

# TE-Device Workshop 2017

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<http://ceae.snu.ac.th>

# Outline

Presentation

1

Smart Technology

2

Center of Excellence on  
Alternative Energy

3

Thai Thermoelectric Society

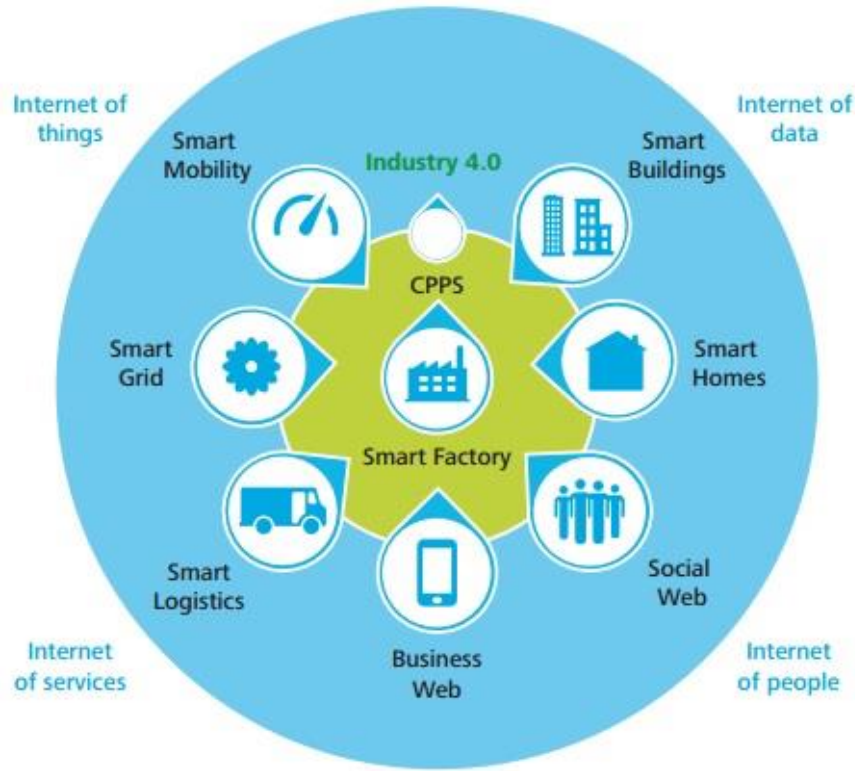
4

Thermoelectric Technology

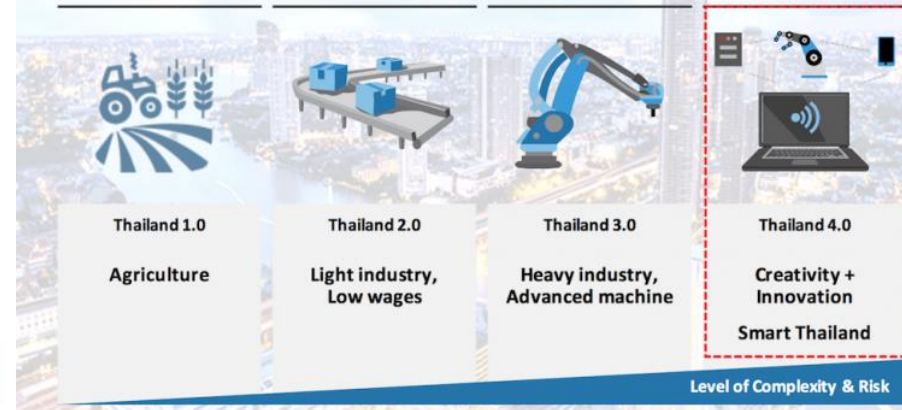
5

Invention 2017

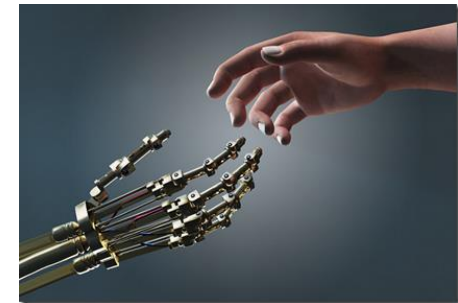
# Technology 4.0



## Thailand 4.0 (Smart Industry + Smart City + Smart People)



## Smart Robots for Smart Factories



**SMART :**

**Specific :** Target a specific area for improvement.

**Measurable :** Quantify or at least suggest an indicator of progress.

**Achievable :** State what results can realistically be achieved, given available resources.

**Responsible :** Specify who will do it.

**Time-related :** Specify when the result(s) can be achieved.



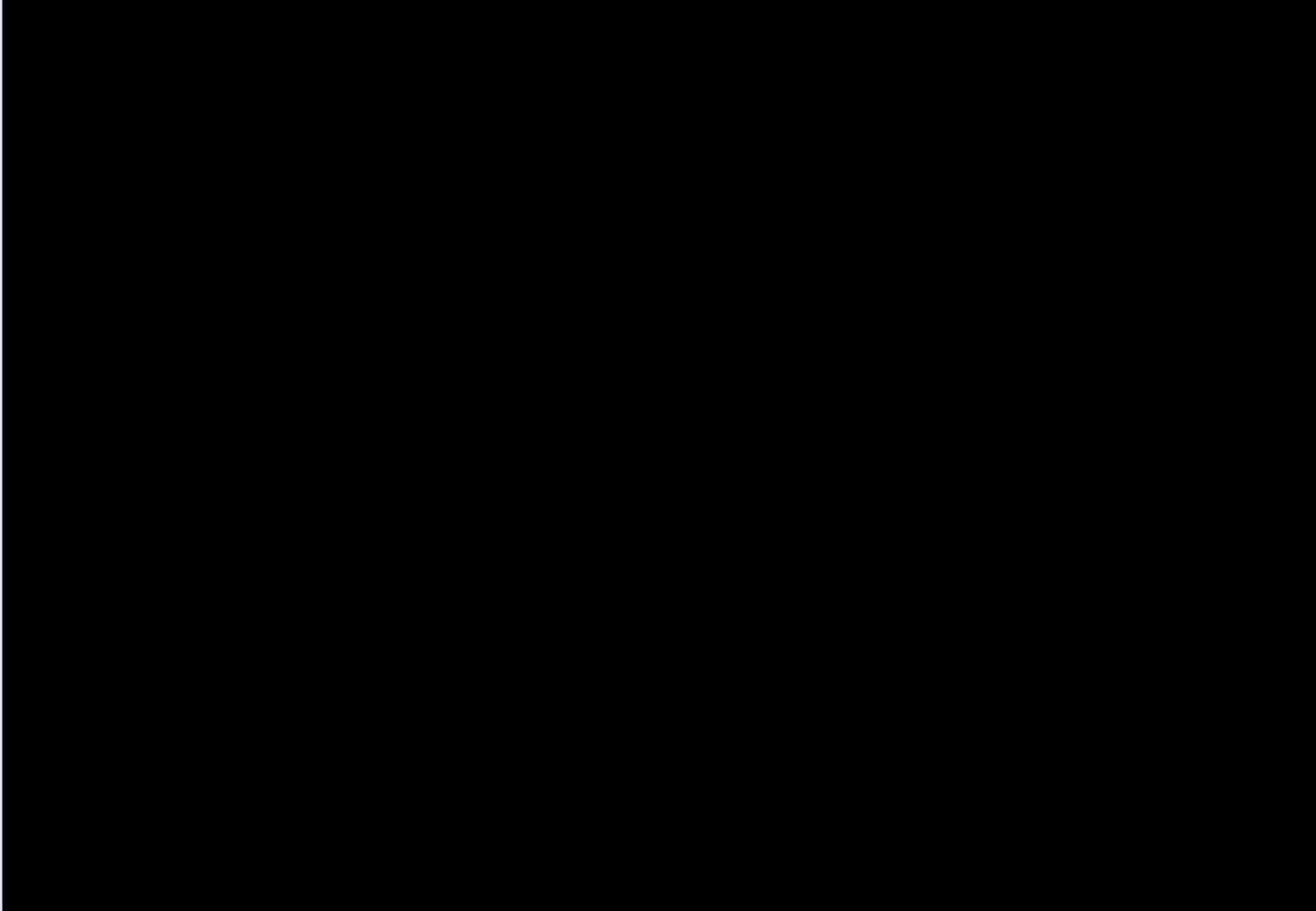
# Smart /Stupid Automobile



# 40 Key Technologies

Ghost in the Shell Movie

40 เทคโนโลยีแห่งอนาคต



# Outline

itation

2

**Center of Excellence on  
Alternative Energy**

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Center of Excellence on Alternative Energy,  
Research and Development Institute,  
Sakon Nakhon Rajabhat University

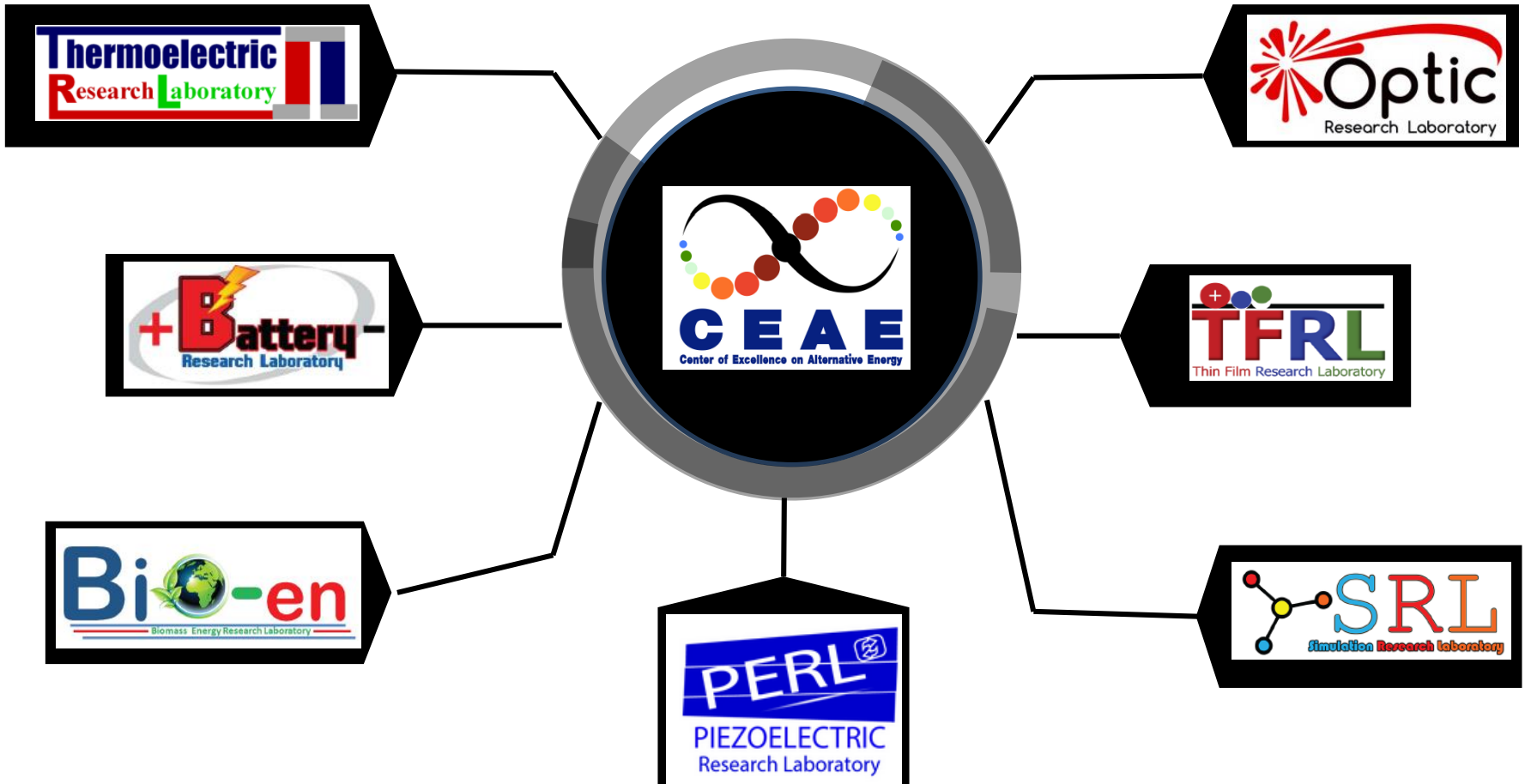
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680 ถนนมิตรภาพ ตำบลธาตุเชิงชุม  
อำเภอเมืองสกลนคร จังหวัดสกลนคร  
โทรศัพท์/โทรสาร 0 4274 4319  
<http://ceae.snru.ac.th>  
E-mail : [ceae@snru.ac.th](mailto:ceae@snru.ac.th)



