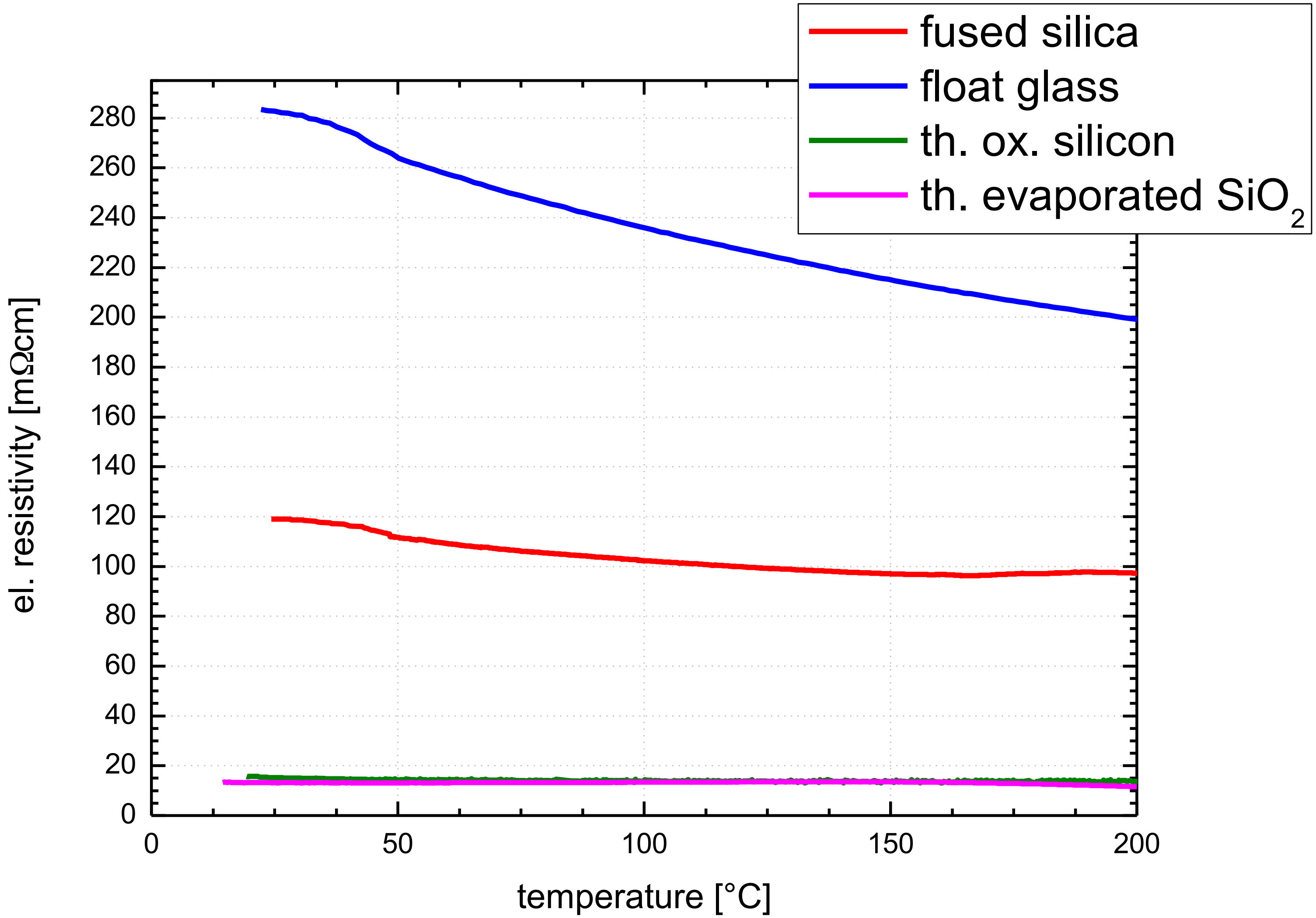


Contact resistivity by TLM

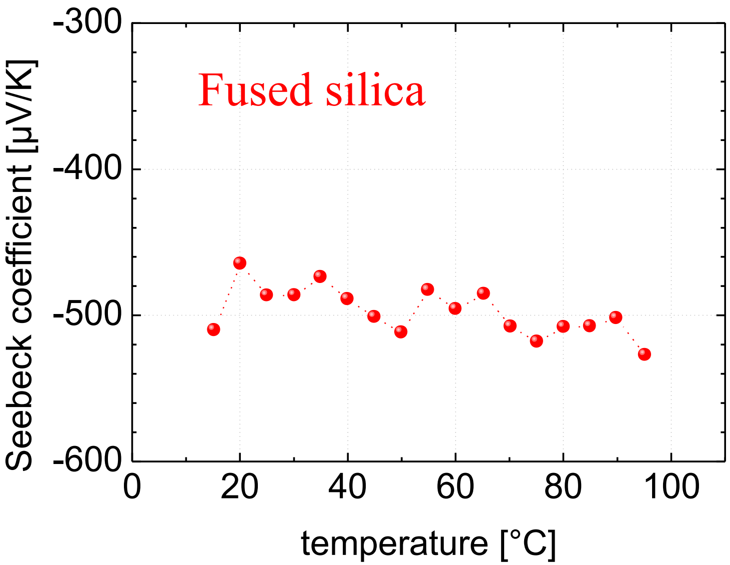


