EPSRC 2016

# Electrical characteristics of **metallization interface** for high temperature chalcogenide thermoelectric module

2016. 04. 21

Advanced Materials and Devices Laboratory
Korea Institute of Energy Research
**Sang Hyun Park**

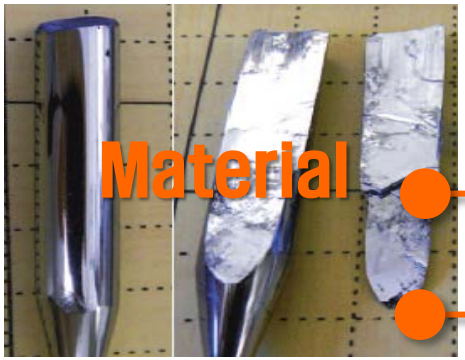
# 1.5 KIER's Research Sites

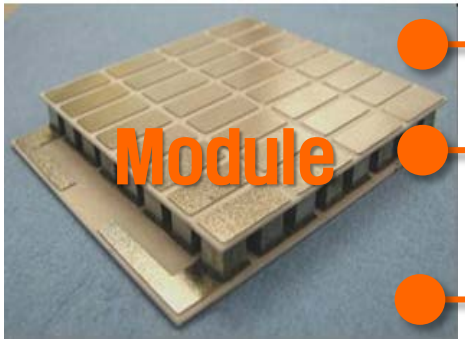
KIER is headquartered in Daejeon with regional research sites in Jeju island, Buan and Ulsan with an aim to enhance global research capacity and foster open collaborative research.

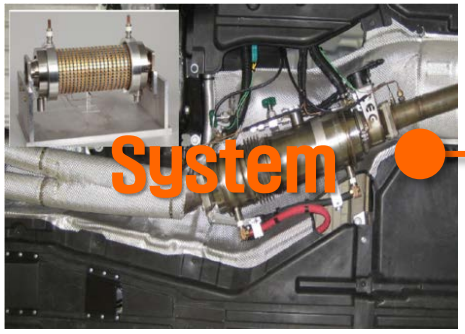

## Headquarters

- Location : Yuseong-gu, Daejeon
- Land : 121,668m$^2$
- Main Research Areas
  - Energy efficiency
  - Renewable energy
  - Climate change
  - Advanced materials

# Main Research Scopes



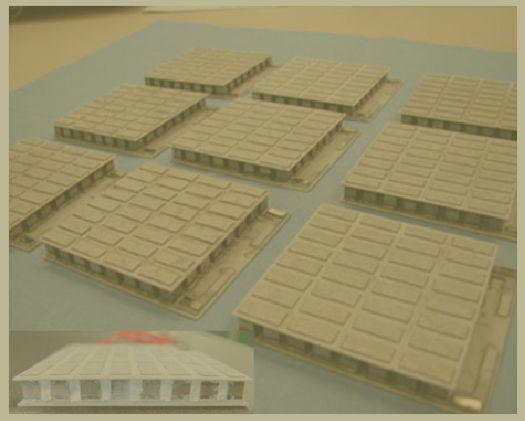



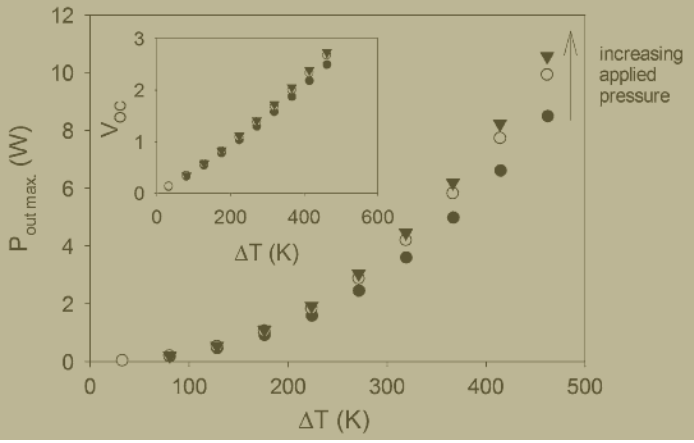

- Intermediate temp. material (SNU)
- Metallization and Bonding
- Intermediate temp. uni couple
- Intermediate temp. TEG
- Intermediate temp. thermoelectric system

