高效能熱電元件的研製和開發

學生：蔡輔安
指導教授：廖洺漢
台灣大學　機械系

2017/04/23

Increasing 2D Thermoelectric Cooler efficiency by annealing (1/5)

NTU CERES SoC Platform Technology

- The generated voltage by the 2D device can be improved approximately 70% by annealing after the deposited process is done.

a. Wafer cleaning in Acetone

b. N-type, P-type, connector deposition

c. Annealing at 200˚C for 120 min

d. Electrical properties measurement

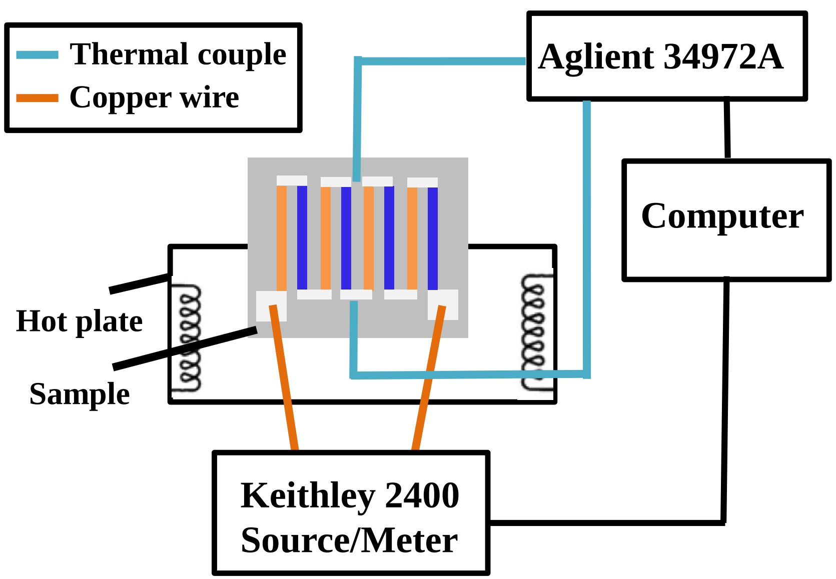

Fig. 1-2. Schematic of the measurement system

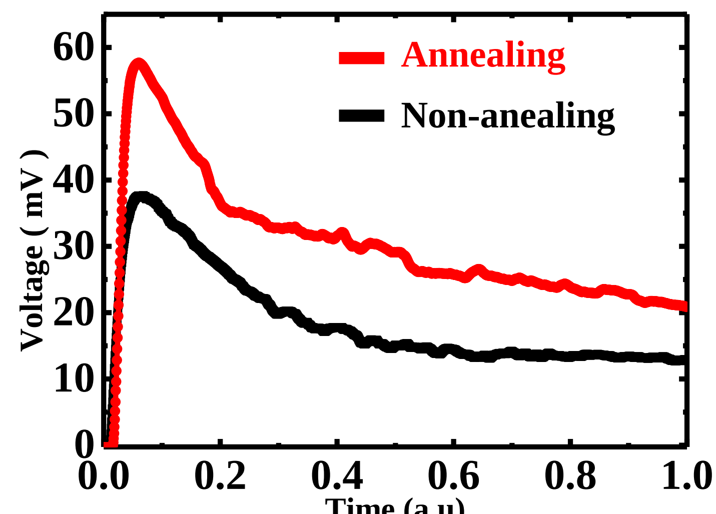

Fig. 1-3. Time versus voltage of non-annealing 2D cooler compared with annealing 2D cooler at 30K temperature difference.

Electrical Conductivity Measurement for 2D Thermoelectric Cooler(2/5)

NTU CERES SoC Platform Technology

- The electrical conductivity of 2D thermoelectric cooler is almost the same as spark plasma sintered $Si_{80}Ge_{20}$ in 50˚C. (Fig. 2-3)

