Evaluation systems of thermoelectric properties of electrochemically deposited Bi_2Te_3 films and nanowire arrays

Yoshikazu Shinohara*, Marisol Martin-Gonzalez**

* National Institute for Materials Science, Japan

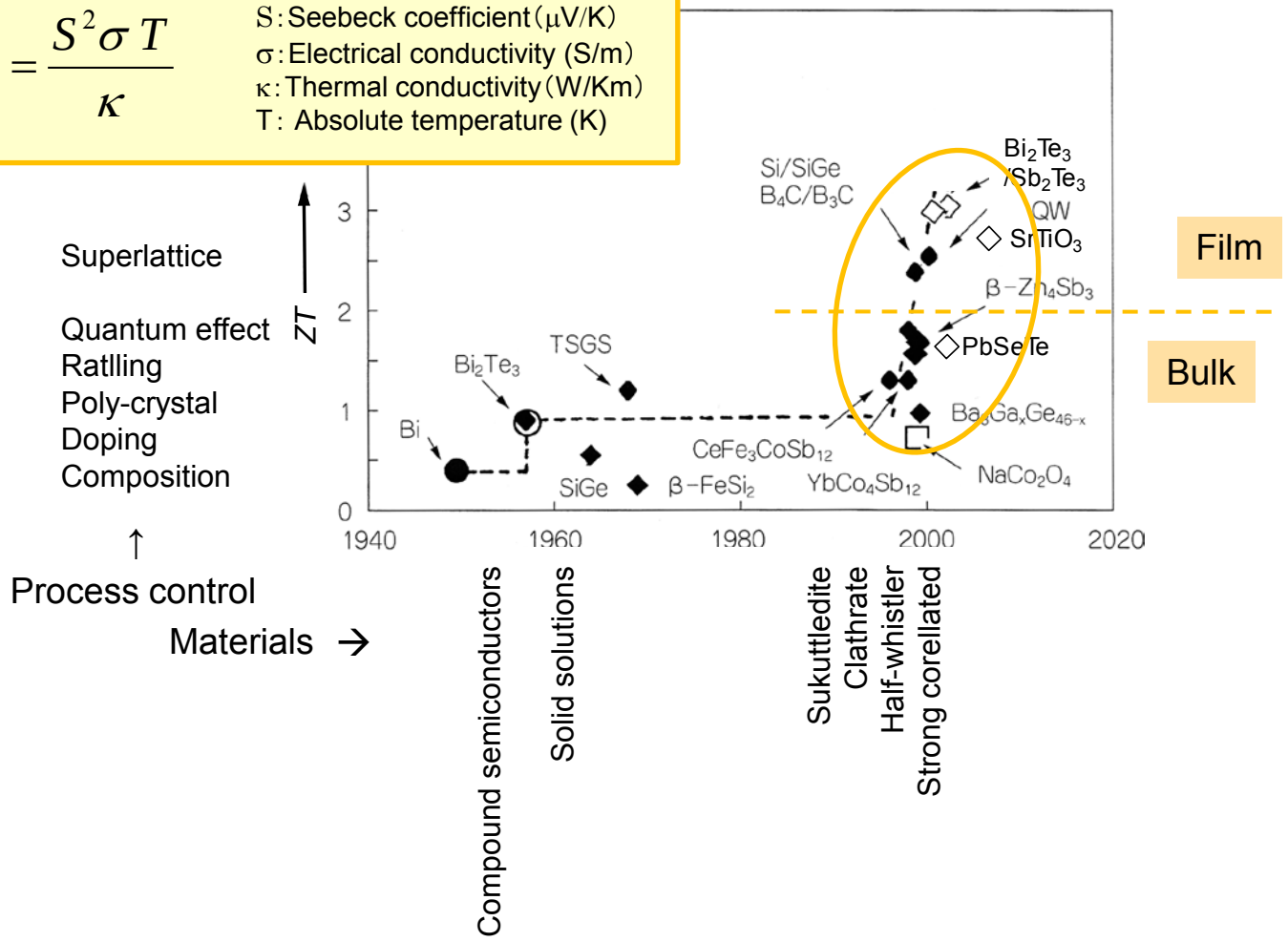
** Instituto Microelectrónica de Madrid, Spain