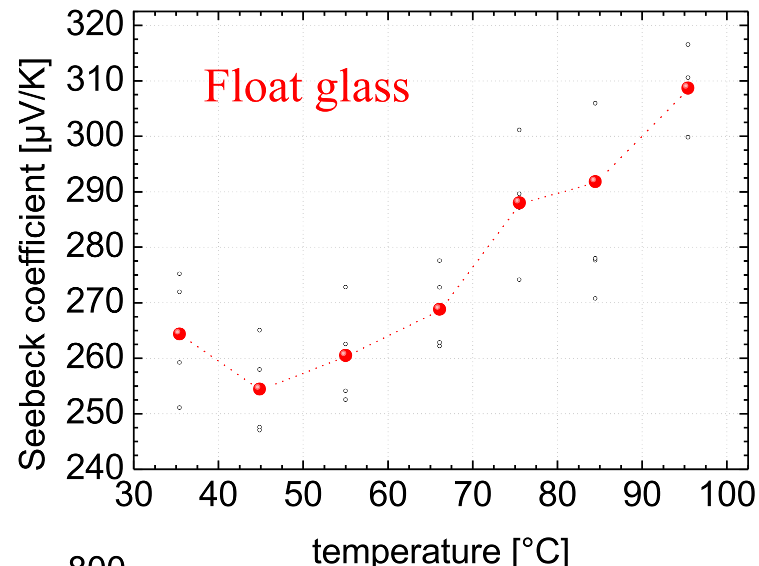
Electrical conductivity in a 4-probe-setup