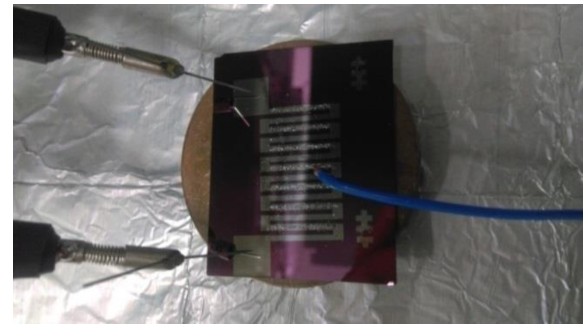

Fig. 2-1. Experimental set-up for determining conductivity

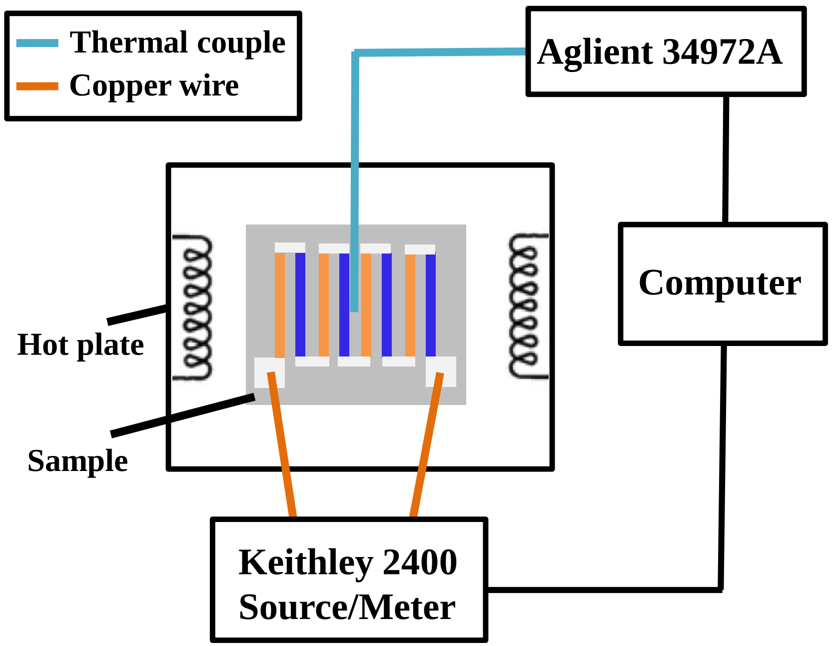

Fig. 2-2. Schematic of the measurement system

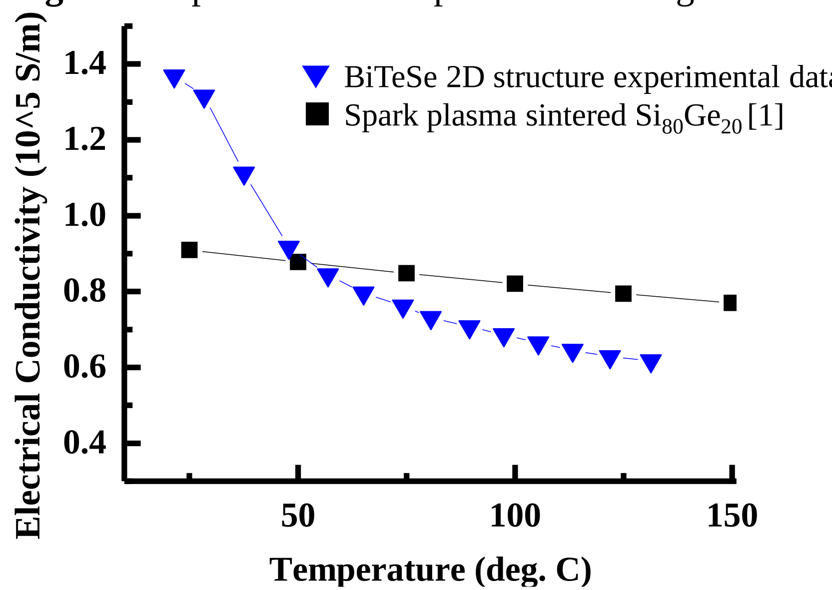

Fig. 2-3. Temperature dependence of the conductivity of 2D cooler compared with spark plasma sintered $Si_{80}Ge_{20}$.