# Research Area of KIER

| Temperature range | Material | Module | System |
|---|---|---|---|
| High temp. ( 1000℃ 이상) | | | |
| Intermediate Temp. ( 300 ~ 800℃ ) | KIER TEG | | |
| Low temp. ( 100 ~ 200℃ ) | | | |

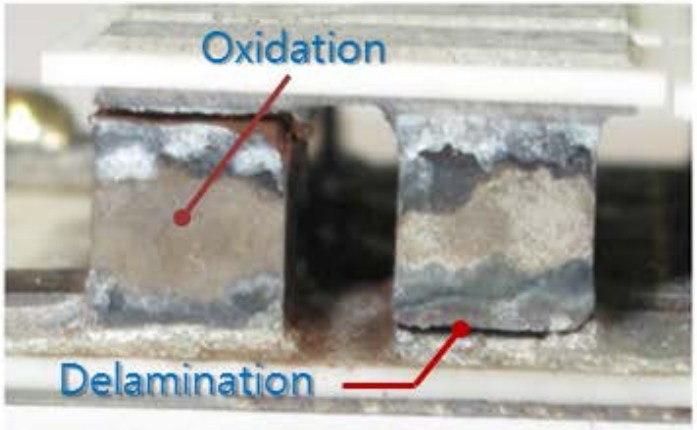
# Main technological issues 1

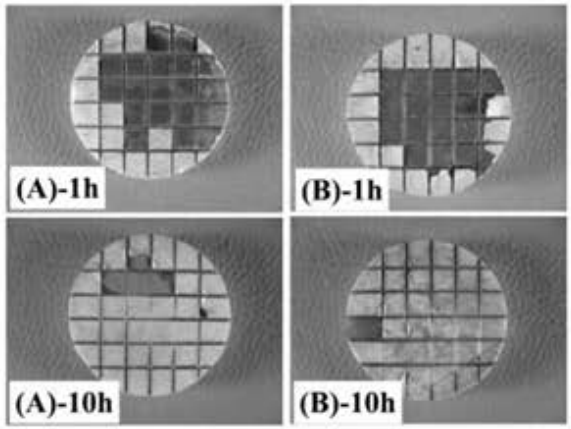





**General Motors**
(2012, 2013)

Based on skutterudite
8 W/ 25cm$^2$ (at ΔT 500℃)
**320 mW/cm$^2$**
Voc 2.7 V




# Thermoelectric Material : **SnSe**

# Thermoelectric Material : SnSe

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日本語要約

## Ultralow thermal conductivity and high thermoelectric figure of merit in SnSe crystals

Li-Dong Zhao, Shih-Han Lo, Yongsheng Zhang, Hui Sun, Gangjian Tan, Ctirad Uher, C. Wolverton, Vinayak P. Dravid & Mercouri G. Kanatzidis