**CEAE**  
Center of Excellence on Alternative Energy

# Center of Excellence on Alternative Energy SNRU





**Prof. Dr. Chaohai Zhang**  
 Plasma & Electrical  
 Environment Laboratory,  
 Harbin Institute of Technology

**Prof. Dr. Shinsuke Yamanaka**  
 Yamnaka Laboratory,  
 OSAKA University

**Prof. Dr. Jeon Geop Han**  
 Excellency Center for Advanced  
 Plasma Surface Technology,  
 SUNGKYUNKWAN University

**Prof. Dr. Atsuko Kosuga**  
 Kosuga Laboratory,  
 OSAKAPREFECTURE  
 University

**Prof. Dr. Phan Bach Thang**  
 Department of Nano and  
 Thin Film Materials,  
 University of SCIENCE



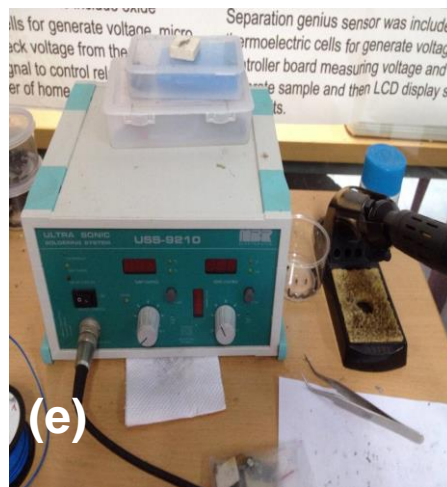
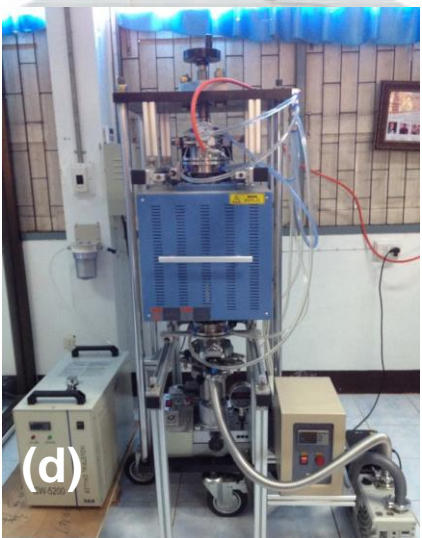
**Dr. Melania Suweni Muntini**  
 Department of Physics,  
 Institut Teknologi Sepuluh Nopember

- 1 KATAR
- 2 ZJEDNOCZONE EMIRATY ARABSKIE
- 3 IZRAEL
- 4 PALESTYNA

0 500 1000 km



# CEAE Instruments



- (a) Seebeck Coefficient and Resistivity Measurement
- (b) Thermal Conductivity Measurement
- (c) Efficiency of Thermoelectric Module Measurement
- (d) Hot Press 1200 °C
- (e) Ultrasonic Soldering
- (f) Thermoelectric Cell Measurement