The state of arts of thermoelectric materials

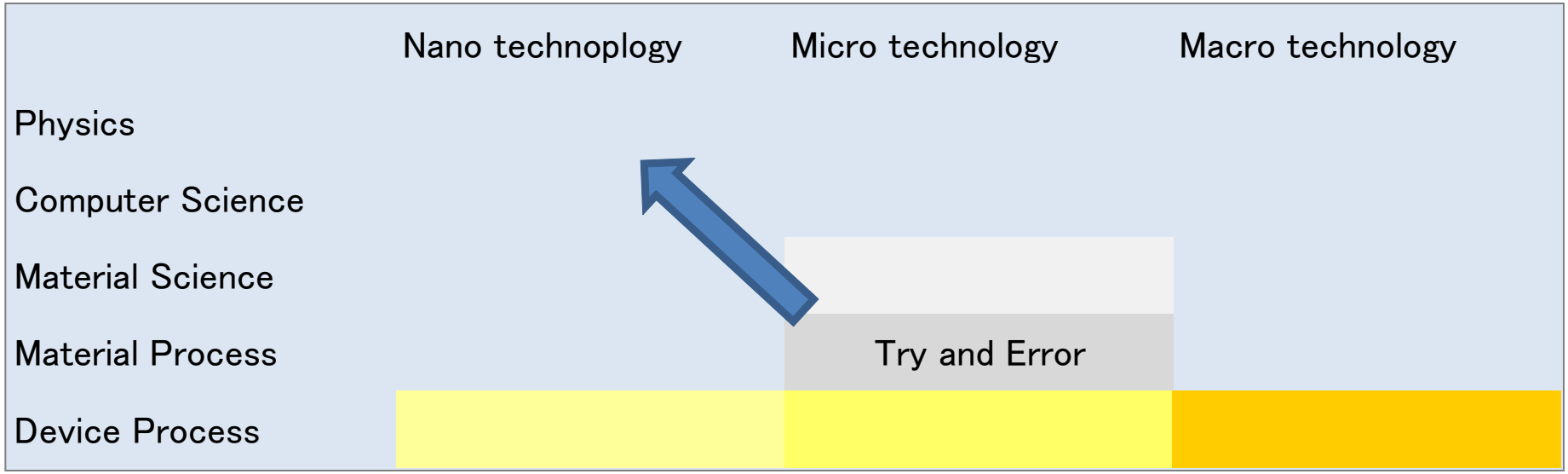
Dimensionless figure-of-merit

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

S: Seebeck coefficient (μV/K)
σ: Electrical conductivity (S/m)
κ: Thermal conductivity (W/Km)
T: Absolute temperature (K)



How to overcome the dilemma?



Dilemma between nanotechnology and macro application(waste heat recovery)

FY2009 Strategic Japanese-Spanish Cooperative Program

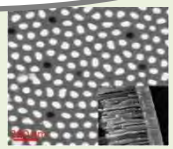
Research Field: "Nanoscience and New Materials for Environmental Challenges"

Spain

Instituto Microelectrónica de Madrid

Synthesis Technology

Bi-Te nanowire array



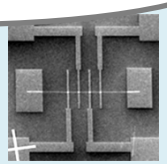
+

Japan

National Institute for Materials Science

Measurement Technology

Quantitative evaluation



Project Leader: Dr. M. Martin-Gonzalez

Project Leader: Dr. Y. Shinohara

Cooperative Research Project (2010-2012)

First steps towards the integration of nanowire arrays on practical thermoelectric devices for Energy applications -NANOTHERMA-

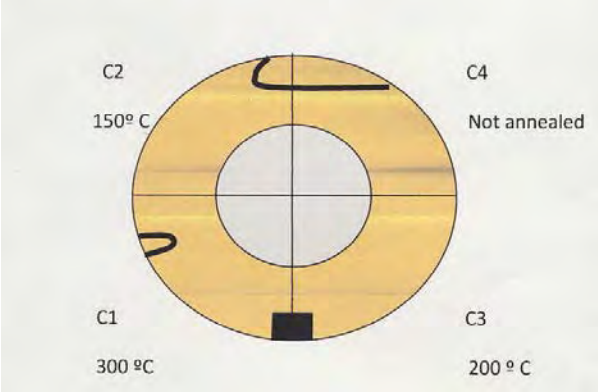
Exchange of technology, idea and researchers

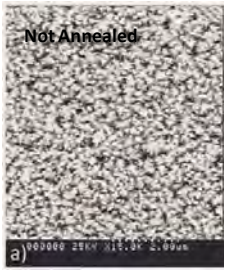
Good cooperation in the near future

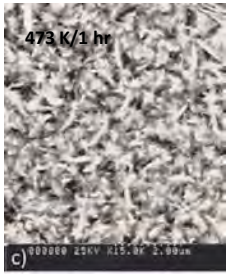
performance.