Affiliations | Contributions | Corresponding author

*Nature* **508**, 373–377 (17 April 2014) | doi:10.1038/nature13184

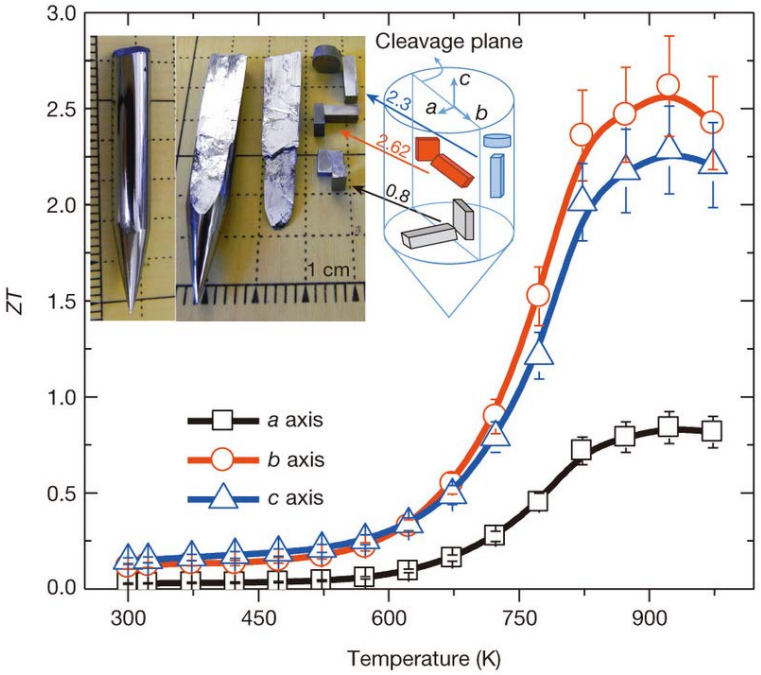
Received 26 November 2013 | Accepted 24 February 2014 | Published online 16 April 2014

Citation | Reprints | Rights & permissions | Article metrics

The thermoelectric effect enables direct and reversible conversion between thermal and electrical energy, and provides a viable route for power generation from waste heat. The efficiency of

World top ZT record 2014

**ZT = 2.6** @900K



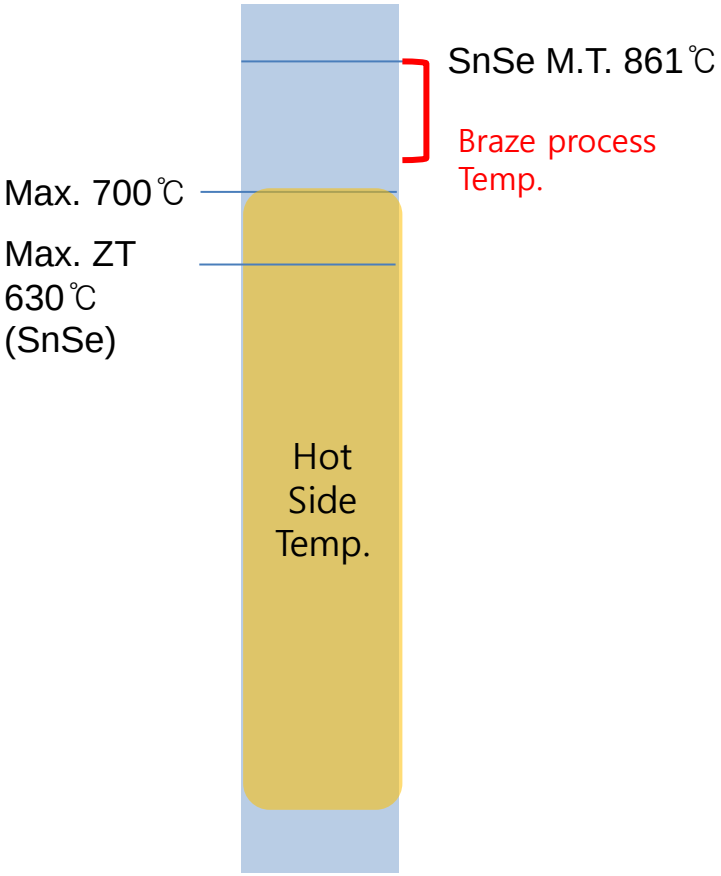
# Material issues

## Practical limitation of previous thermoelectric materials

| | Low ZT (ZT< 1) | Hazard (Environment) | Expensive (Rare earth) | Low mechanical property |
|---|---|---|---|---|
| BiTe | | ● | ● | ● |
| **PbTe** | | ● | ● | |
| $Mg_2Si$ | ● | | | |
| Oxides | ● | | | |
| $CoAs_3$ | | | ● | ● |
| Hf-Heusler | | | ● | |
| **SnSe** | | | | |