**Micro Hardness Tester**



**Density Kit**



**TRC-ZTM2**



**X-Ray Diffractometer**



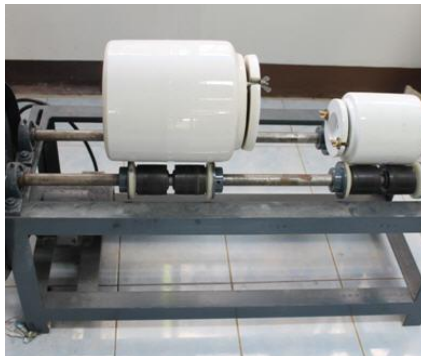
**Grinder-Polisher**



**Isomet Low Speed Saw**



**Electric Furnace 1,200 °C**



**Ball Milling**



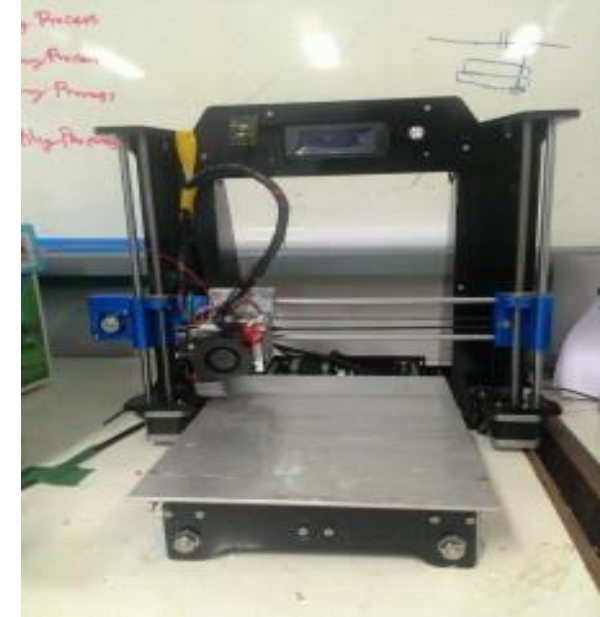
**Computer Simulation**



**Nano Size Particle Extraction**



**Magnetron Sputtering System**



**3D Printer**



**P-E Hysteresis Loop Tester**



**Electric Furnace 1,500 °C**



**Sieve Shaker**



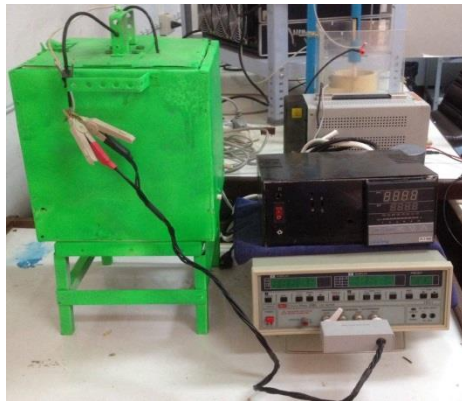
**Planetary ball mill**



**S&R measurement**



**Piezoelectric Poling Machine**



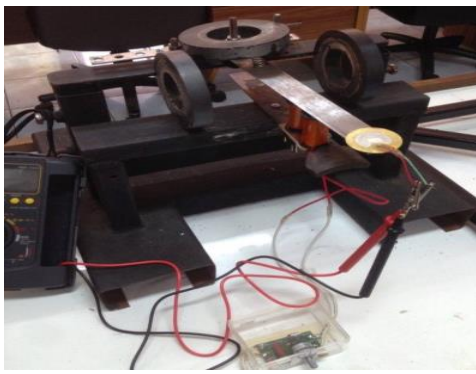
**Dielectric Constant Meter**



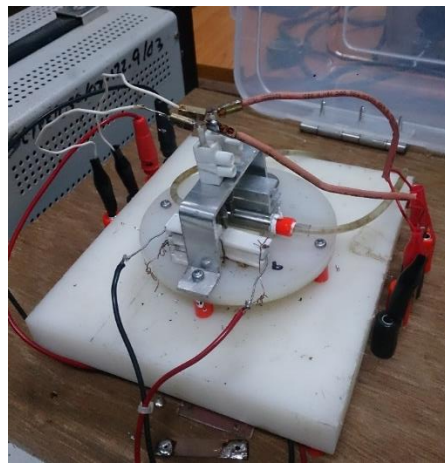
**Hysteresis Loop Meter**



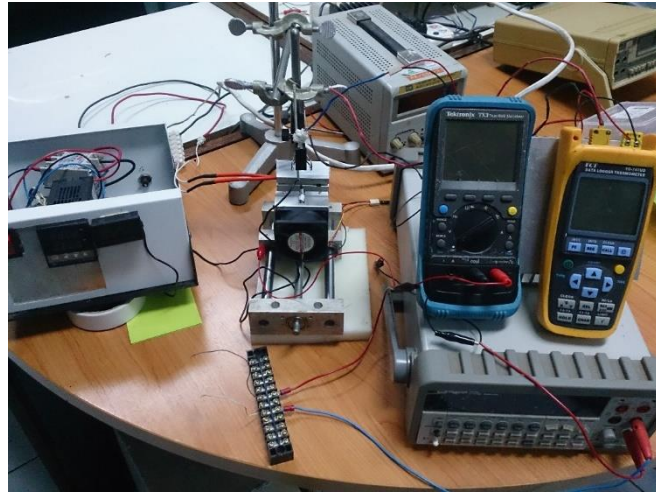
**Piezoelectric Coefficient Meter**



**Piezoelectric Harvesting Machine**



**Four Point Probe**



**Electrical Power**

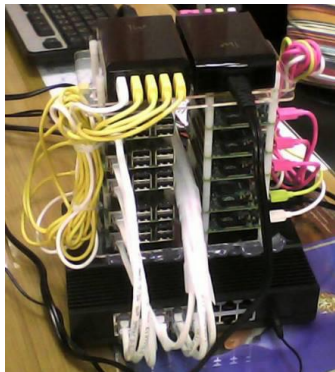
**Seebeck Coefficient Thin Film**



**Ultrasonic Cleaner**



**2 Zone Vacuum Tube Furnace**



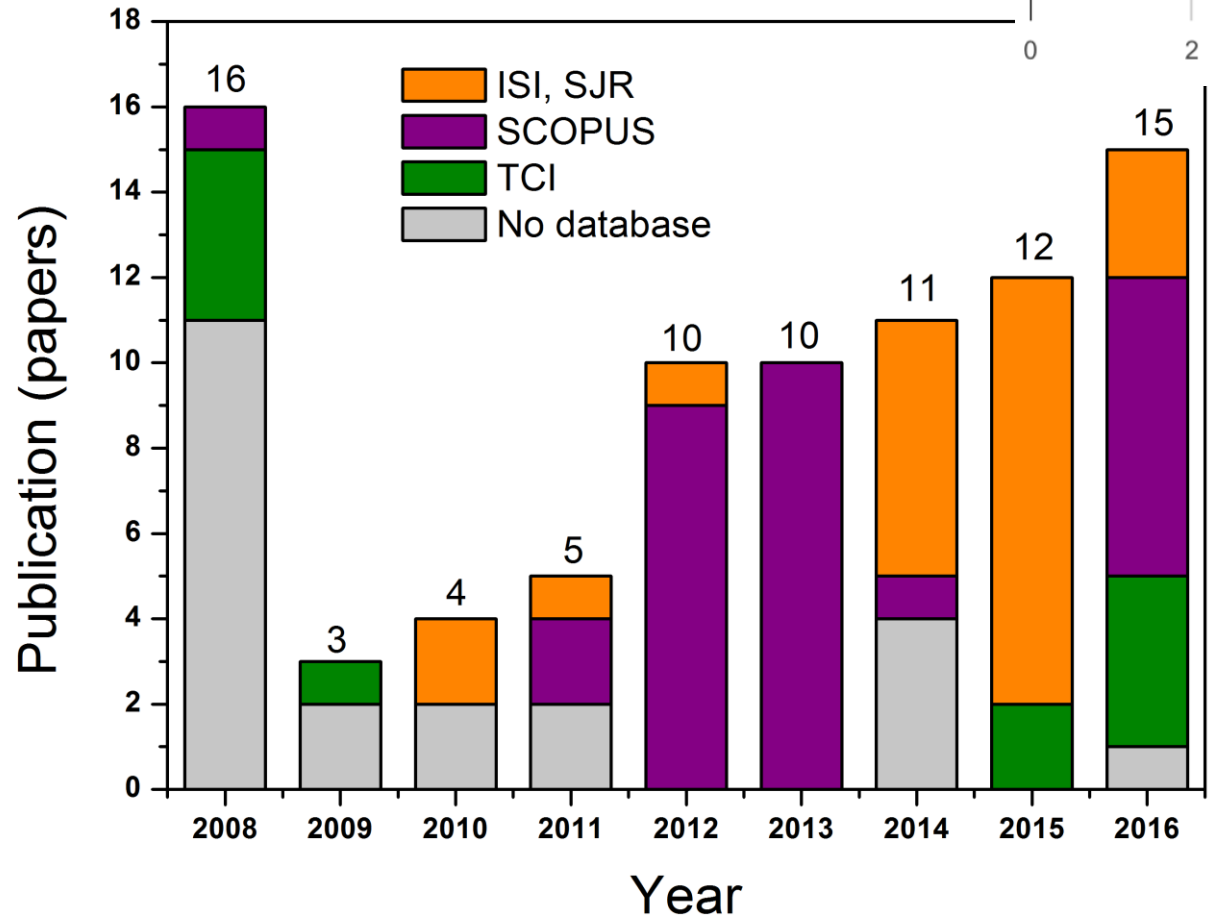
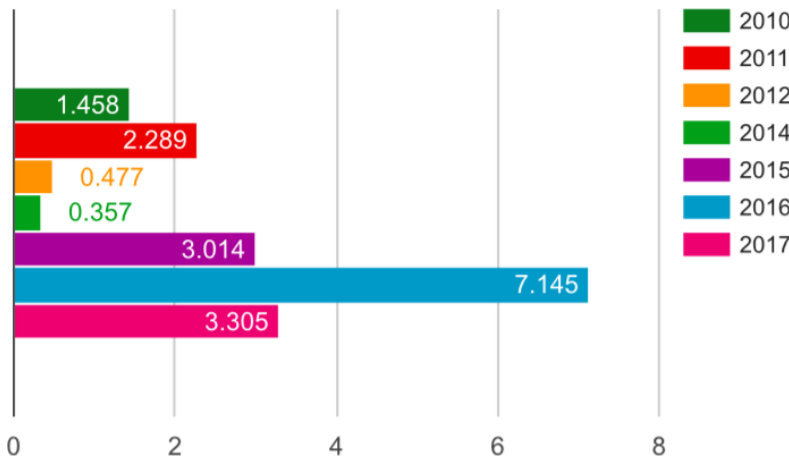
**Raspberry Pi Cluster Computer**



**UV-Vis Spectrophotometer**

# CEAE Publications

## Max. Impact Factor



# Outline

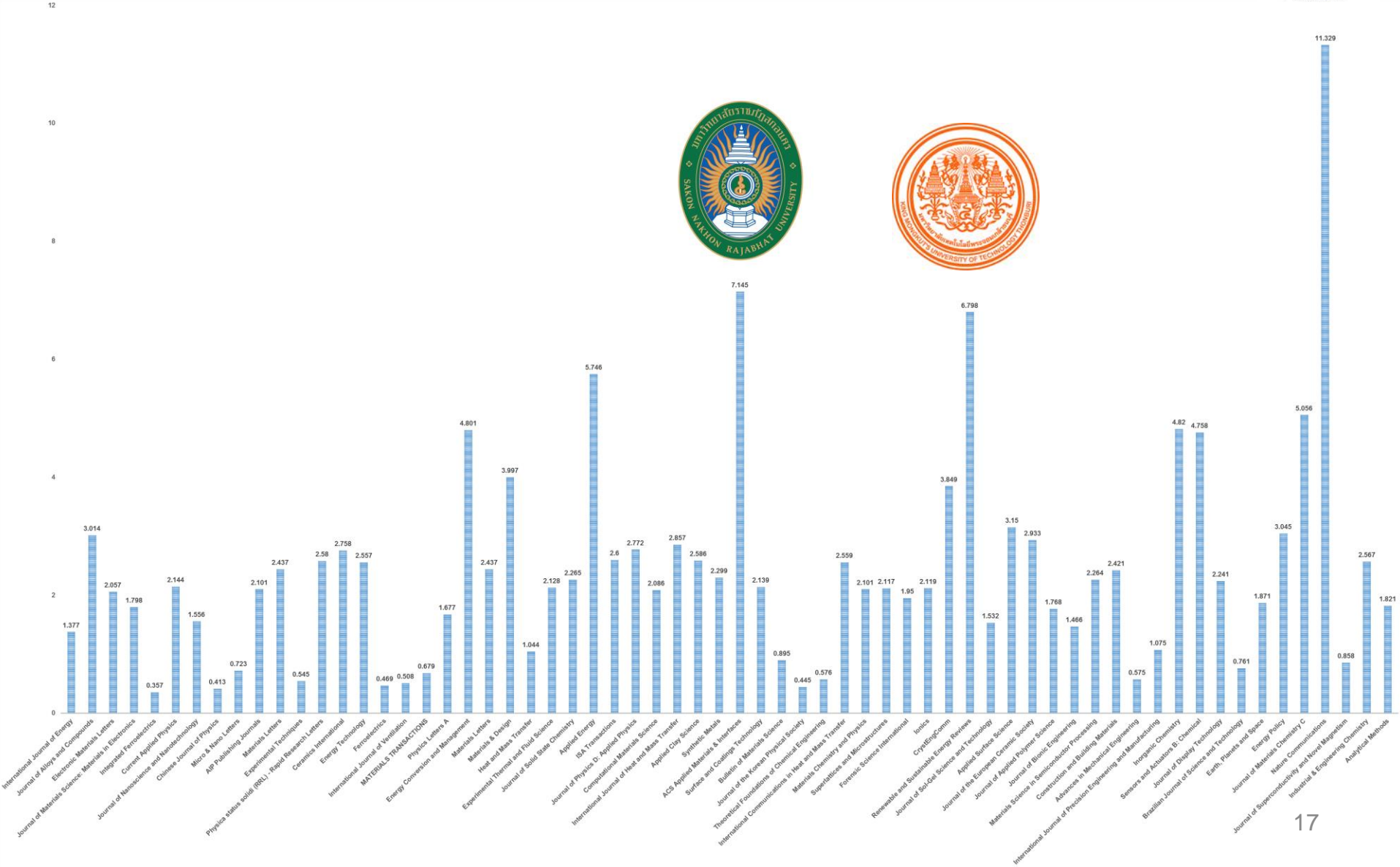






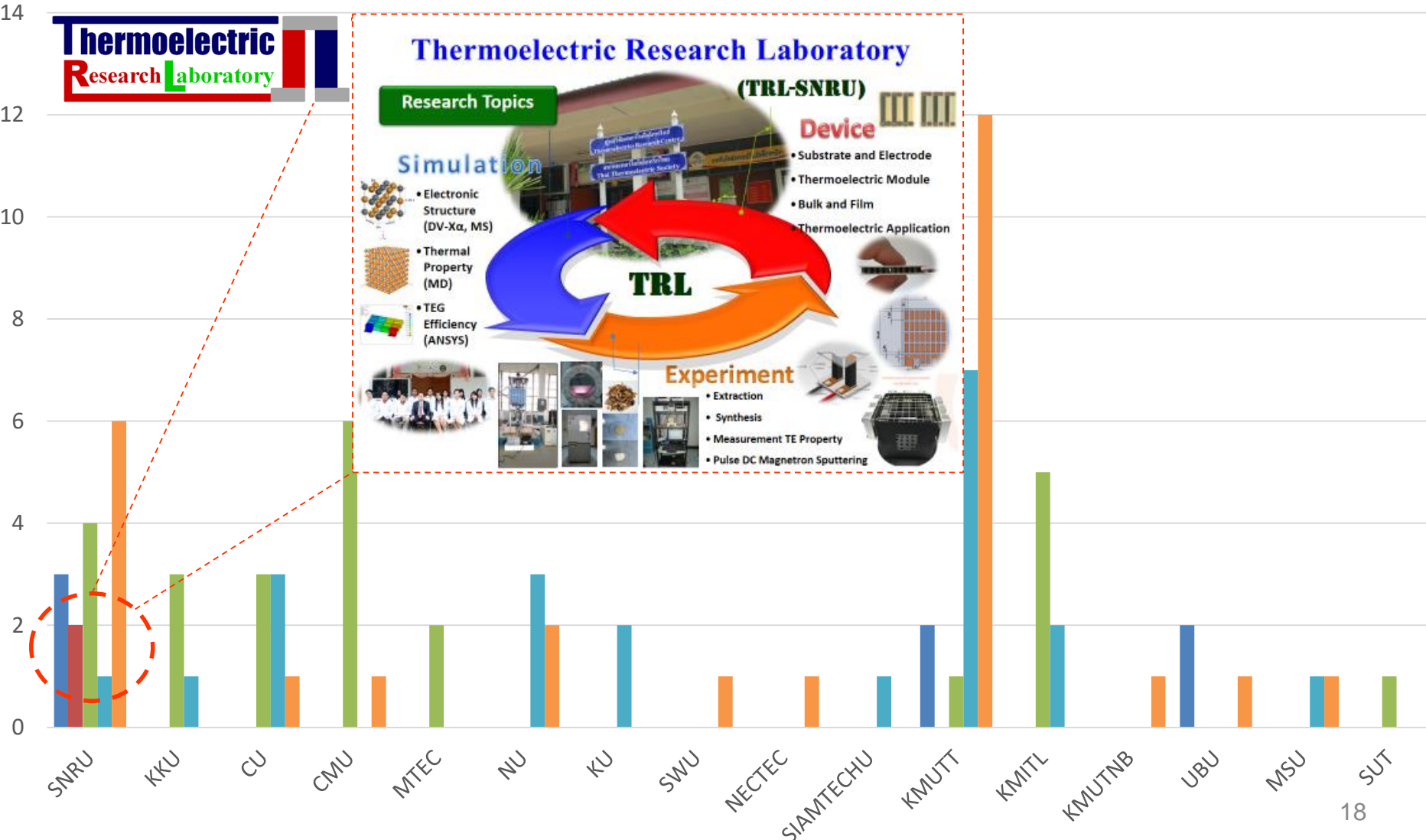
# Publications

## Thermoelectric Researchers in Thailand



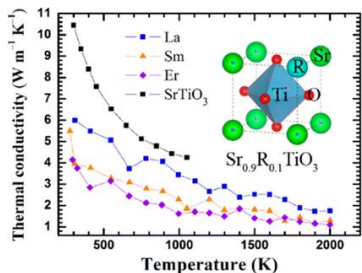
# Thermoelectric Research Types in Thailand

