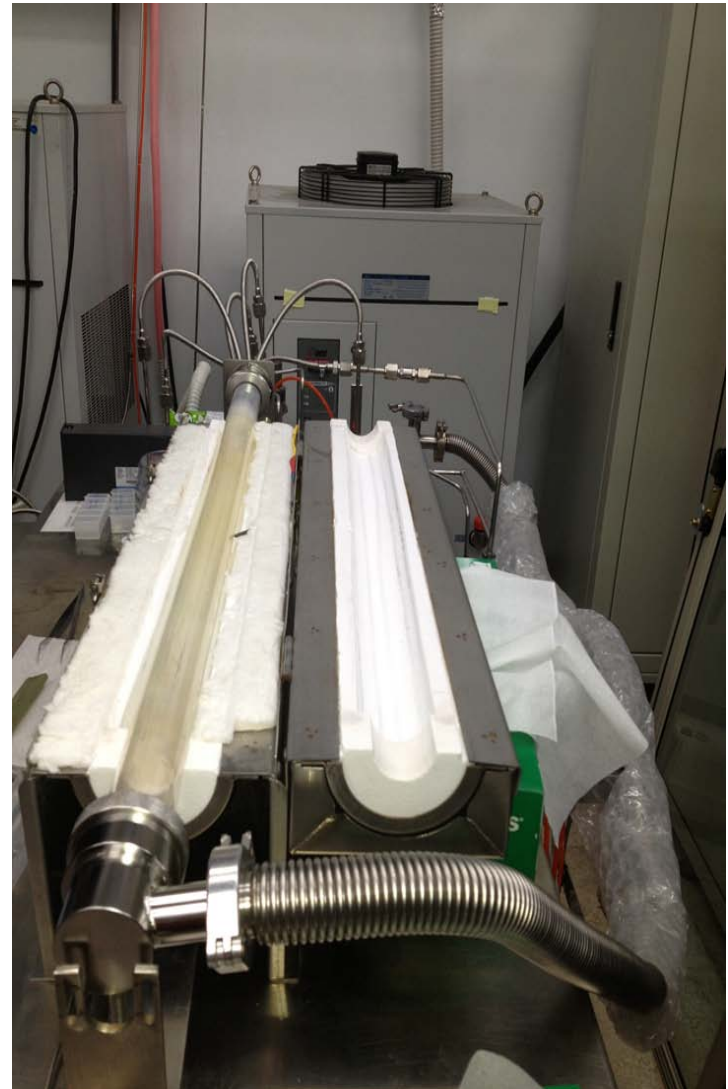


Atomic Layer Deposition (ALD)

- This technique is a thin film deposition technique.
- By keeping the precursors separate throughout the coating process, atomic layer control of film growth can be obtained as fine as $\sim 0.1 \text{ \AA}$ (10 pm) per cycle.
- Application: Atomic layered - Metal oxides, such as Zinc Oxides (ZnO) and Aluminum Zinc Oxide (AZO).



RF Sputter machine



- Application: Deposition of metallic layers (Cu, Zn, Sn), and metal oxide layers(ITO, ZnO).

Selenization Chamber

- Application: CIGS, CZTSe, CIS Solar Cells.



Electron cyclotron resonance plasma enhanced chemical vapor deposition (ECR CVD)

In semiconductor industrial, ECR-CVD is widely used for preparing dielectric film and for patterned etch purpose. The advantages of the ECR-CVD system are a high plasma density at low-pressure conditions in the mTorr-range.