Almost all materials have their own limitation
for industrializing this technology

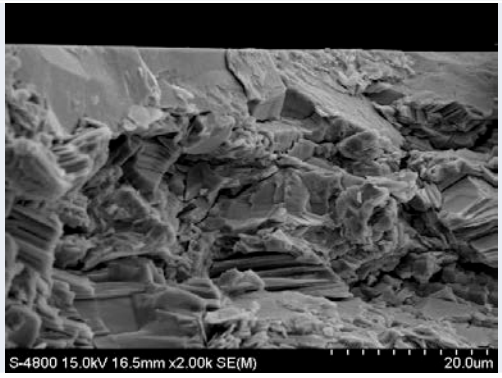
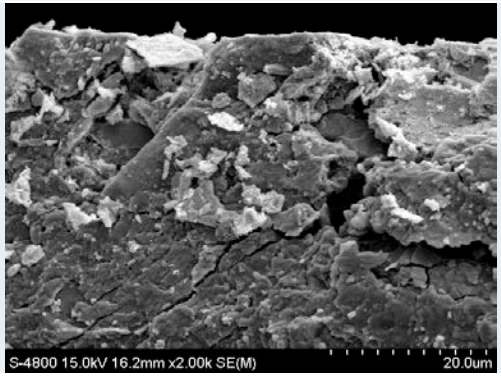
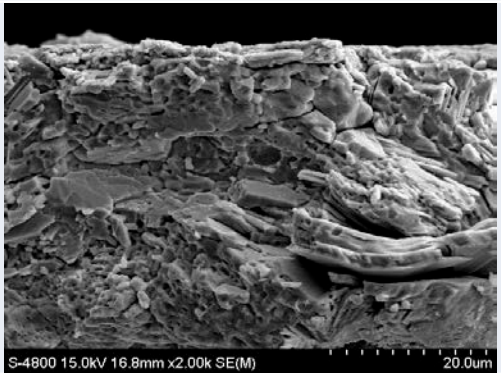
# Difficulties in handling SnSe 1



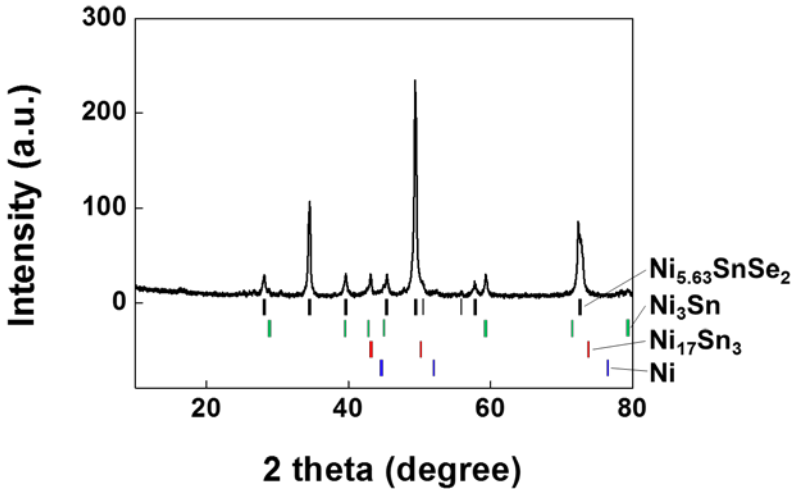

| Alloys | L.T. (℃) | B.T. (℃) |
|---|---|---|
| Palcusil 10 | 852 | |
| Silcoro 60 | 845 | |
| 95% Silver 5% Aluminum | 830 | |
| Cusil-ABA | 815 | |
| Cusin-1-ABA | 805 | |
| Nicusil 3 | 795 | 815-840 |
| 90% Silver 10% Gernamium | 790 | |
| Cusil | 780 | |
| Cusiltin™5 | 760 | |
| Incusil 10 | 730 | |
| Incusil ®15 | 725 | |
| Cusiltin | 718 | |
| Incusil-ABA | 715 | 715-740 |