[1] A. Lahwal, X. Zeng, S. Bhattacharya, M. Zhou, D. Hitchcock, M. Enhancing Thermoelectric Properties of Si80Ge20 Alloys Utilizing the Decomposition of NaBH4 in the Spark Plasma Sintering Process. Energies. 2017, 8, 10958-10970

Seebeck Coefficent Measurement for 2D Thermoelectric Cooler(3/5)

NTU CERES SoC Platform Technology

- Seebeck coefficient determined by measuring electric potential emergent across 2D cooler in a thermal gradient:

$$S_{ab} = \lim_{\Delta T \to 0} \frac{\Delta V_{ab}}{\Delta T}$$

- The Seebeck coeff. are higher than $Si_{80}Ge_{20}$ in all range temperature.

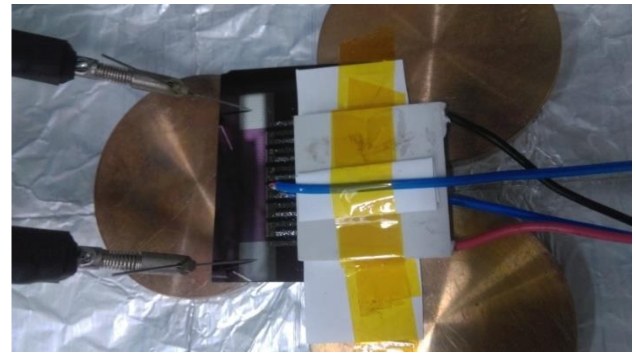

Fig. 3-1. Experimental set-up for determining Seebeck Coeff.