Simulation    Extration    Synthesis    Generator    Refrigerator



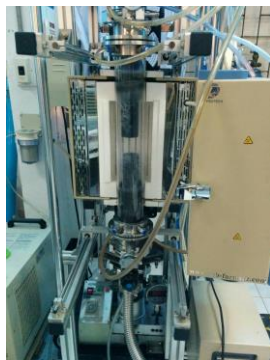


Appl. Mater. Interfaces, 2016, 8 (49)  
 33916–33923, IF = 7.145



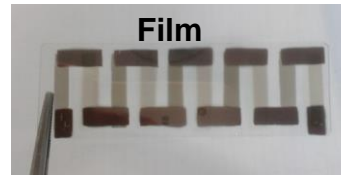
Inorg. Chem., 2016, 55 (17),  
 8822–8826, IF = 4.820

HotPress



Prepare & Synthesis & Optimize Materials

Fabricate Bulk and Film Cell & Module prototypes



Apply & Generator & Refrigerator



INVENTIONS

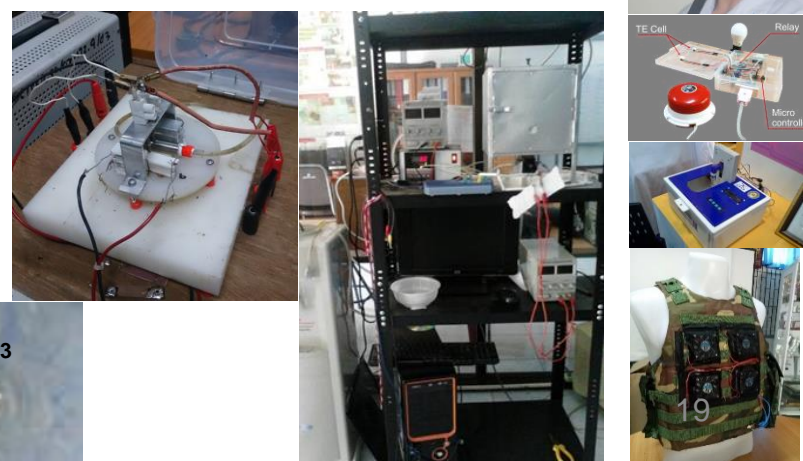


Design & Fabricate & Measurement Apparatus

Investigate & Extract & Optimize Law Materials

Simulate & Design & Modeling

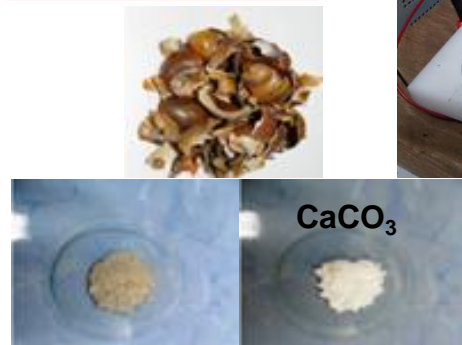
Seebeck & Resistivity & Thermal c.



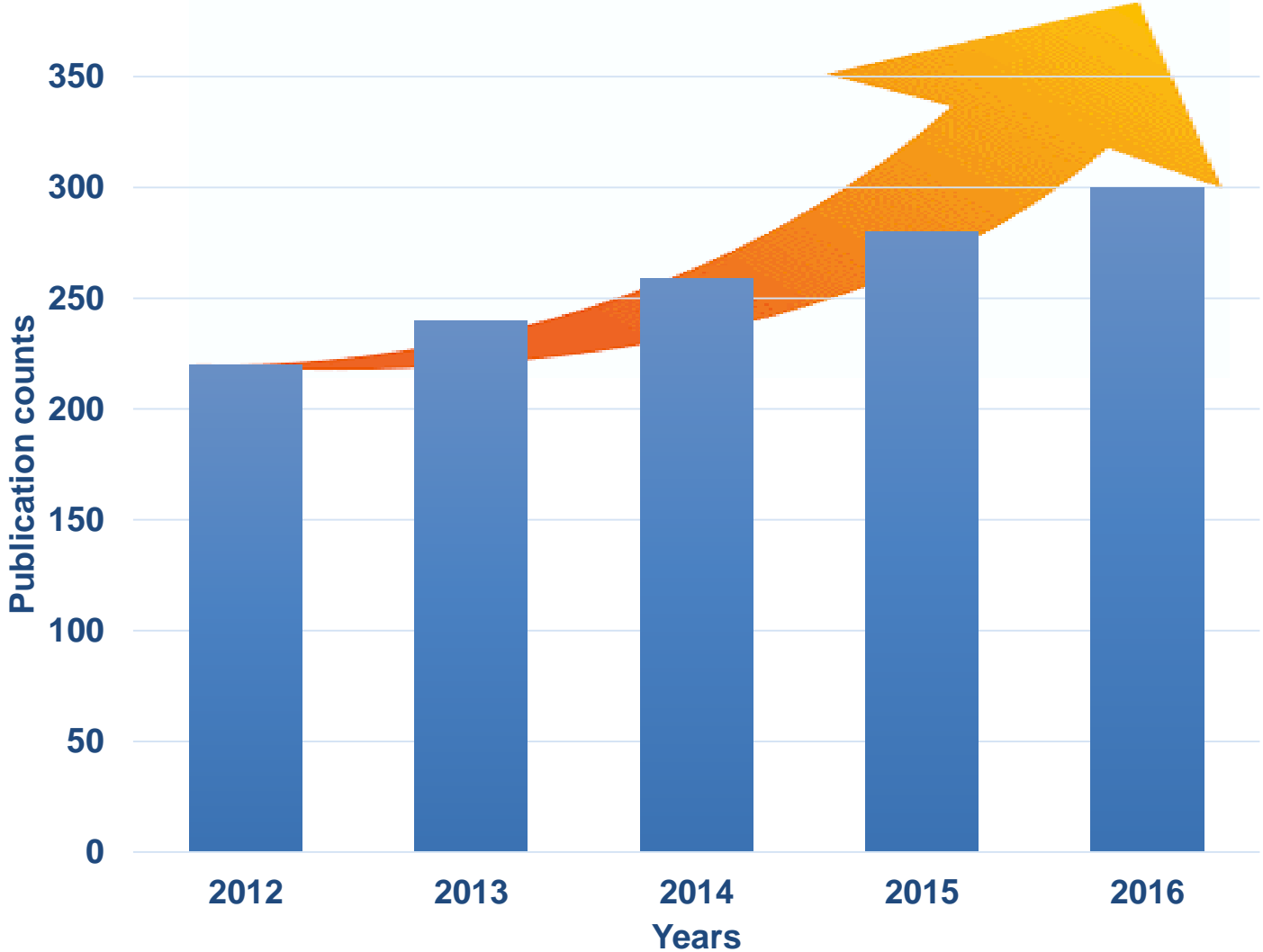
BoltzTraP



Molecular dynamics



# Number of Publications : Thai Thermolectric Research



# Outline

**Small & Smart Technology**

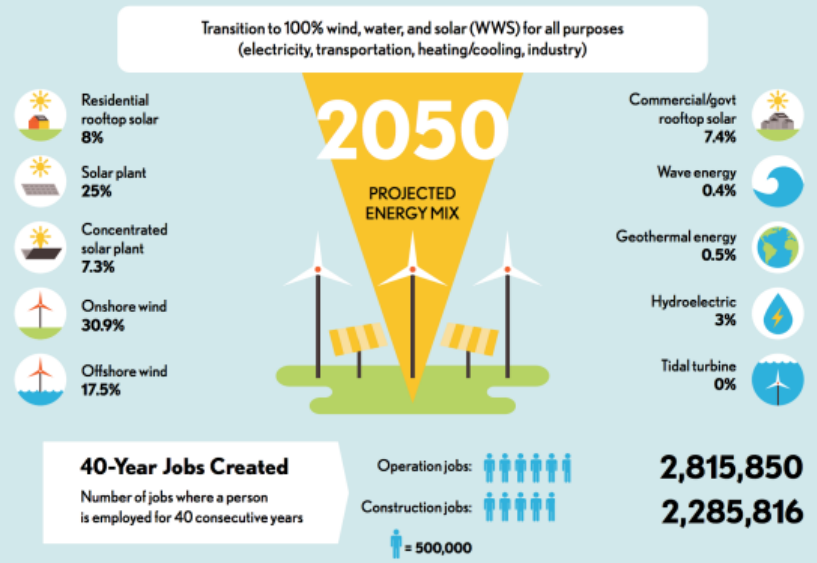
**Alternative Energy**

**Presentation**

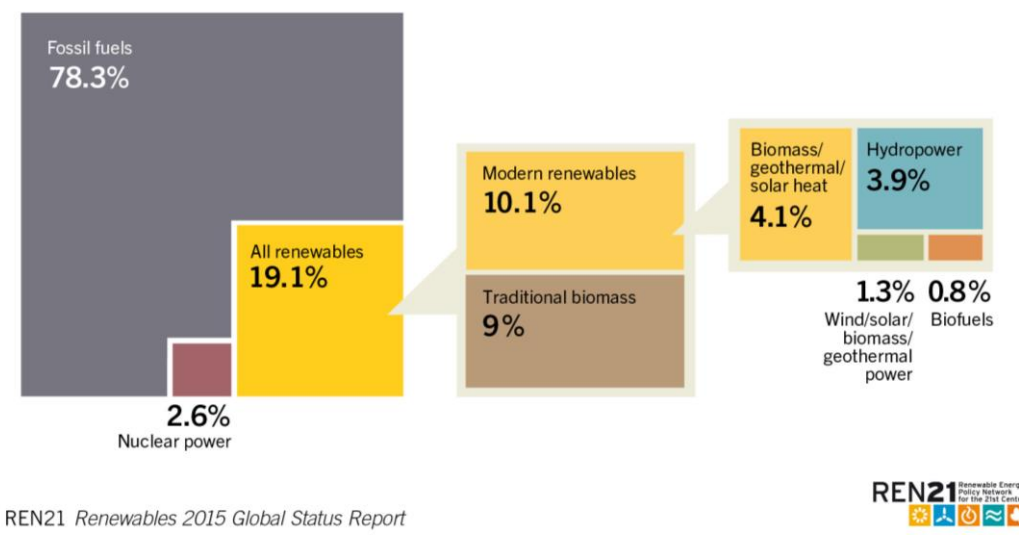
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**Thermoelectric Technology**