# Difficulties in handling SnSe 2



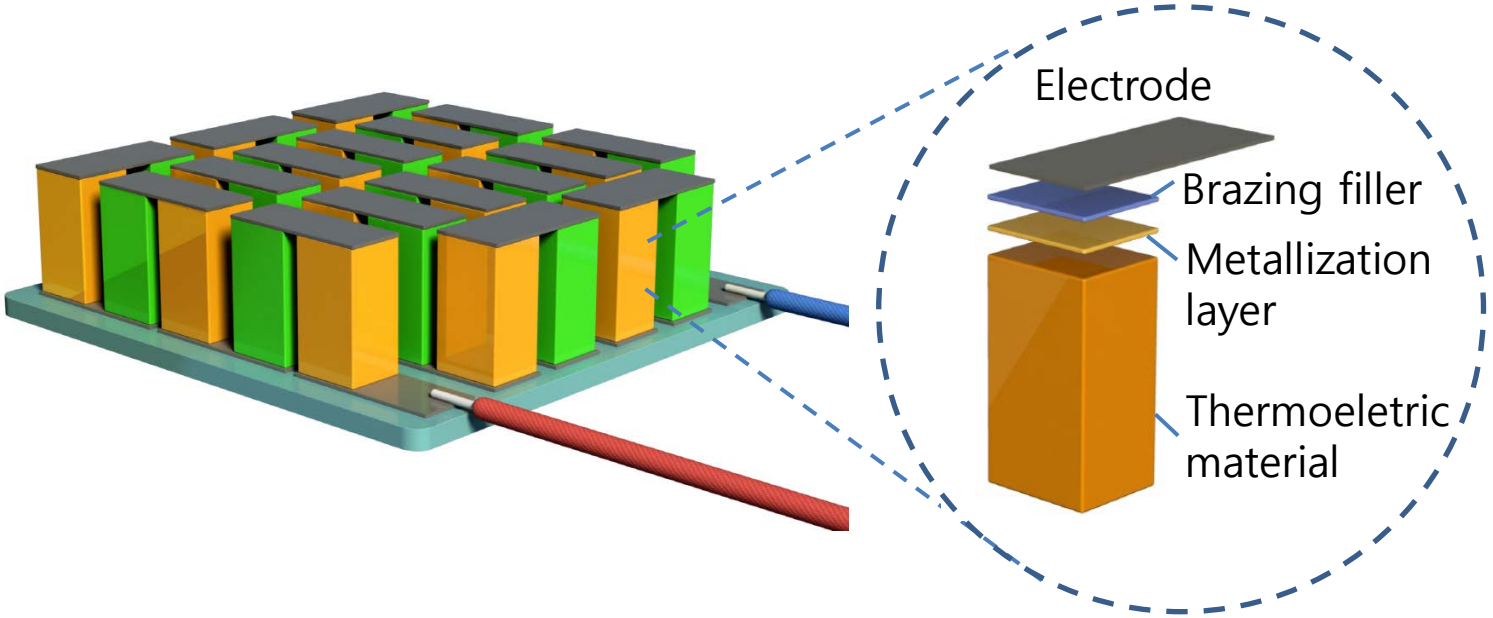
| | Sample 1 (only Polishing) | Sample 2 (650℃ 1h in air) | Sample 3 (650℃ 1h in Ar) |
|---|---|---|---|
| peller |  |  |  |
| X 2K |   |   |   |