Samples

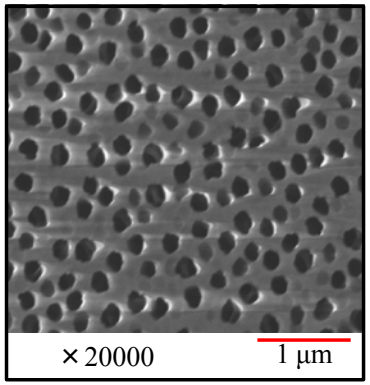
Bi_2Te_3 film

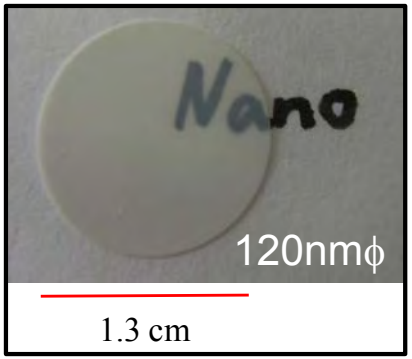




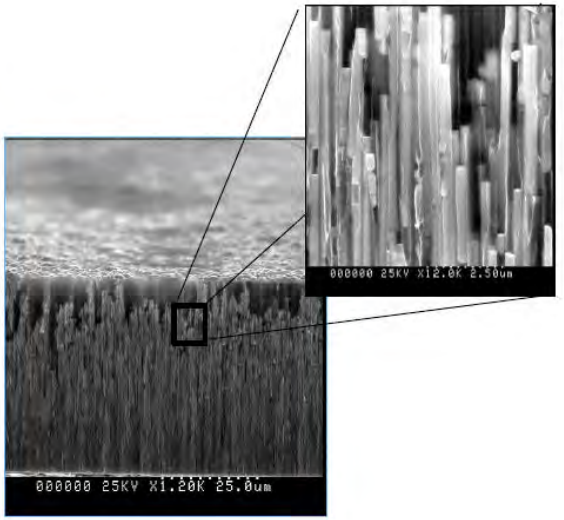


Bi_2Te_3 nanowire array

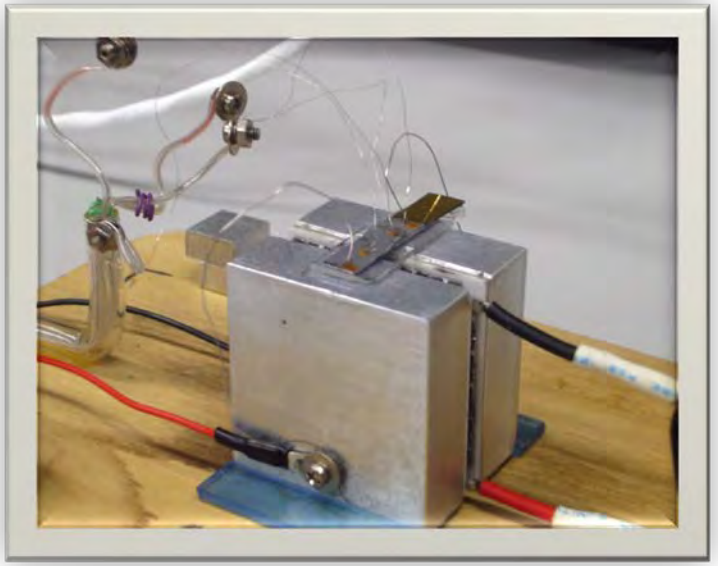


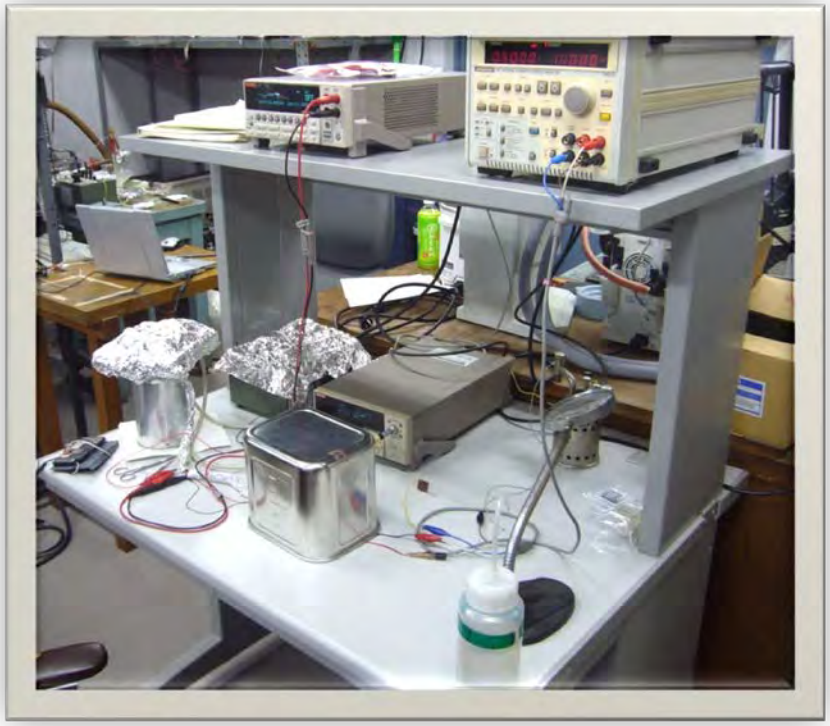


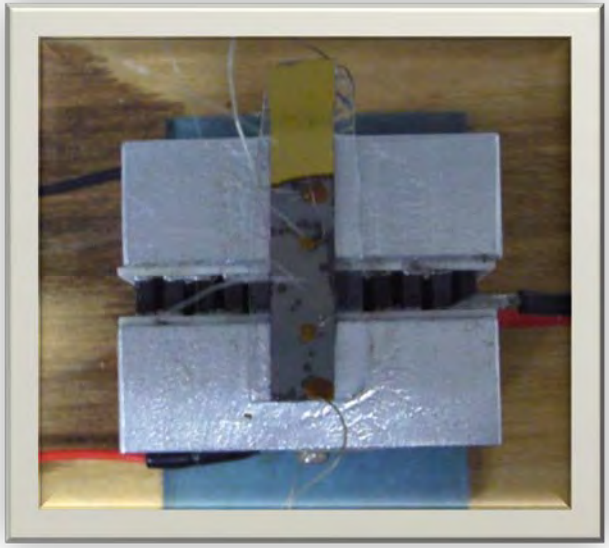
Alumina template.