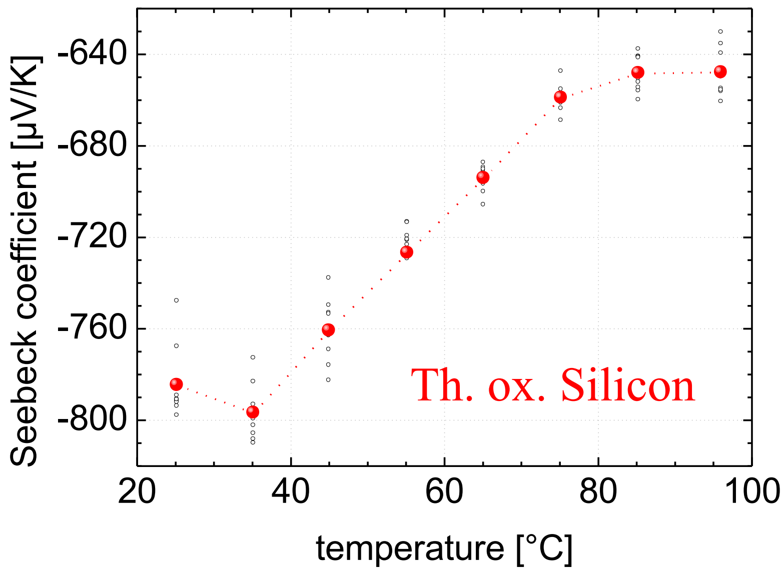
Results
Electrical Resistivity

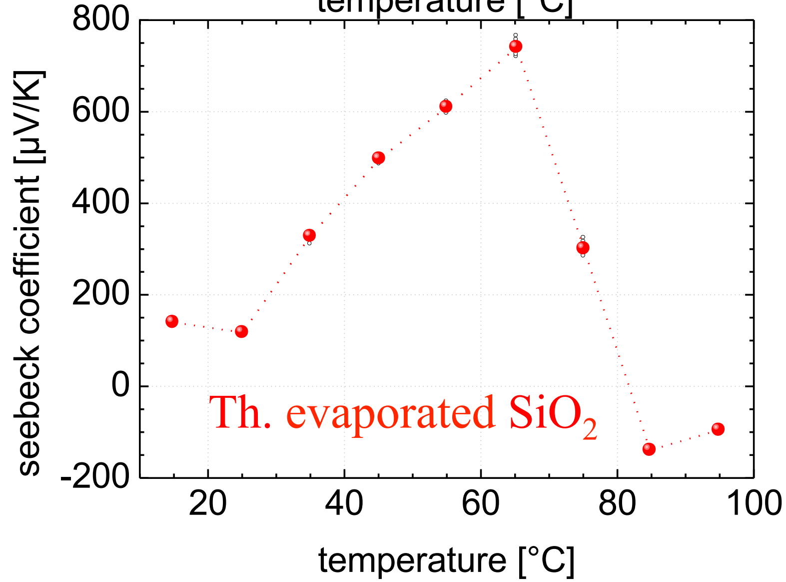


Results
Seebeck Coefficient

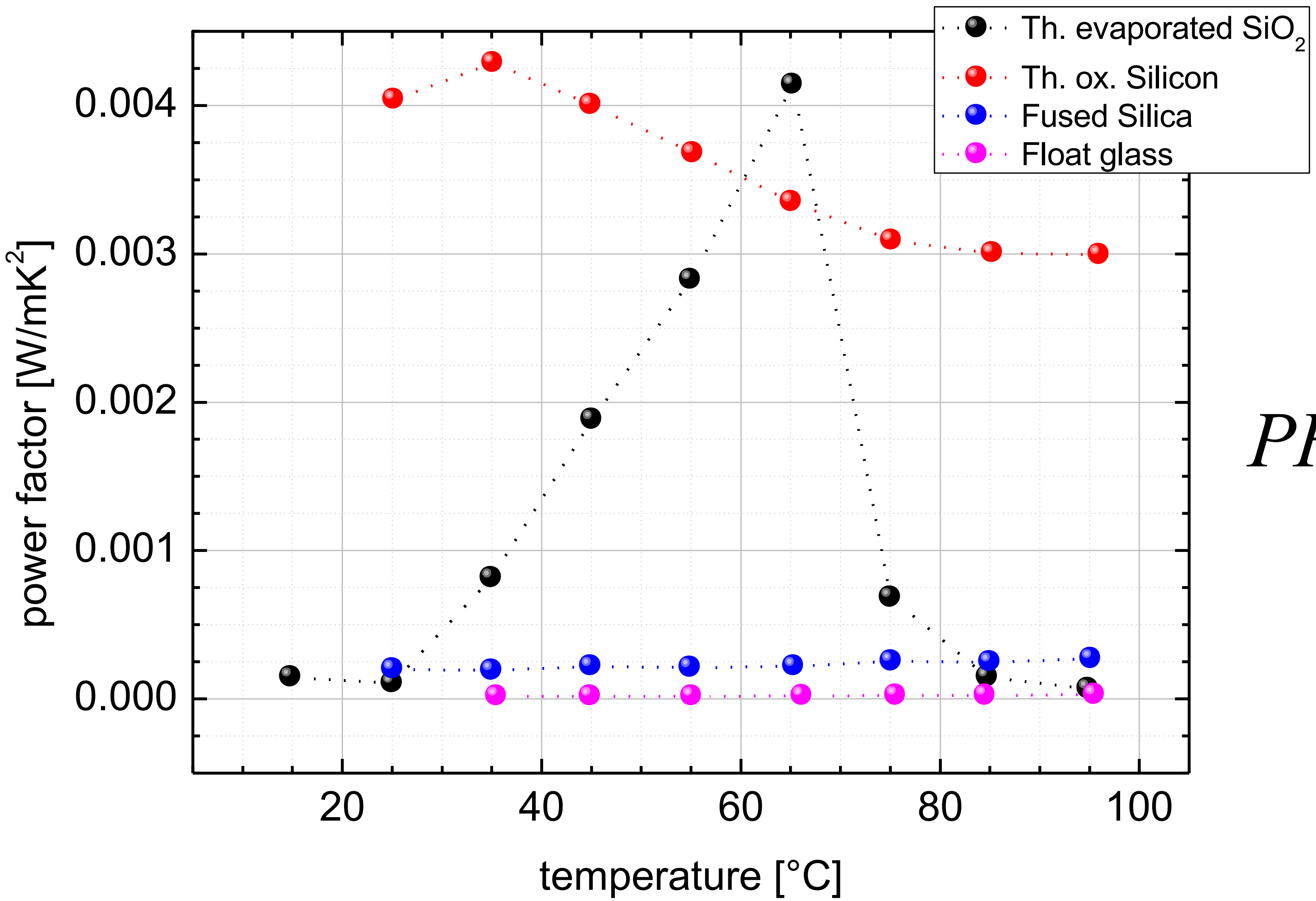






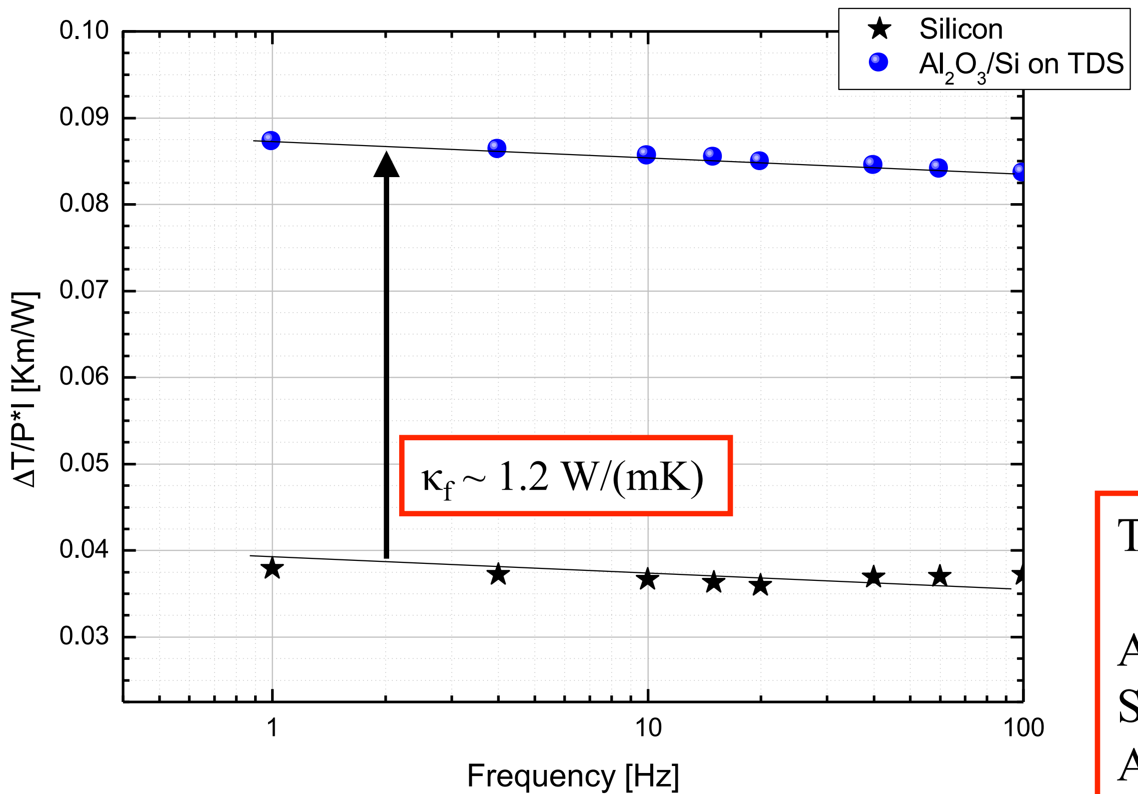


Results
Power Factor



$$PF = \alpha^2 \sigma$$

Results
Thermal conductivity and ZT



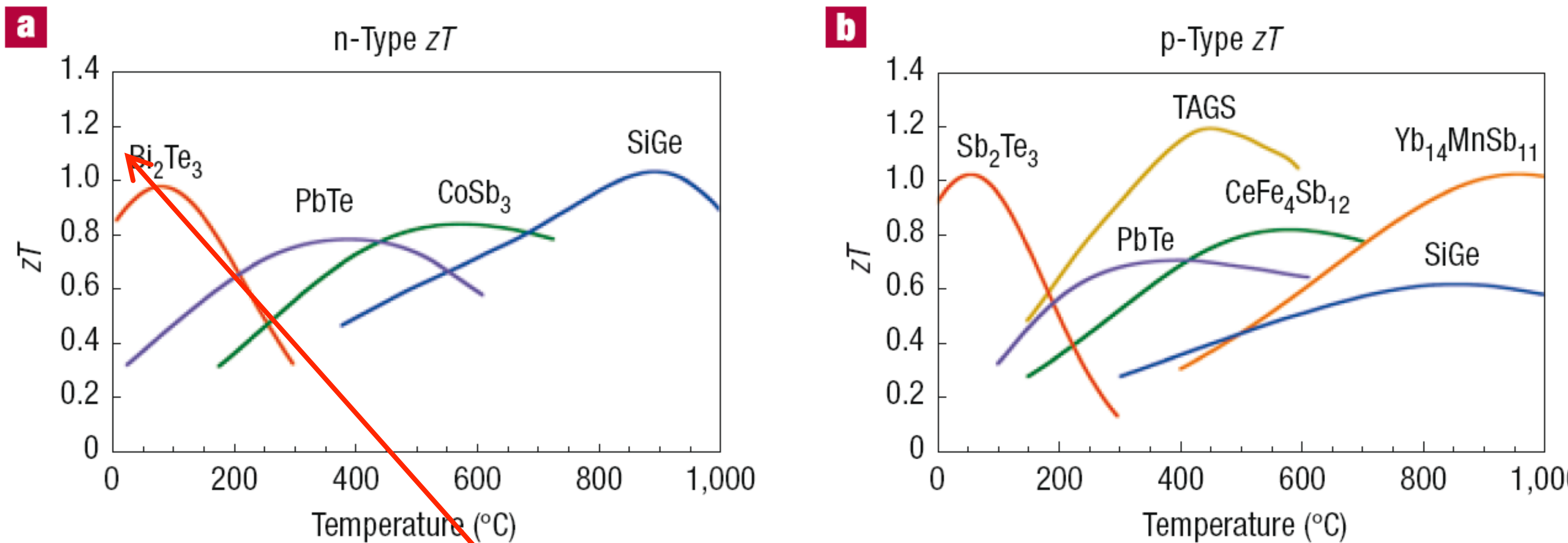