# Difficulties in handling SnSe 3

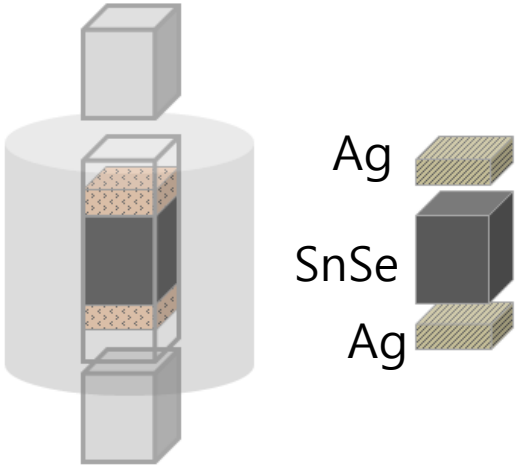



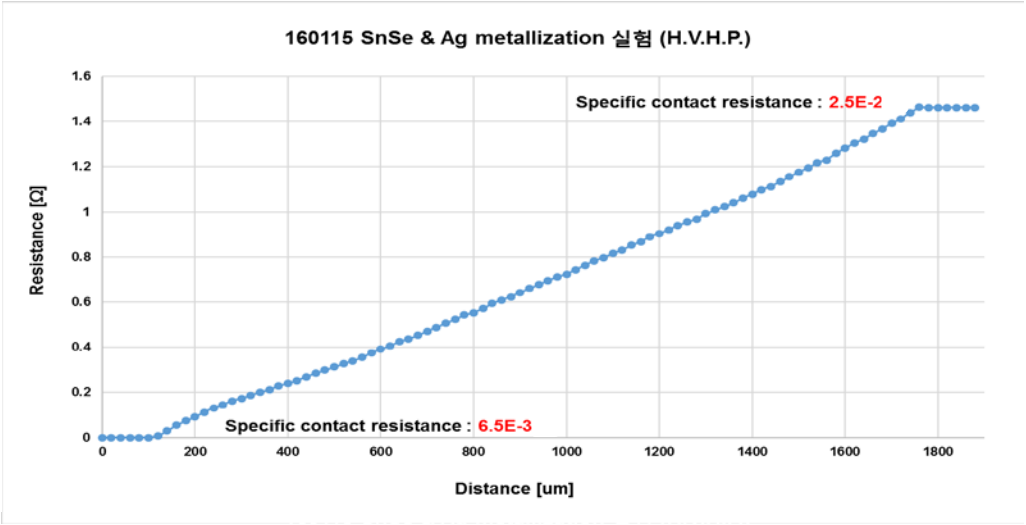
# Thermoelectric leg metallization

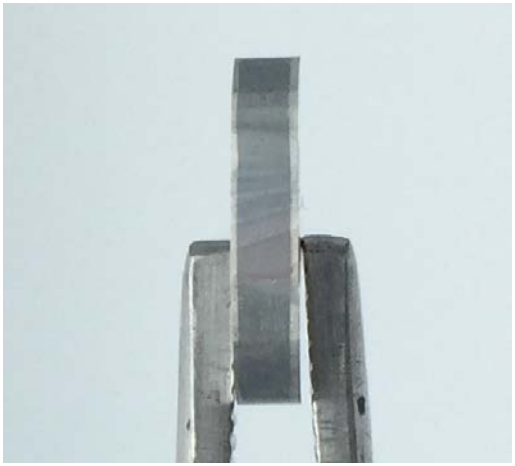
# SnSe Metallization

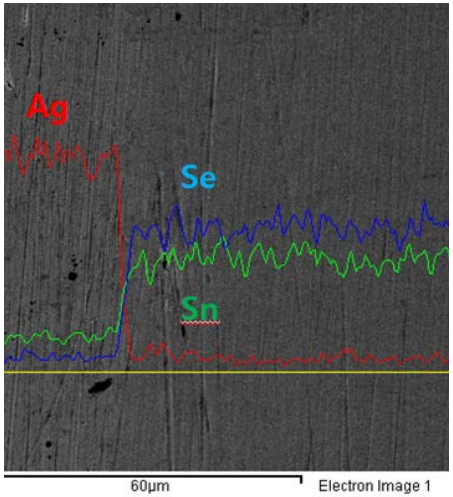


# Ag Metallization

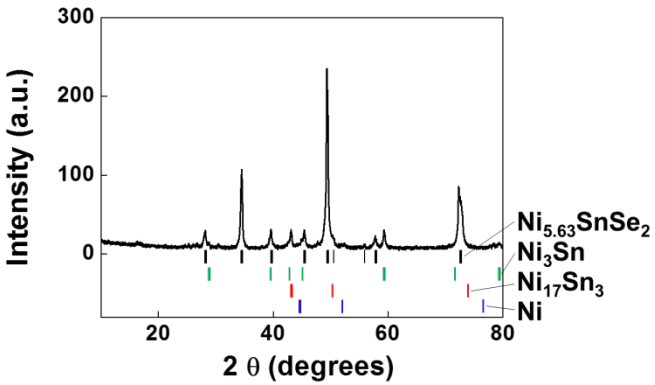




# Ni Metallization




The thermal expansion coefficient differences