# 100% UNITED STATES

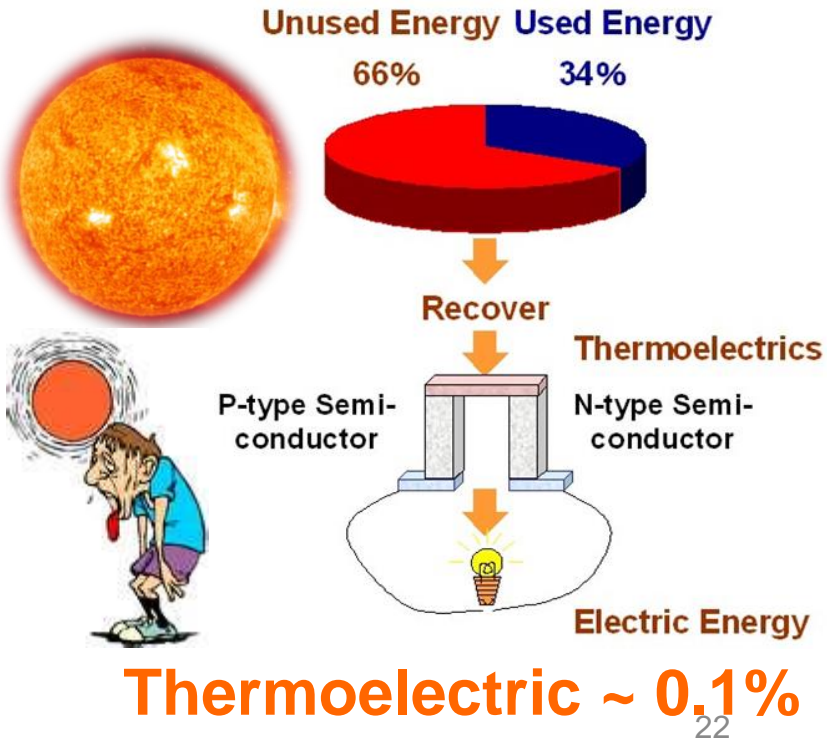


## Estimated Renewable Energy Share of Global Final Energy Consumption, 2013



## Thailand

Renewable Energy	As of 2015	Target in 2036
1. Solar Cell	1,298.51 MW	6,000 MW
2. Wind Energy	224.47 MW	3,002 MW
3. Biomass	2,451.82 MW	5,570 MW
4. Biogas (Wastewater/sludge)	311.50 MW	600 MW
5. Biogas (Energy crops)	Pending	680 MW
6. Waste (Municipal Solid Waste)	65.72 MW	500 MW
7. Waste (Industrial Waste)	Pending	50 MW
8. Small Hydro Power	142.01 MW	376 MW
9. Hydro Power	Pending	2,906.40 MW*
<b>Total in MW</b>	<b>4,494.03 MW</b>	<b>19,684.40 MW</b>



# What is thermoelectric?

- TE can directly conversion of temperature difference to electric and vice versa.
- Thermoelectric materials
- Thermoelectric cell
- Thermoelectric module
- Thermoelectric generator
- Thermoelectric cooler

The diagram shows the equation  $ZT = \frac{S^2 \sigma T}{K}$  on a blue background. Red arrows point from text labels to the variables in the equation: 'Seebeck coefficient' points to  $S$ , 'Electrical conductivity' points to  $\sigma$ , 'Absolute temperature' points to  $T$ , and 'Thermal conductivity' points to  $K$ . A red arrow points from the entire equation to the label 'Dimensionless figure of merit'.

Seebeck coefficient

Electrical conductivity

Absolute temperature

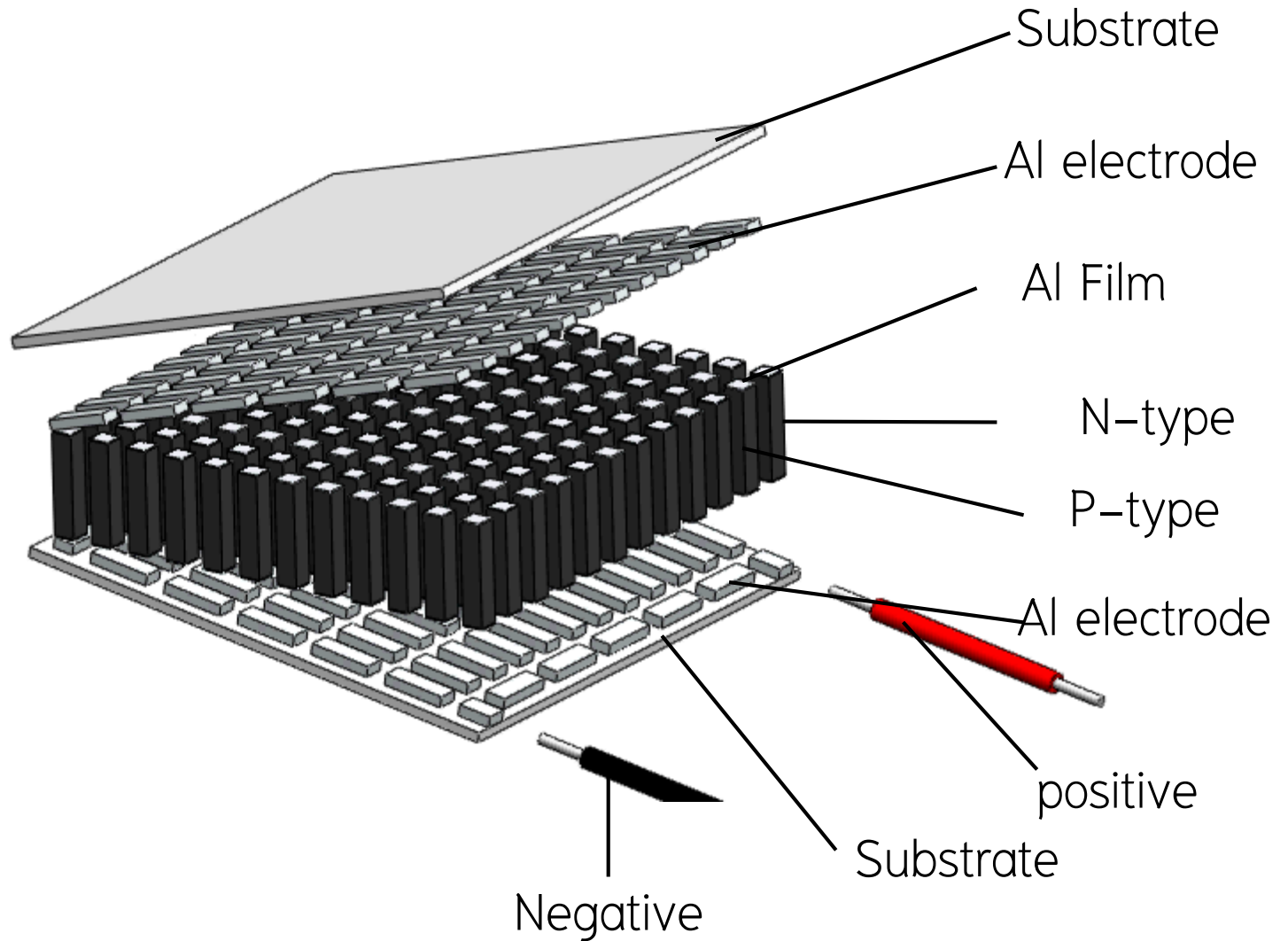
$$ZT = \frac{S^2 \sigma T}{K}$$

Thermal conductivity

Dimensionless figure of merit

We need low thermal conductivity and high Seebeck coefficient and electrical conductivity.

# Thermoelectric Module



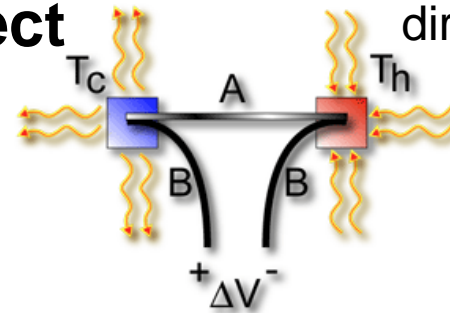


# TE Effects



In 1821, Germany Physicist

## Seebeck effect



Conversion  $\Delta T$  directly into electricity.

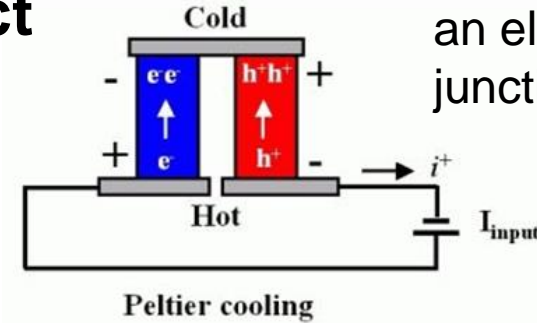
$$V = S_{AB}(T_h - T_c)$$

**Thomas Johann Seebeck**



In 1834, France Physicist

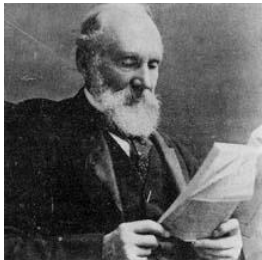
## Peltier effect



Heating or cooling at an electrified junction.