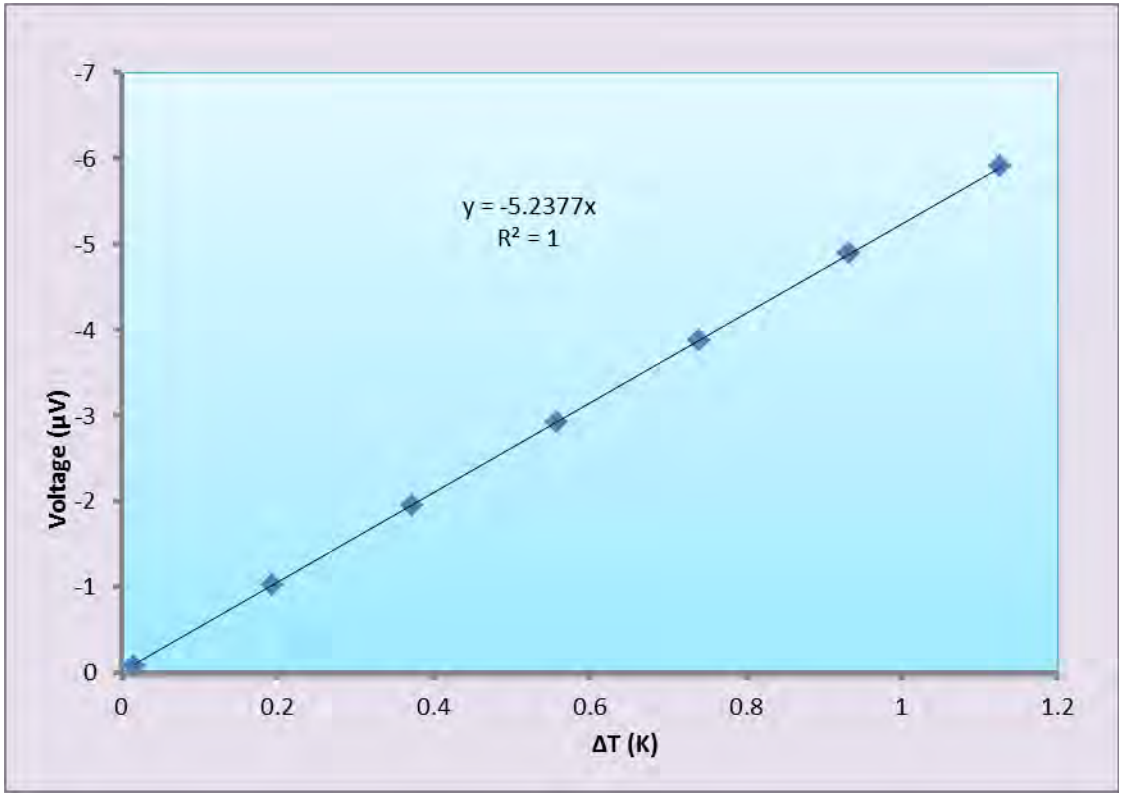
Experimental Setup for films (in-plane direction)







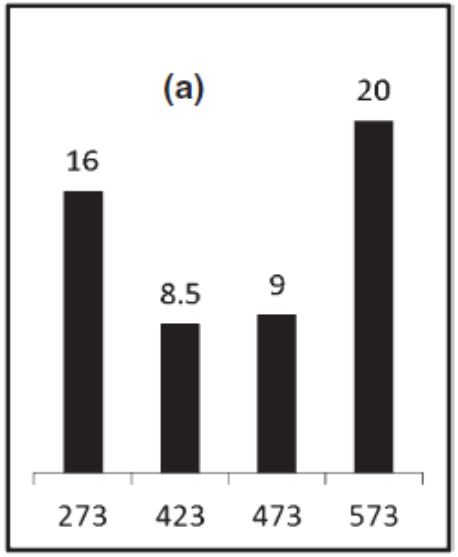
Measurement of Seebeck coefficient for Standard sample (Pt wire)



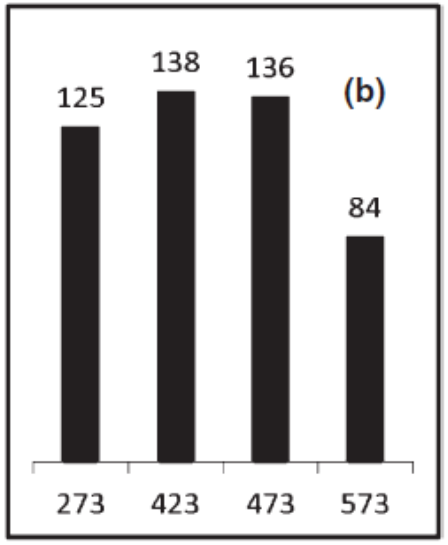
The measured value agrees well with the reference value of -5.24μV/K