$$\Delta T_f = \frac{P}{l}\frac{1}{\kappa_f}\frac{t}{2b}$$

Thermal Conductivities:

Aluminum: 236 W/(mK)
Silicon: 148 W/(mK)
Aluminum Oxide: 28 W/(mK)
Silicon Oxide: 1.4 W/(mK)
Glass: 0.76 W/(mK)

Results

Figure of Merit ZT



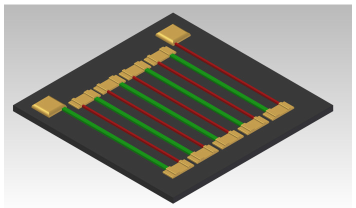
J. Snyder, Nature **7**, 105 ff. (2008)

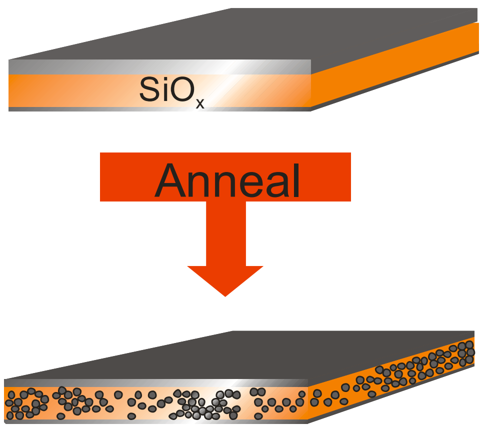
Substrate: TDS

$ZT \sim 1.1$ @ 310K

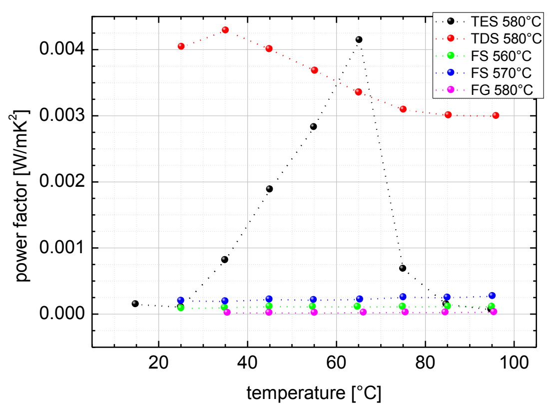
$$ZT = \frac{\alpha^2 \sigma}{\kappa} T$$

Conclusion





- The material is fully integrable in Si-Technology
- Its Production is cheap, easy and non toxic
- The power factor is high enough for common applications
- The efficiency is close to the high efficiency thermoelectric materials



Substrate: TDS

$ZT \sim 1.1$ @ 310K

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