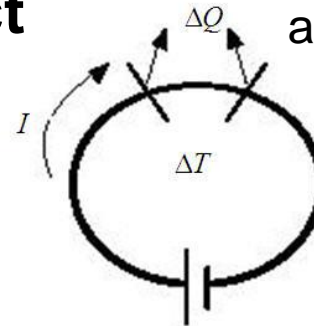
$$Q = \pi_{ab}I$$

**Jean Charles Athanase Peltier**



In 1854, Scotland Physicist

## Thomson effect

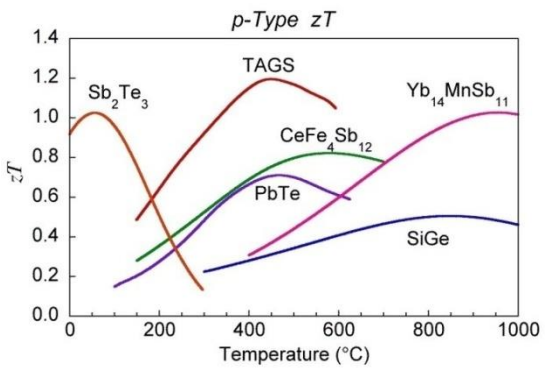
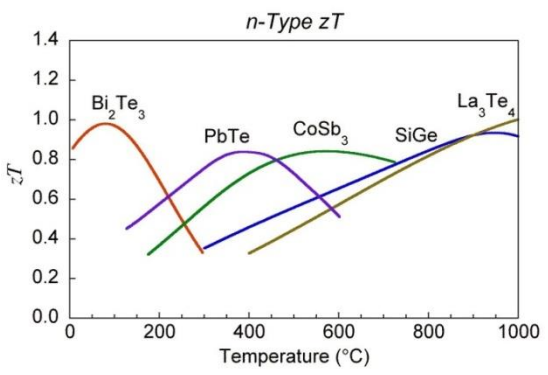
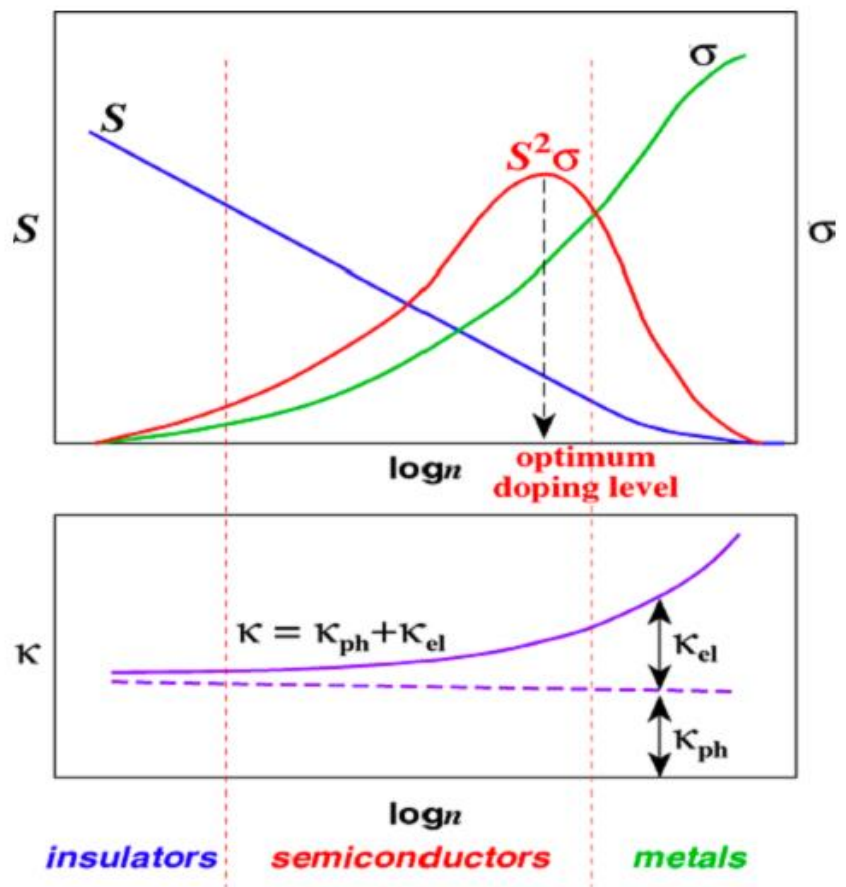
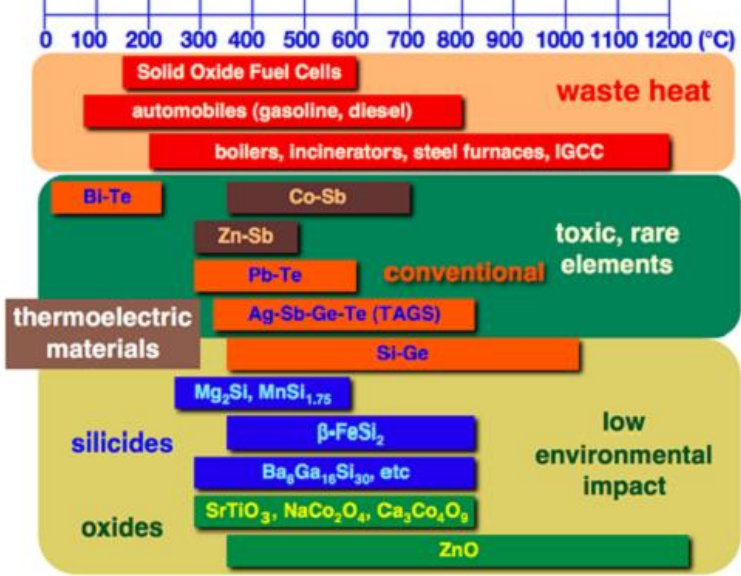


Related Seebeck effect and Peltier effect.

$$\dot{Q} = \frac{dQ}{dt} = \tau I \frac{dT}{dx}$$

**William Thomas (Lord Kelvin)**

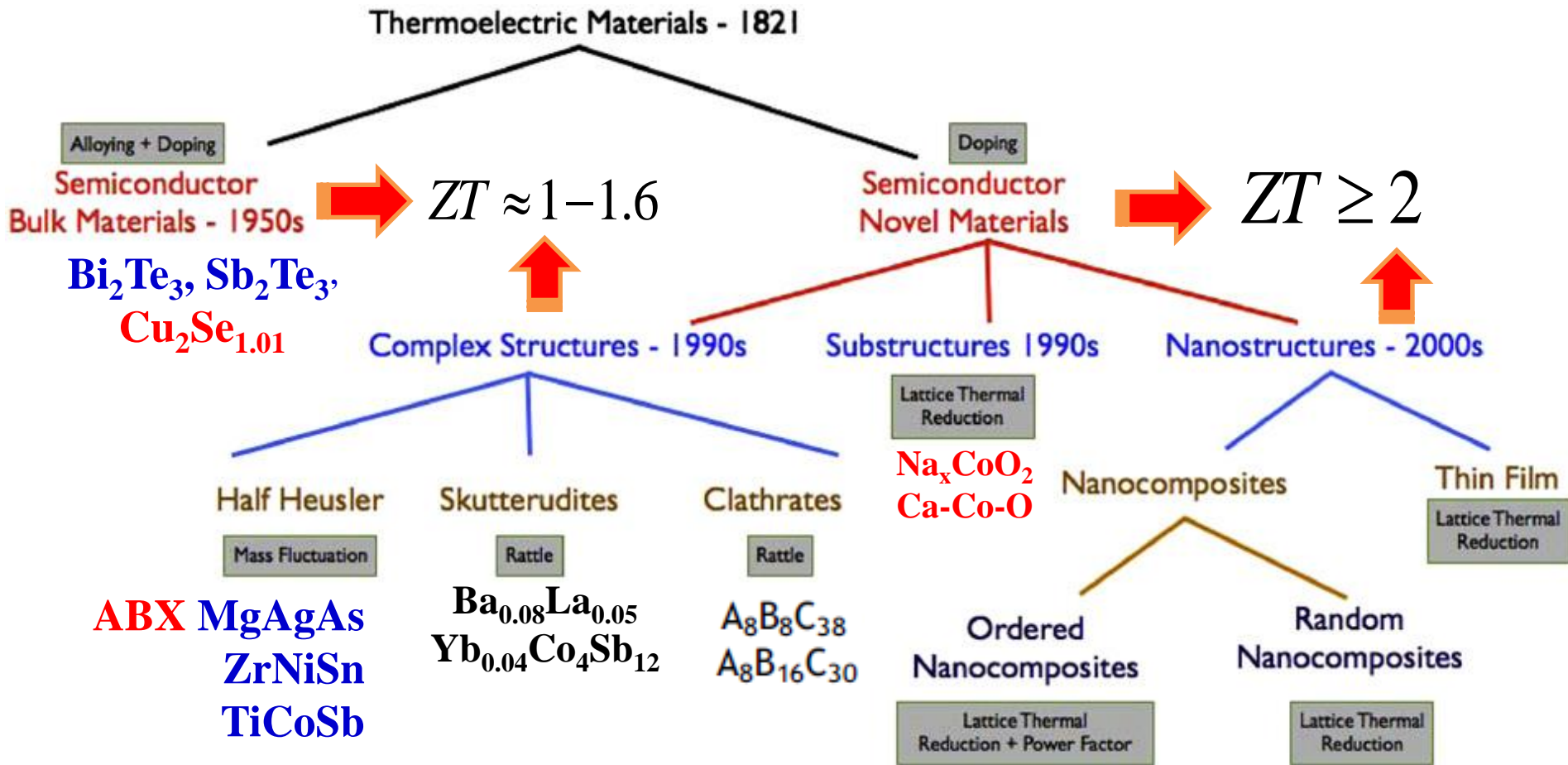
# TE Materials



Property	Metals	Semiconductors	Insulators
$S / (\mu\text{V}\cdot\text{K}^{-1})$	$\sim 5$	$\sim 200$	$\sim 1000$
$\sigma / (\Omega^{-1}\cdot\text{cm}^{-1})$	$\sim 10^6$	$\sim 10^3$	$\sim 10^{-12}$
$Z / \text{K}^{-1}$	$\sim 3 \times 10^{-6}$	$\sim 2 \times 10^{-3}$	$\sim 5 \times 10^{-17}$

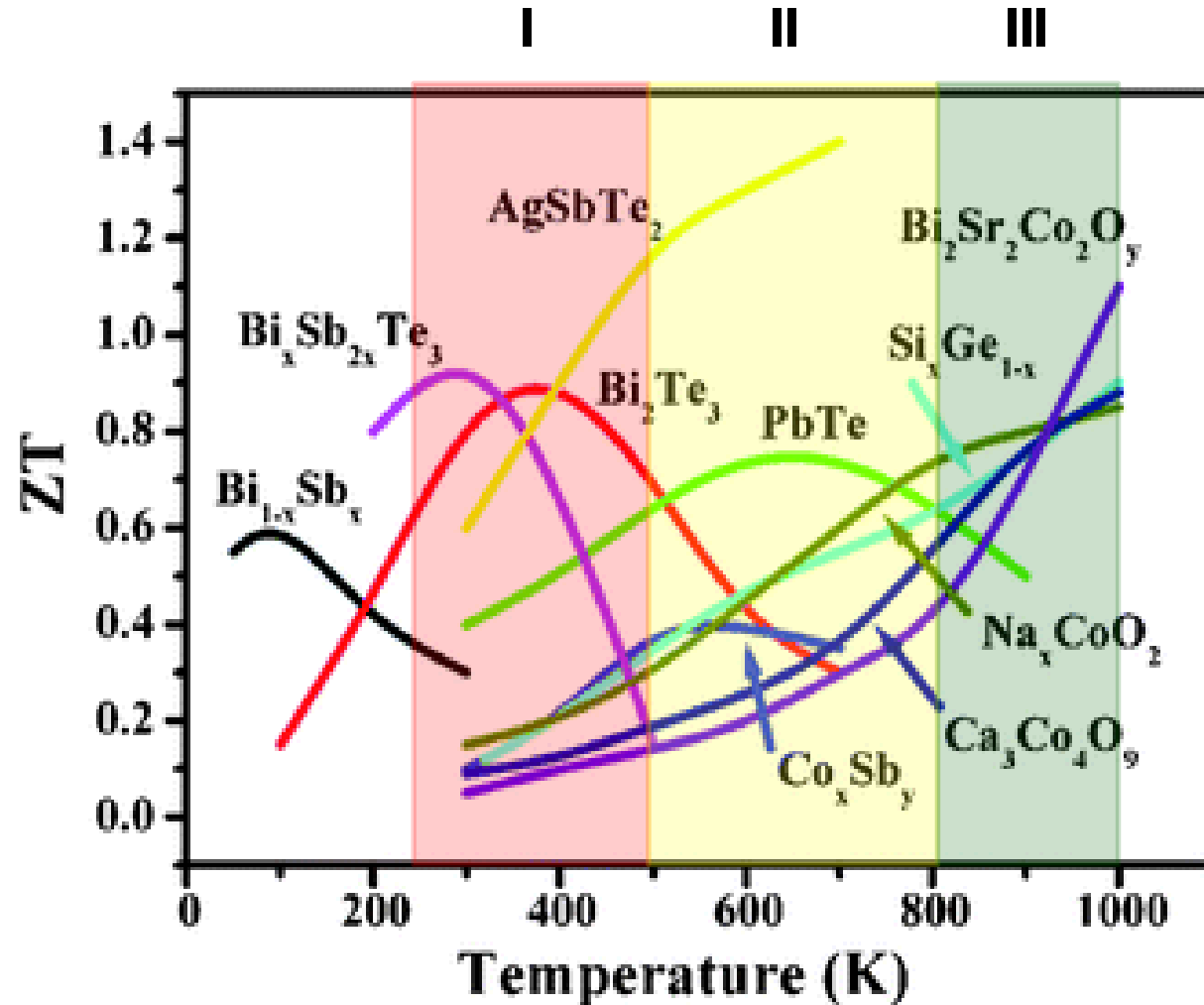
<http://web.mit.edu/nanoengineering/research/te.shtml>