between SnSe ($3.9\times10^{-6}K^{-1}$) and $Ni_3Sn$ ($18\times10^{-6}\,K^{-1}$). **460%**

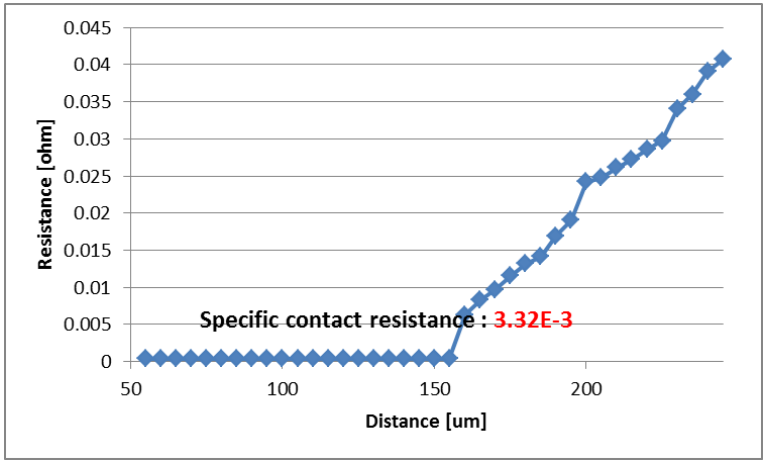
# Ag+Ni Metallization

Ag + Ni

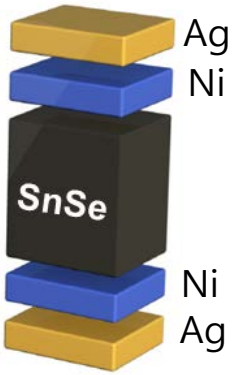
SnSe

Ag + Ni

- Stable metallization layer without cracks
- $10^{-3}$ Ωcm$^2$ range contact characteristics



# Ag/Ni Metallization




# Research in KIER

Thermoelectric material

[ ZT 1.5]