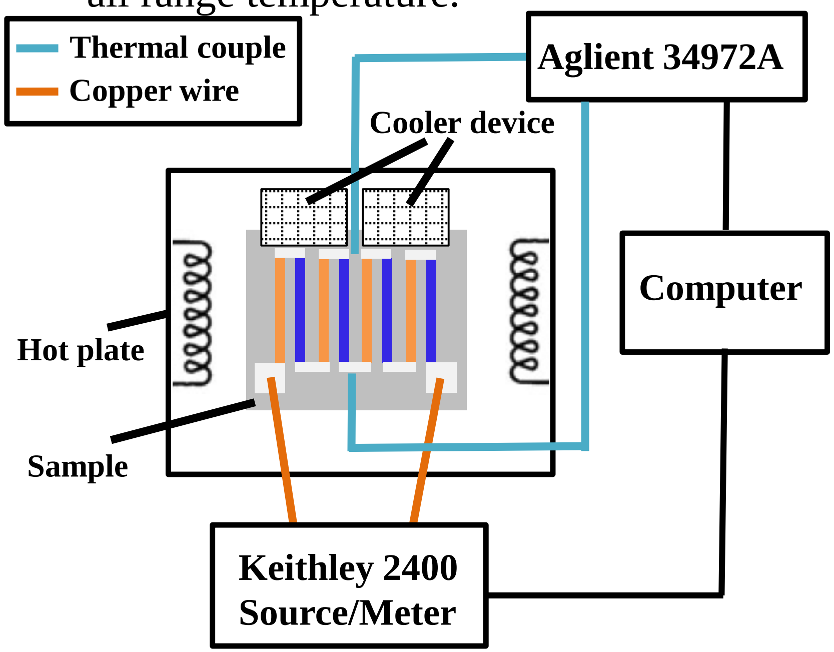

Fig. 3-2. Schematic of the measurement system

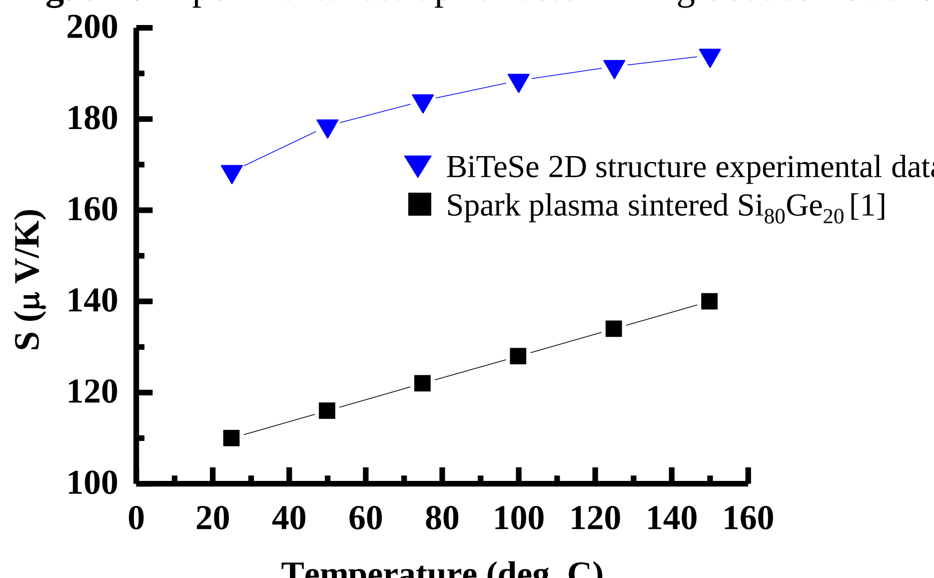

Fig. 3-3. Temperature dependence of the Seebeck coeff. of 2D cooler compared with spark plasma sintered $Si_{80}Ge_{20}$.

[1] A. Lahwal, X. Zeng, S. Bhattacharya, M. Zhou, D. Hitchcock, M. Enhancing Thermoelectric Properties of Si80Ge20 Alloys Utilizing the Decomposition of NaBH4 in the Spark Plasma Sintering Process. Energies. 2017, 8, 10958-10970

Power Factor Calculation for 2D Thermoelectric Cooler(4/5)

NTU CERES SoC Platform Technology

- Power factor can be determined by the equation below: $Power\ Factor = \sigma S^2$
- The higher value of power factor is, the more energy the device can generate.
- The power factor of 2D cooler is higher than $Si_{80}Ge_{20}$ in 25 °C, but it drop quickly near 50°C.

Temperature	Power factor (uW cm-1 k-2)
25	11.74496644
50	12.38390093
75	12.93103448
100	13.40482574
125	13.81909548
150	14.18439716

Fig. 4-1. Power factor data sheet of spark plasma sintered $Si_{80}Ge_{20}$.

Temperature	Power factor (uW cm-1 k-2)
32	36.558428
43	31.6266255
61	26.41480536
79	25.01687552
99	24.3040572
122	24.26123504
148	24.04899556

Fig. 4-2. Power factor data sheet of 2D thermoelectric cooler.

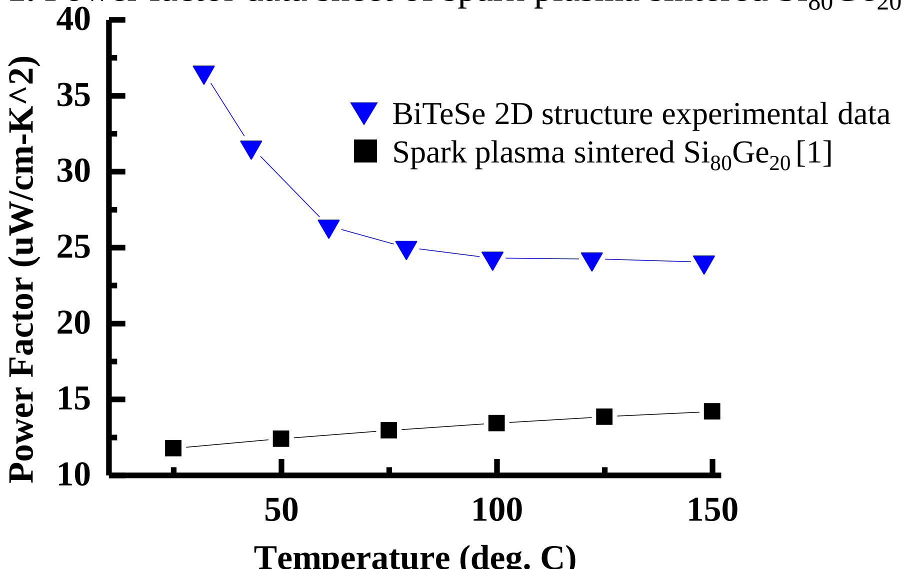

Fig. 4-3. Temperature dependence of the power factor of 2D cooler compared with spark plasma sintered $Si_{80}Ge_{20}$.