# TE Materials



**Bulk & Film--->Nano Materials**

# How are select TE materials?



**I Low Region**

**(250-500 K) :**

Tellurides

**II Medium Region**

**(500-800 K) :**

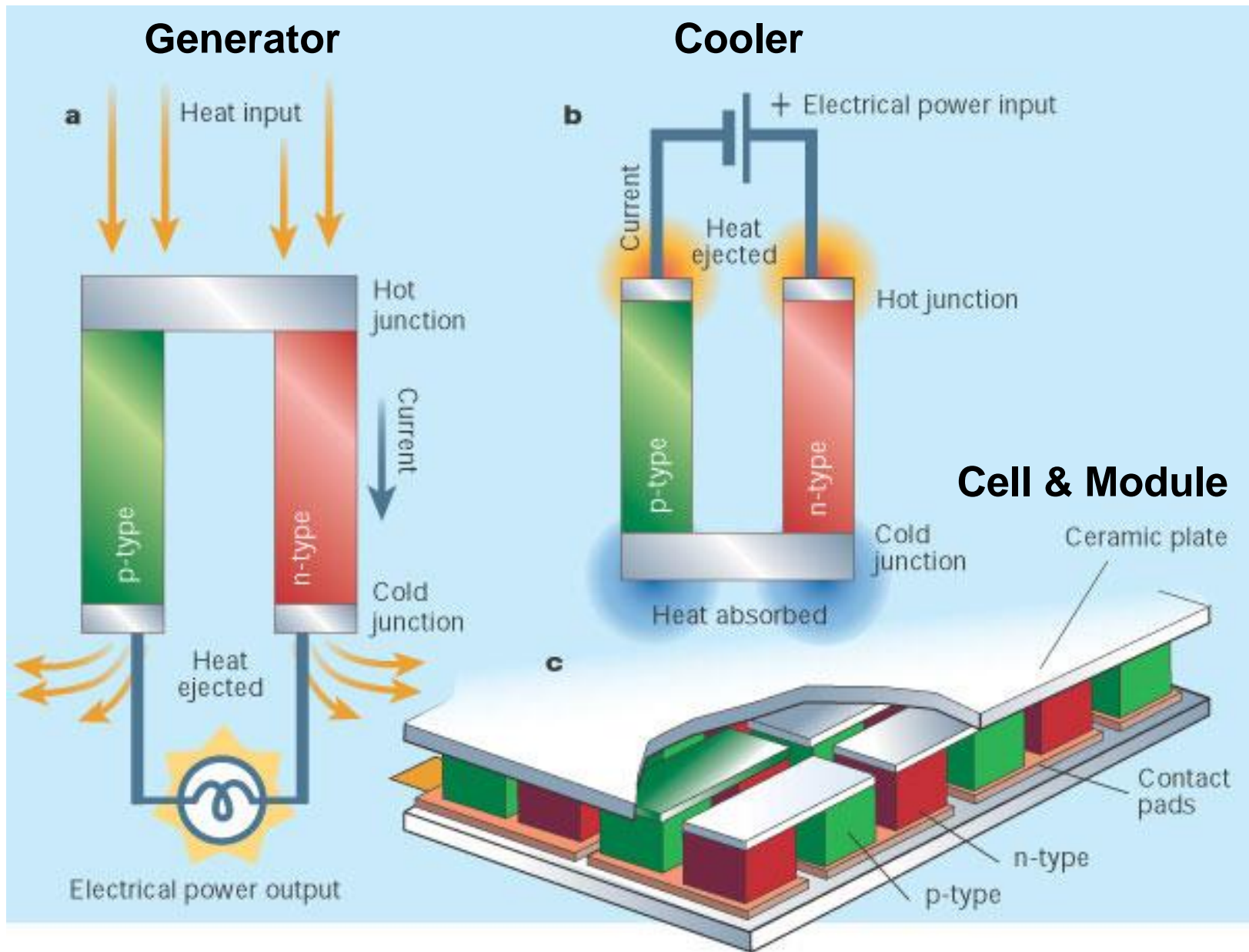
Skutterudites and  
Silicides

**III High Region**

**(800-1000 K) :**

Oxides

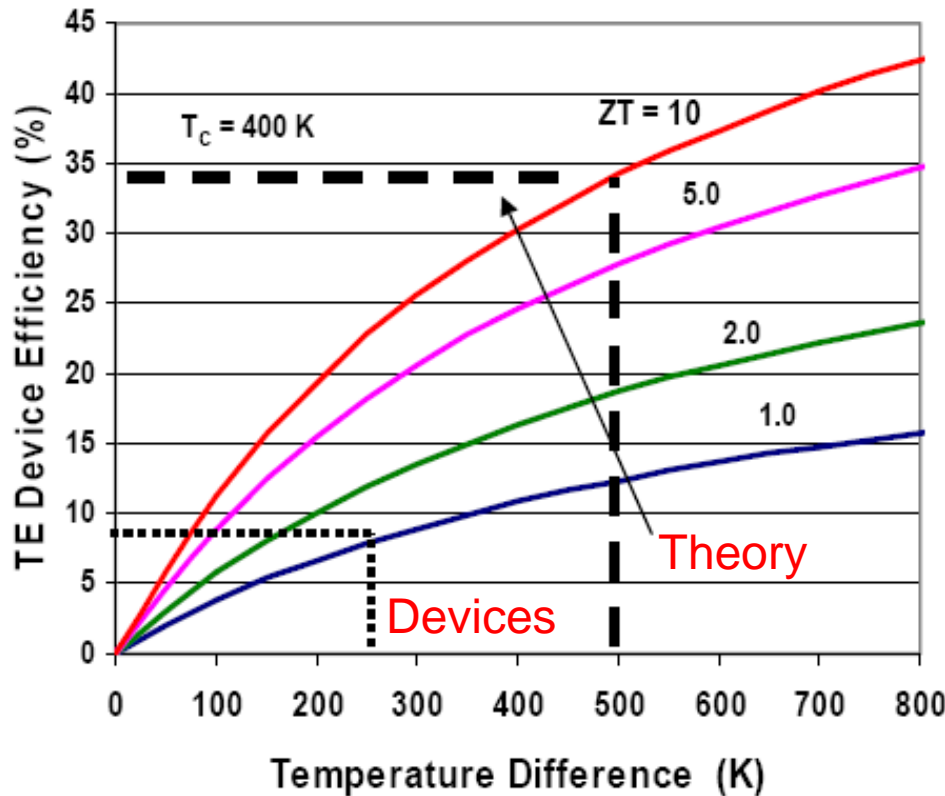
# Thermoelectric Cell & Module?



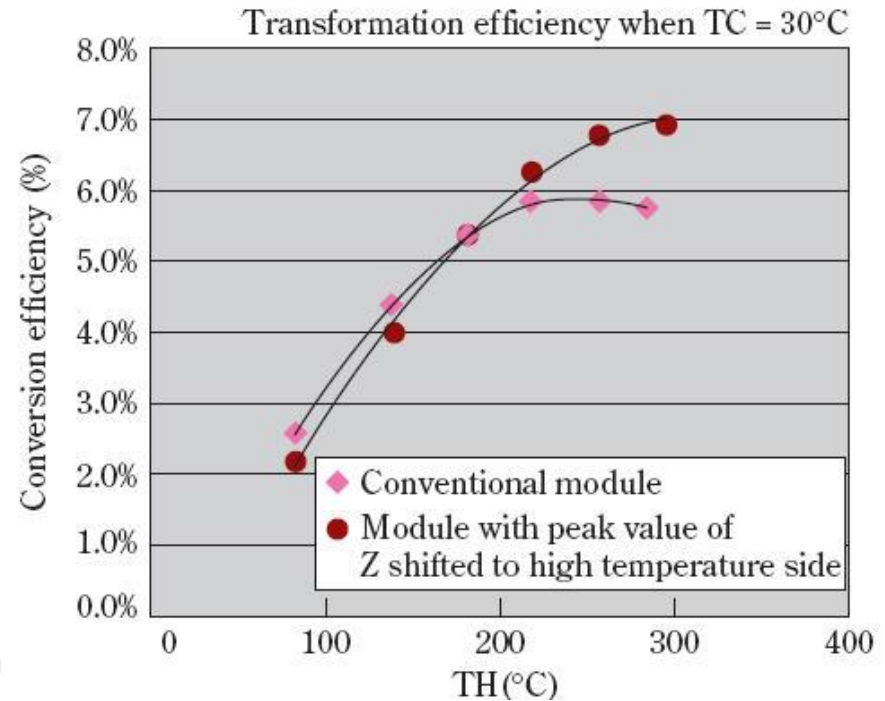
# Thermoelectric Efficiency

$$\eta = \frac{W}{Q_H} = \frac{I \left[ (S_p - S_n) \Delta T - IR \right]}{K \Delta T + (S_p - S_n) I T_H - \frac{1}{2} I^2 R}$$

## Theory

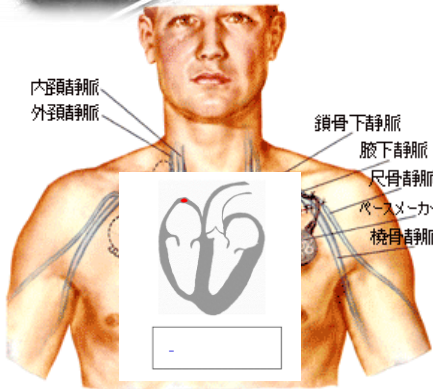


## Commercial

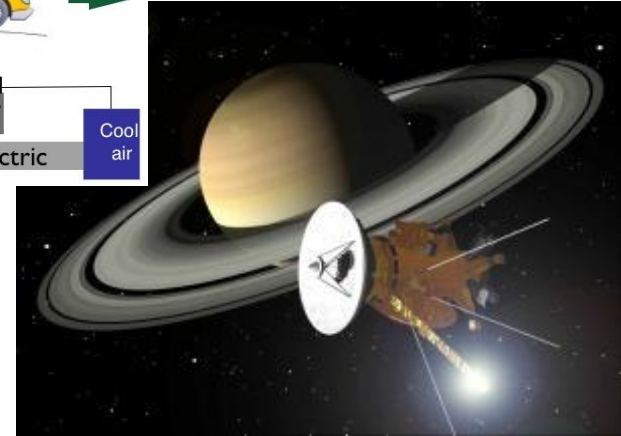
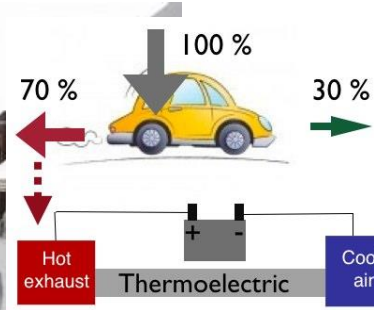


Sano S., et al. (2003)

# TE Applications



**PACEMAKER**



**CASSINI SPACECRAFT**

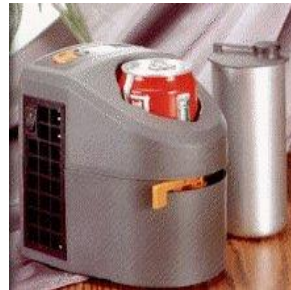
(The power source is TE generation.)