- **Materials prepared in our lab using ECR-CVD (some examples):**
- Preparation of polycrystalline SiCN film ^[1]
- Preparation of nanotips array template for various application
- Different materials with nanotips structure were prepared, such as single-crystal silicon (Si); polycrystalline silicon (poly-Si); epitaxial gallium nitride (GaN) film on sapphire; single-crystal gallium phosphide (GaP); sapphire; and aluminum.^[2]



Electron cyclotron resonance plasma enhanced chemical vapor deposition (ECR CVD)

- For various application:

(1)Field emission ^[3]

(2)Broad-band antireflection (Vis-IR)
 $R \ll 0.1 \%$ ^[4]

(3) High potential in molecular sensing via SERS was demonstrated. ^[5]

(4)Electrically driven light emission under a low voltage in nanotip LED. ^[6]

- [1] Kuei-Hsien Chen et al., Thin solid films 355, 205 (1999).
- [2] Chih-Hsun Hsu et al., Nanoletter 4, 471 (2004).
- [3] Hung-Chun Lo et al., Appl. Phys. Lett. 83, 1420 (2003).
- [4] Yi-Fan Huang et al., Nature Nanotechnology 2, 770 (2007).
- [5] Surojit Chattopadhyay et al., Chem. Materials 17 (3), 553 (2005).
- [6] Ya-Ping Hsieh et al., Nanoletter 9, 1839 (2009).



Thermal CVD

Application : Growth of III-V semiconductor materials, such as GaN.
Or provide inert atmosphere(Nitrogen, argon) annealing process.

ZEM-3



Seebeck effect

(Power generation application)

$$S = \Delta V / \Delta T$$

Peltier effect

(Cooling application)

Measure Seebeck coefficient and thermal conductivity coefficient

ZT Figure of Merit

$$ZT = \frac{S^2 \sigma T}{\kappa_{lattice} + \kappa_{electronic}}$$

Electron - **Phonon**

S Seebeck Coefficient = $\Delta V / \Delta T$

High in Crystalline Semiconductor

$$S = \frac{8\pi^2 k_B^2}{3eh^2} m^* T \left(\frac{\pi}{3n} \right)^{\frac{2}{3}}$$

Carrier Concentration
Tuning

σ Electrical Conductivity

High in Crystalline Metal

$$\sigma = ne\mu = \frac{ne^2 \tau}{m^*}$$

Band Structure
Engineering

κ Thermal Conductivity

Low for glass

$$\kappa = \kappa_l + \kappa_e$$

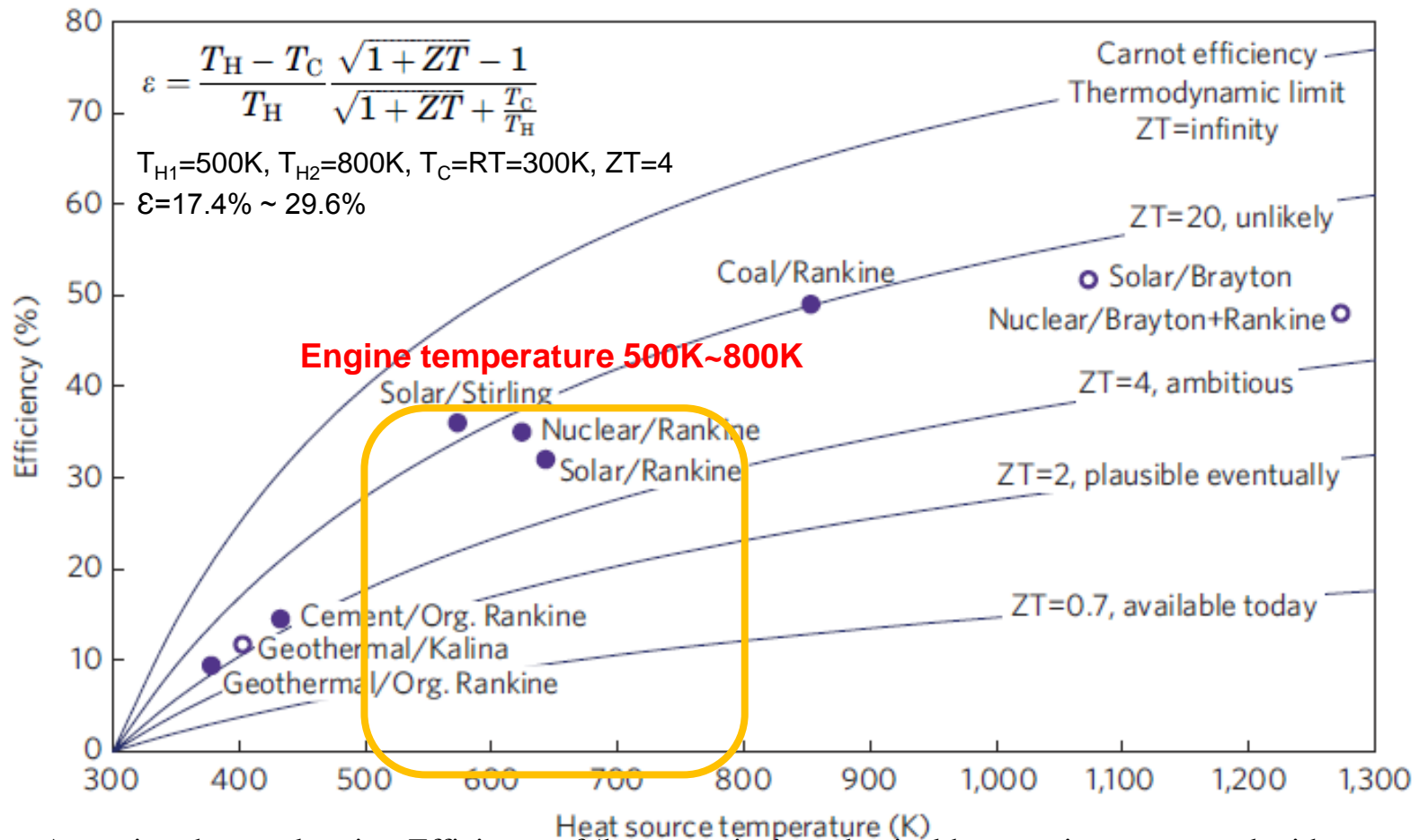
$$\kappa_{lattice} = \frac{1}{3} (C_v v_s \lambda_{ph})$$