Samples → / Experiments ↓	As prepared (273K)	423 K	473 K	573 K	Substrate Si/Ti/Au
Measured resistance	0.23 Ω	0.14 Ω	0.15 Ω	0.28 Ω	1.81 Ω
Seebeck coefficient	-4.57 μV/K	-6.58 μV/K	-6.36 μV/K	-9.33 μV/K	-104.47 μV/K

All resistance measured with probe distance ~ 5 mm



Seebeck coefficient (μV/K)

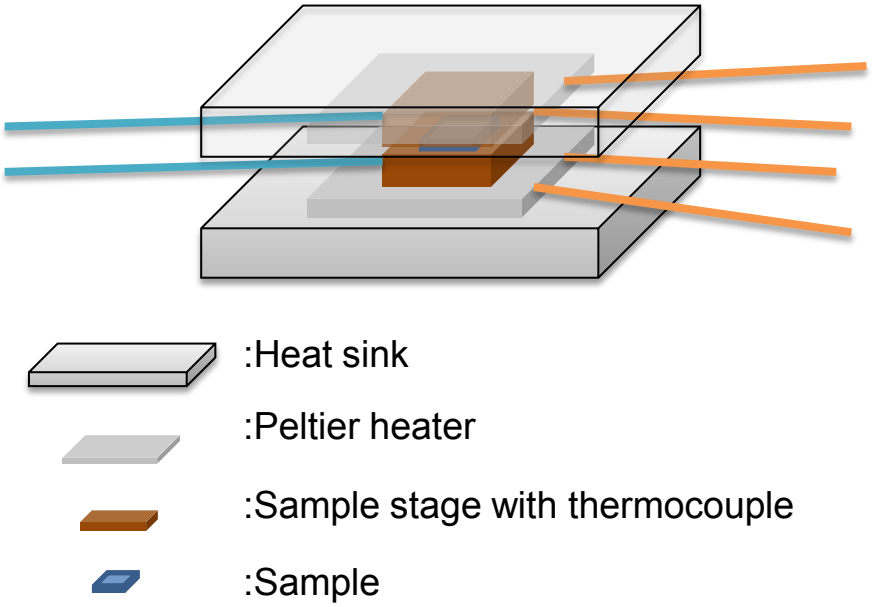


Electrical conductivity (S/cm)

Experimental Setup for nanowire array (thickness direction)

Thermocouples: T-type 0.127 mmϕ
Peltier heater: 4cm × 4cm Max. input 6W

Fig. Sample stage with thermocouple



Seebeck coefficient
Standard measurement using Si wafer (thickness **500** μm)