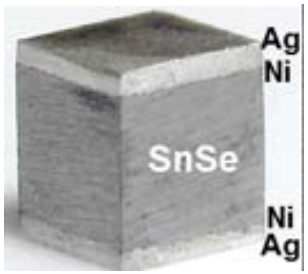
Optimized
bonding technology


Specific
Contact resistance

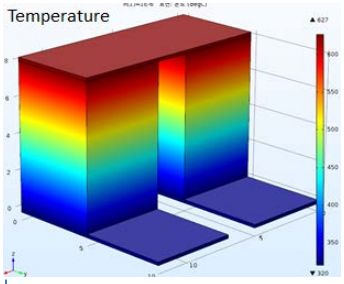
# ** Research Collaboration

# International Collaboration with KIER

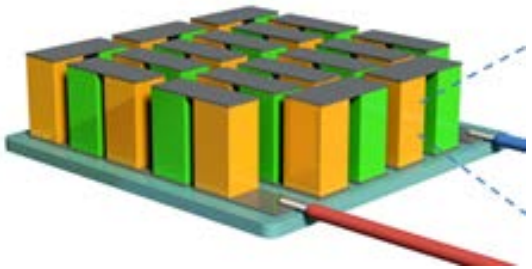
- SnSe post engineering




- Microstructure Analysis
- Interfacial Analysis
- Interface bandgap Engineering
- Material screening




- Thermoelectric Leg design



- Thermoelectric module design
- Novel module structure design

# International Research Projects

1. EU horizon 2020 based Korean-EU joint project (Korean governmental)


**EU horizon 2020**

Three different countries team mandatory

Researcher from EU should be chief of research

Korea : Industrialized Country
=> Mutual funding

- **Research 120,000 € /y**
- (MSCA) 40,000 € /y

# International Research Projects

**참고** **2015년 EU 협력진흥사업 개요**

☐ **사업목적**
- ○ EU Horizon2020에 국내 연구진의 참여 활성화를 위하여 참여 준비를 위한 활동 지원

☐ **지원분야**
- ○ Horizon2020 프로그램 과학기술 및 ICT 분야

☐ **지원규모 및 내용**
- ○ **지원규모 및 기간**
  - – 지원규모 : 과제당 연 25백만원 내외 ※ 3책5공 예외
  - – 지원기간 : 1년 ※ 간접비는 계상하지 않음
- ○ **지원내용** : 연구 컨소시엄 구성을 위한 활동경비, 연구과제 제안서 작성을 위한 법률자문비 등

☐ **신청자격**
- ○ 기초연구진흥 및 기술개발지원에 관한 법률 제14조에 해당하는 기관에 속한 연구자로서 **Horizon2020에 참여 준비 중인 자**
- ○ Horizon2020 과제 신청 관련, 유럽측과 컨소시엄(3개국 이상) 구성을 준비 중인 자

※ EU 협력진흥사업 선정과제는 반드시 EU측 Horizon2020에 신청해야 함

※ EU측 공고 관련(기공고 혹은 예정공고 포함) 컨소시엄 구성단계, 지원서 제출 단계 등 참여준비를 증빙할 수 있는 과제에 한함

※ EU측 평가결과 발표 이전 단계의 과제만 신청 가능함

※ 본 EU 협력진흥사업 내에서는 1인 1과제만 신청 및 수행 가능

☐ **신청방법 및 향후일정**
- ○ **신청접수기간** : 2015.10월초~11월말(재단 및 미래부 홈페이지에 공고 예정)
- ○ **신청방법** : 한국연구재단 연구지원시스템(http://ernd.nrf.re.kr)에 접속하여 신청

2. (Korean governmential)

Horizon 2020 is not mandatory

Supports 1) joint meetings and
2) proposal writing legal advice

20,000 € /y

Planned to proposal call on **this Oct.**

# System test site in KIER


## KIER circulating fluidized bed combustor

3 months operating / year

2MWe power generation

3 different possible hot zones
- under 120 ℃
- 200 ~ 300 ℃
- over 600 ℃

한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH

Toward a content and prosperous society,
led by KIER energy technology

# Global Energy Innovator KIER


The KIER, a global energy innovator, does its best in pursuing its mission to invent world-class energy technologies based on open innovation, life-cycle research quality assurance, participatory and open communication. Therefore the KIER will become the best energy technology R&D institute in the world, contributing to the creation of wealth and improvement of quality of life for the people.