$$\kappa_{electronic} = \sigma L T$$



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

Seebeck Coefficient S points to S^2
 Conductivity σ points to σ
 Temperature T points to T
 Thermal Conductivity K points to K



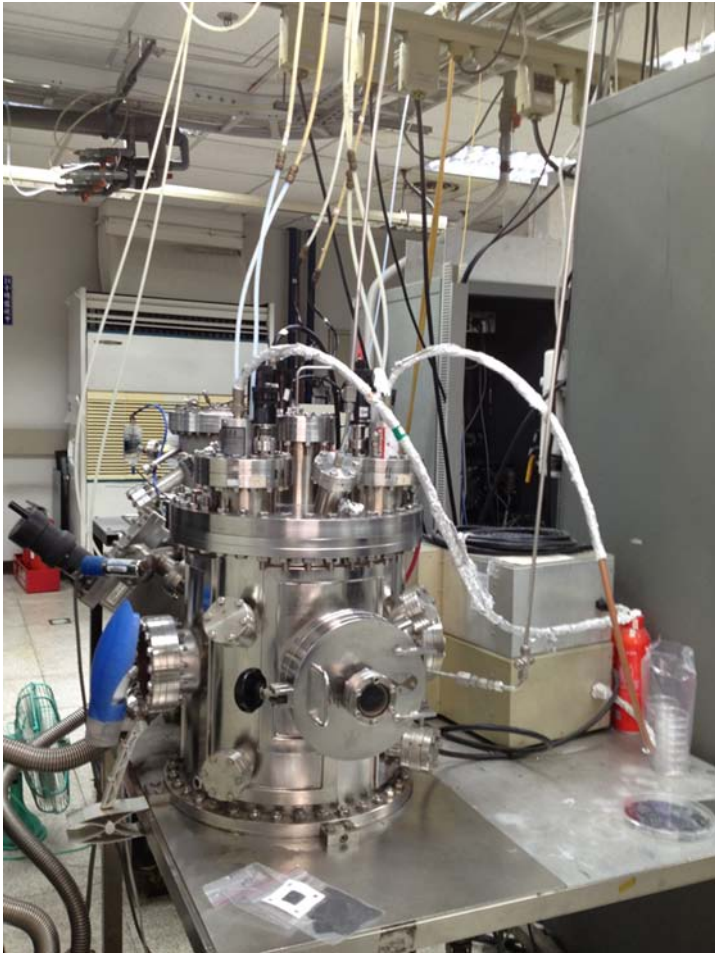
Assessing thermoelectrics. Efficiency of 'best practice' mechanical heat engines compared with an optimistic thermoelectric estimate