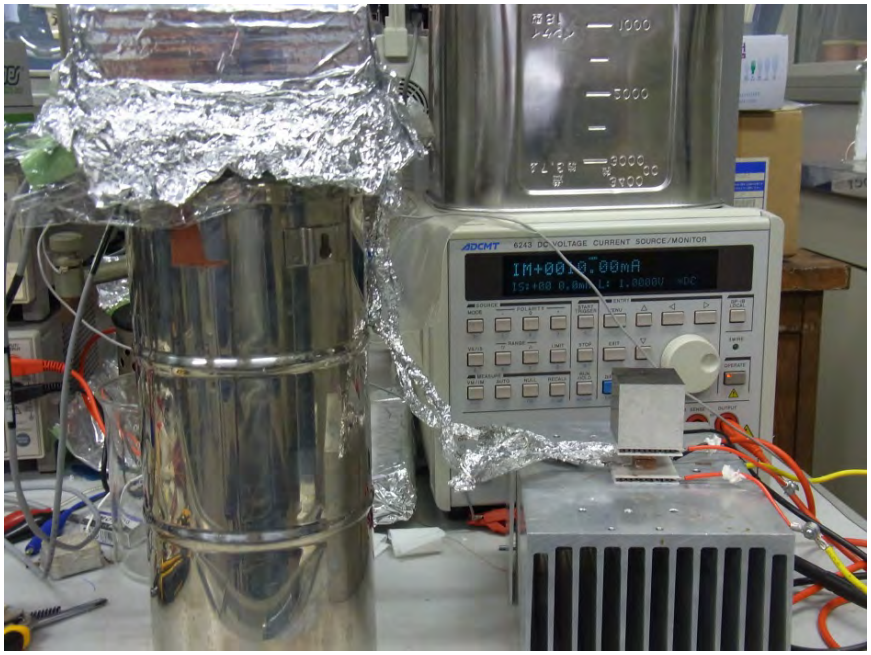


Fig._Home-made apparatus of nanowire array measurement

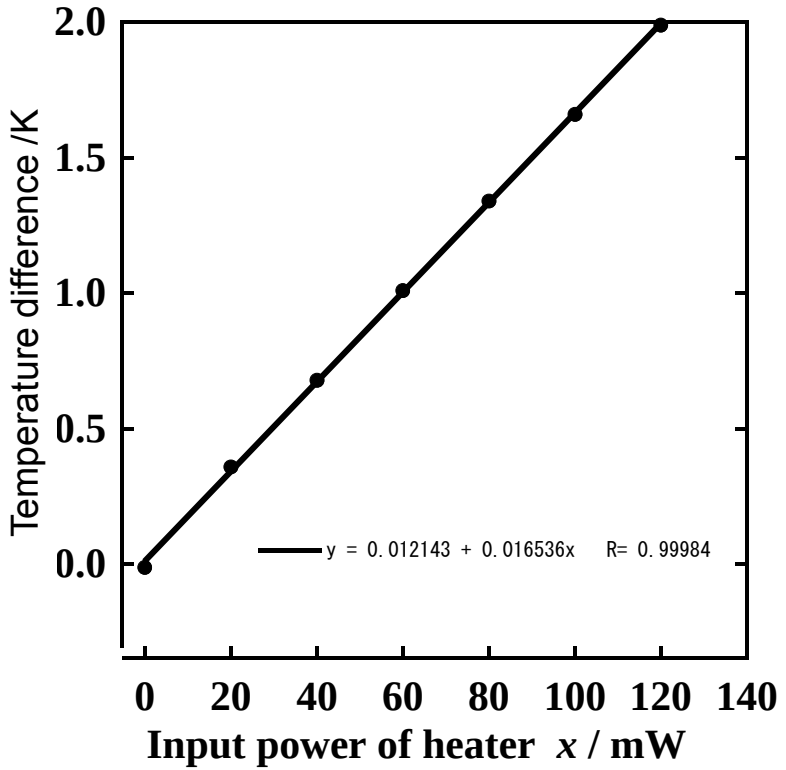


Fig. Temperature difference as a function of input power.

Seebeck coefficient of standard measurement using Si wafer

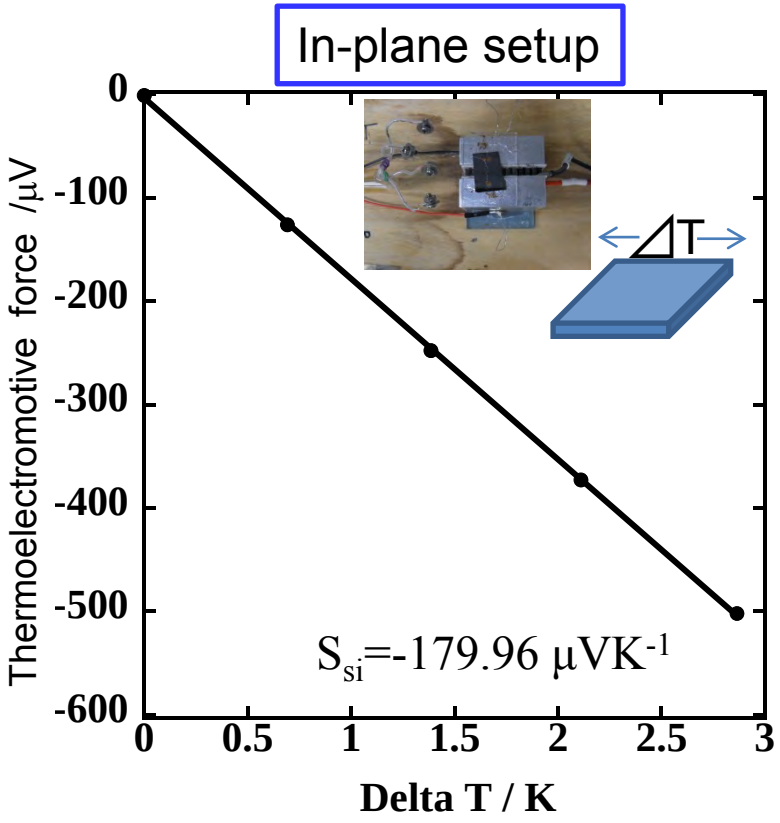


Fig. Relationship between deltaT and total thermoelectric power(TP_{total}) in planar direction of Si.

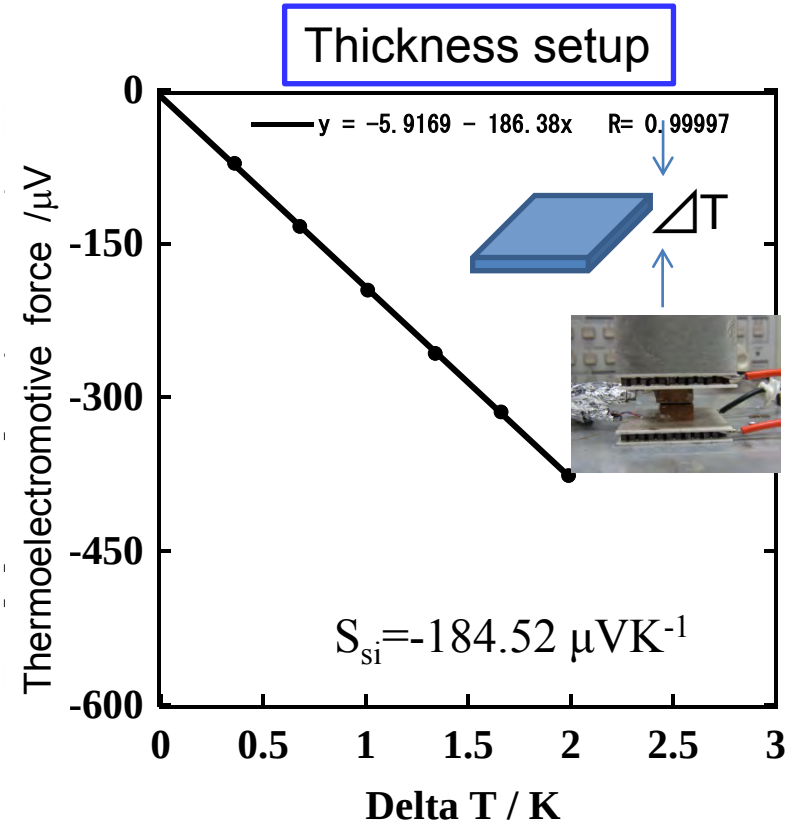


Fig. Relationship between deltaT and total thermoelectric power(TP_{total}) in thickness direction of Si.