[1] A. Lahwal, X. Zeng, S. Bhattacharya, M. Zhou, D. Hitchcock, M. Enhancing Thermoelectric Properties of Si80Ge20 Alloys Utilizing the Decomposition of NaBH4 in the Spark Plasma Sintering Process. Energies. 2017, 8, 10958-10970

Figure of Merit ZT Calculation for 2D Thermoelectric Cooler(5/5)

NTU CERES SoC Platform Technology

- The efficiency of thermoelectric device is determined by the dimensionless figure of merit, defined as: $ZT = \frac{\sigma S^2}{k} T$, where σ and S can be determined from previous page, k is got from the reference[1,2].
- Compare with the reference, the ZT values of 2D cooler is significantly higher than spark plasma sintered $Si_{80}Ge_{20}$, so **our device are more efficient than others**.

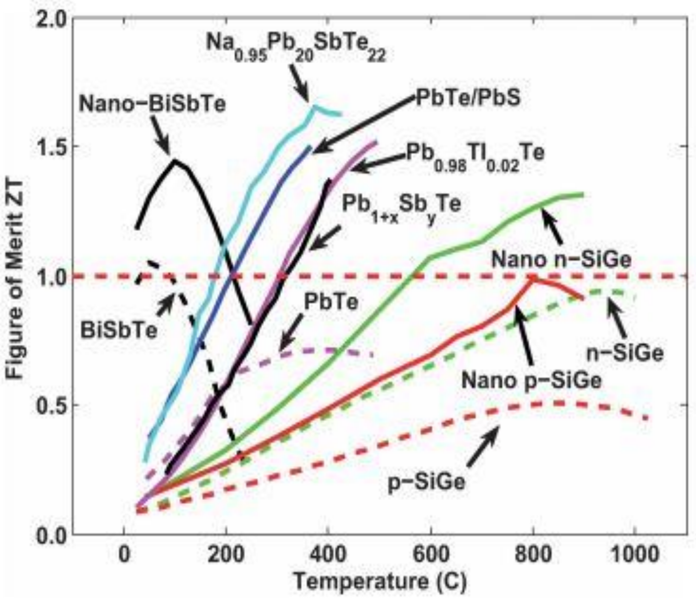

Fig. 5-1. Temperature dependence of the ZT of other materials.

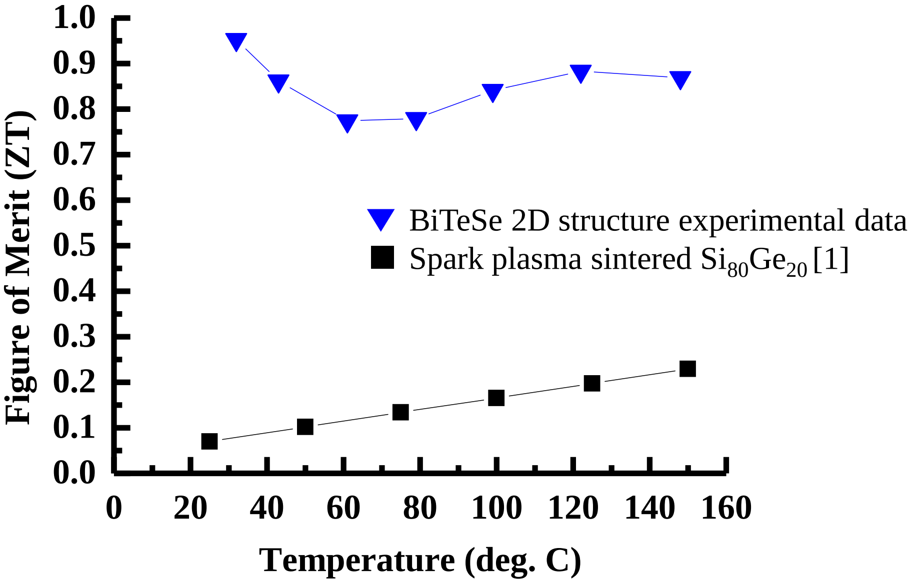

Fig. 5-2. Temperature dependence of the ZT of 2D cooler compared with spark plasma sintered $Si_{80}Ge_{20}$.

[1] A. Lahwal, X. Zeng, S. Bhattacharya, M. Zhou, D. Hitchcock, M. Enhancing Thermoelectric Properties of Si80Ge20 Alloys Utilizing the Decomposition of NaBH4 in the Spark Plasma Sintering Process. Energies. 2017, 8, 10958-10970