Ion-Beam Sputter

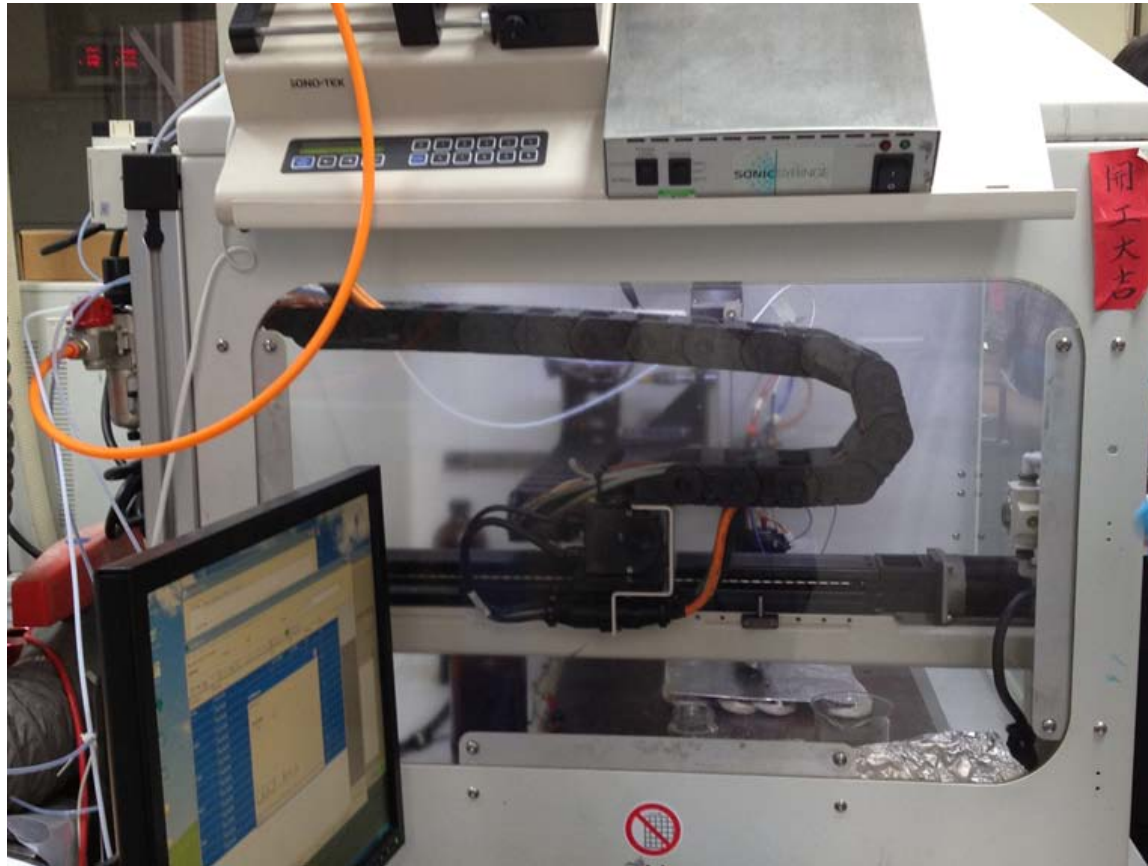


- Application: metallic and metal oxide layers.
- Provide uniform coating.

RF Sputtering



- Application: metallic and metal oxide layers.



Ultrasonic Spray

Application: Solution-based patterned, high uniformity thin film fabrication.