Good matching between in-plane and thickness setups

Seebeck coefficient and electrical conductivity of Bi_2Te_3 nanowire array

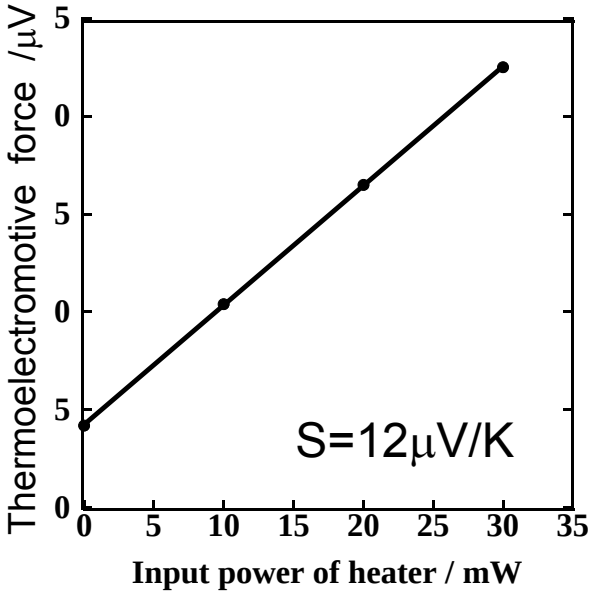
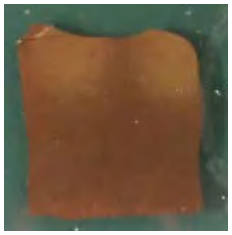


Fig. Thermoelectric power as a function of input power.



厚さ60 μm

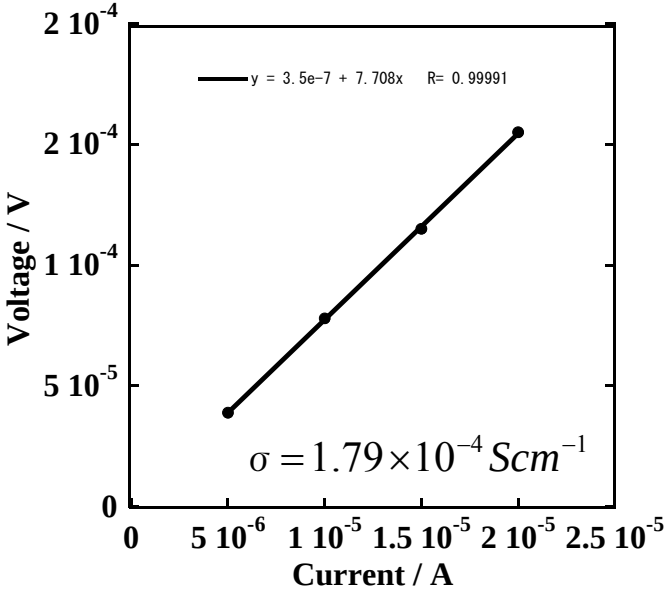
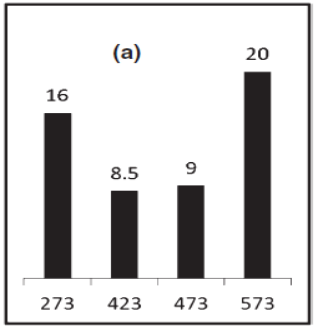
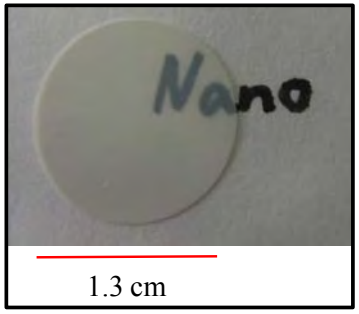


Fig. I-V curve of nanowire-array.



Seebeck coefficient of films



Alumina template.

FY2009 Strategic Japanese-Spanish Cooperative Program

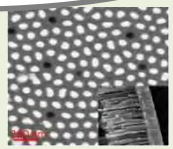
Research Field: "Nanoscience and New Materials for Environmental Challenges"

Spain

Instituto Microelectrónica de Madrid

Synthesis Technology

Bi-Te nanowire array



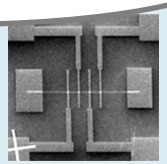
+

Japan

National Institute for Materials Science

Measurement Technology

Quantitative evaluation



Project Leader: Dr. M. Martin-Gonzalez

Project Leader: Dr. Y. Shinohara

Cooperative Research Project (2009-2012)

First steps towards the integration of nanowire arrays on practical thermoelectric devices for Energy applications -NANOTHERMA-

Exchange of technology, idea and researchers

Good results by good collaboration between Japan and Spain

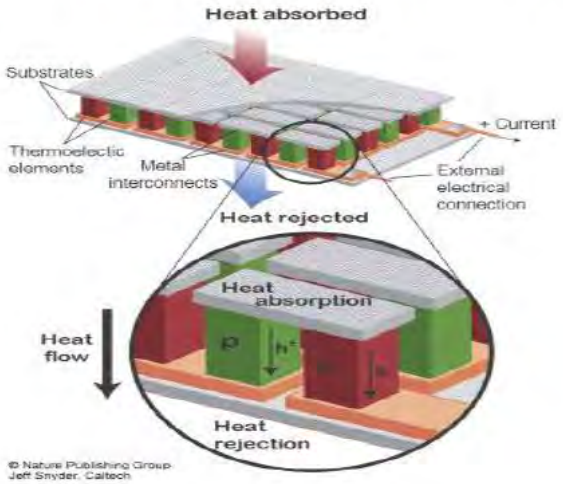
Acknowledgment

- Dr. Yukihiro Isoda
- Dr. BISWAPRIYA DEB
- Dr. Hiroshi Kawakami
- Dr. Olga C. Calero
- Dr. Pablo Díaz Chao
- Ms. Begona A. Mayor
  (Best poster award at the Workshop at Toledo in 2011)

ご清聴ありがとうございました

Marisol Martin's group

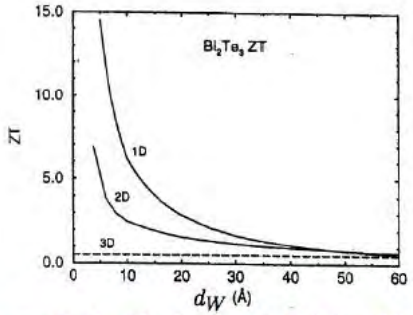
Thermoelectric power generator:



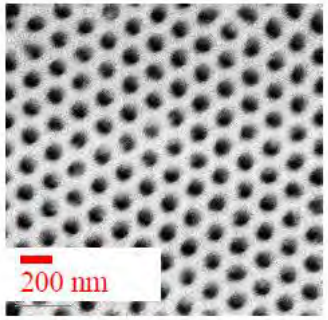
Thermoelectric figure of Merit:

$$ZT = \frac{S^2\sigma}{(\kappa_e + \kappa_l)}T$$

Low-dimensionality theory for TE:

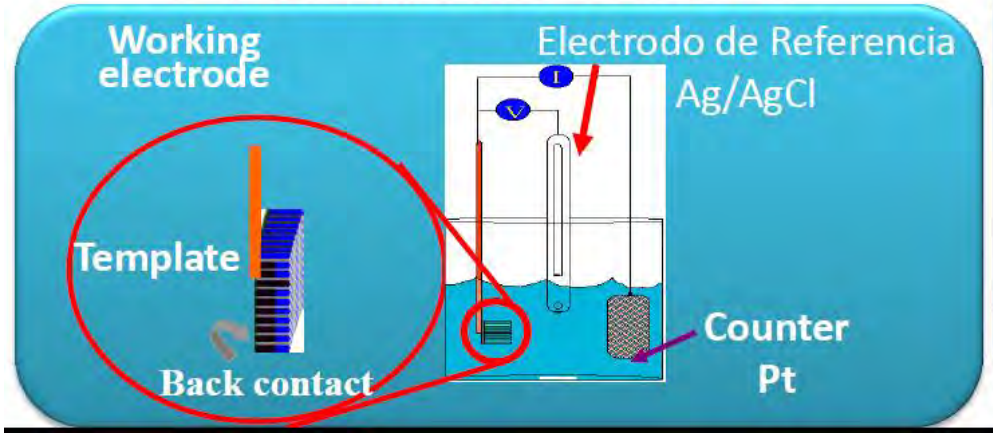


From L.D. Hicks et al. PRB 1993

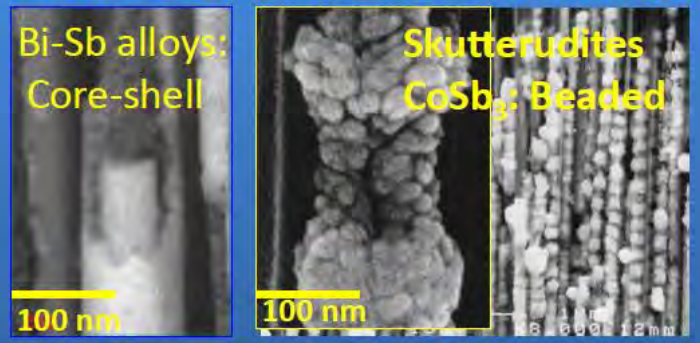


40 nm porous alumina matrix

Experimental: Electrochemical cell



Some thermoelectrics already obtained core-shell, Beaded, multilayer



M. Martín-González Unpublished results