Eco-Drive Thermo  
(Citizen Watch Co., Ltd.)



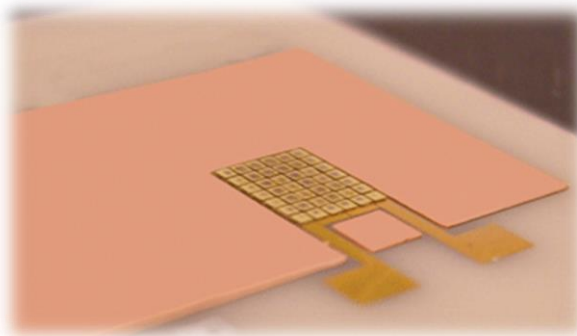
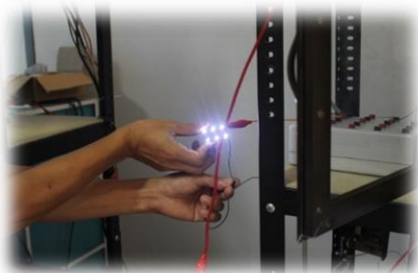
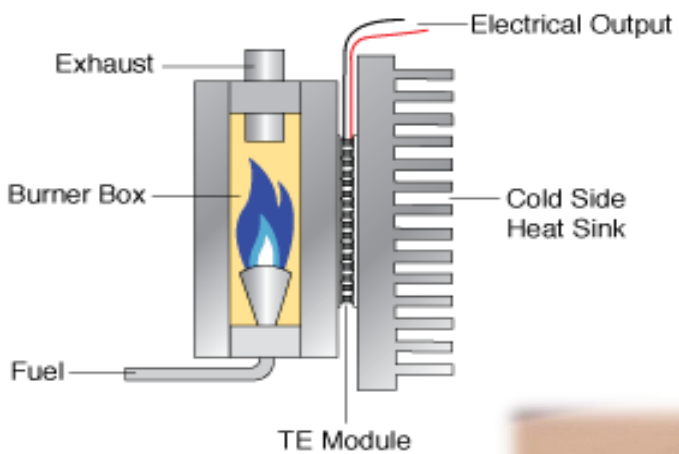
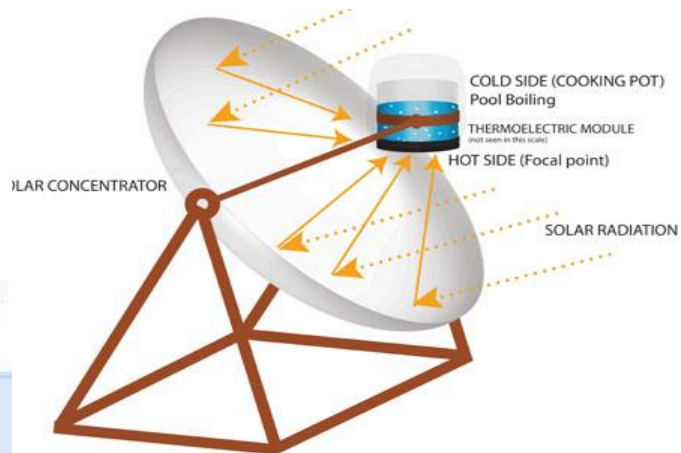
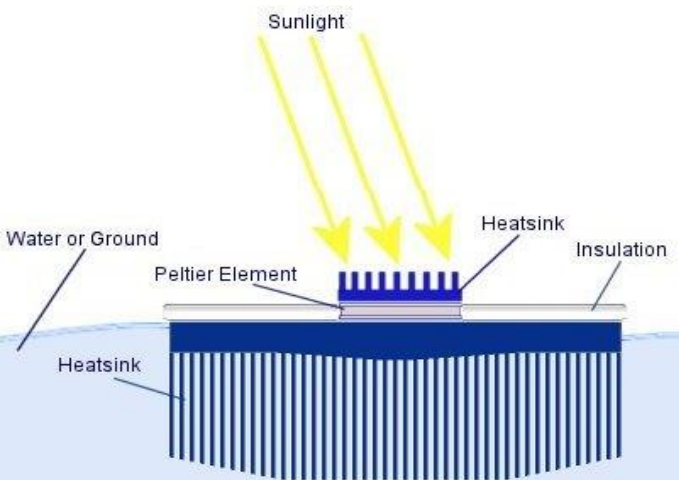
**CPU COOLING  
MODULE**



**CAN COOLER**



ERS Loaded BMW 5 Series  
(Under Development in BMW of North America)



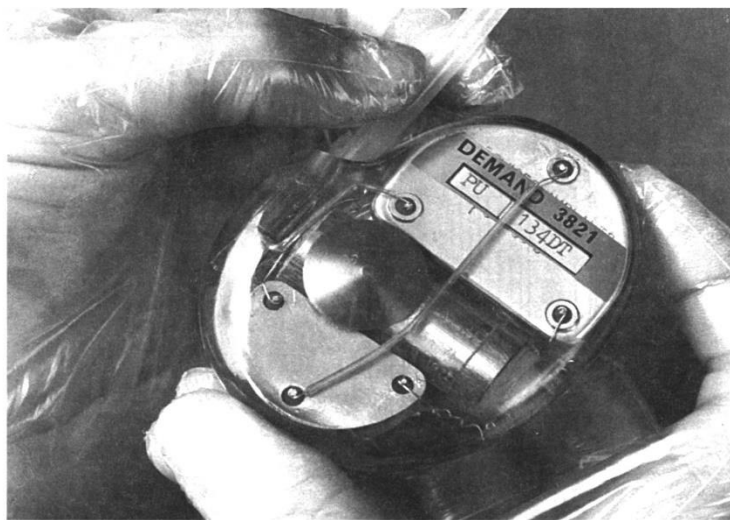


# Thermoelectric Batteries

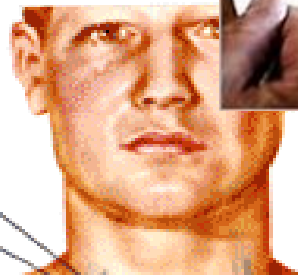


## Pacemaker

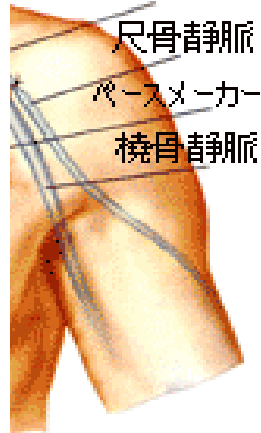
The best-known medical application of thermoelectric batteries is in the cardiac pacemaker.



内頸静脈  
外頸静脈



鎖骨下静脈  
腋静脈  
尺骨静脈  
ペースメーカー  
橈骨静脈



## Thermoelectric Oxide Friendly Environment

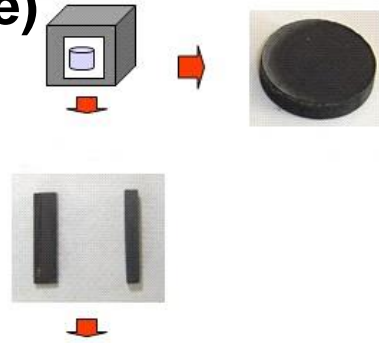
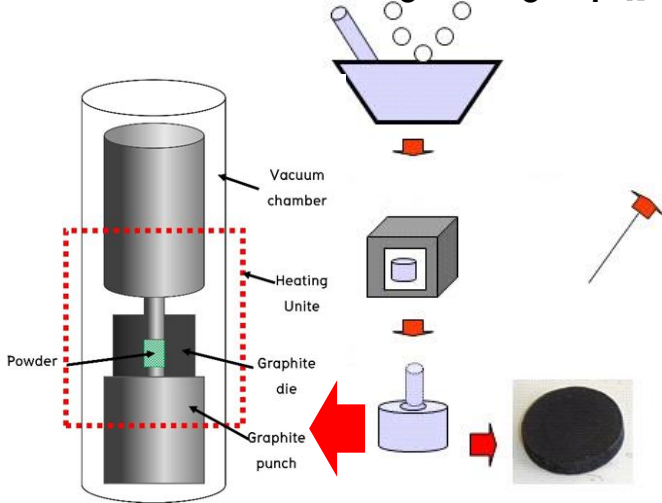
### Typical Specifications

- # Isotope for Heat Source Pu-238
- # Thermoelectric Material  $\text{Bi}_2\text{Te}_3$
- # Output Power : 300  $\mu\text{V}$

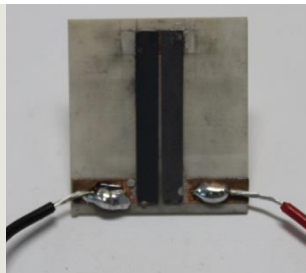
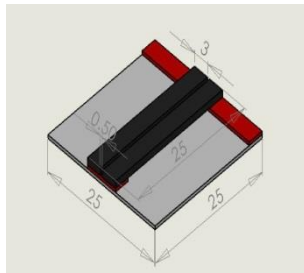
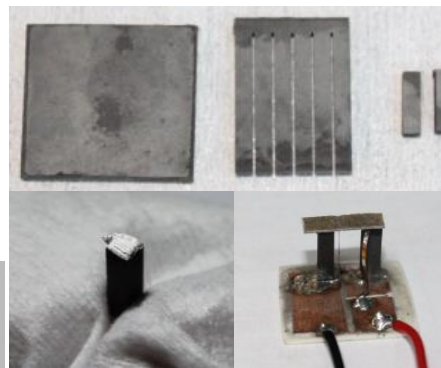
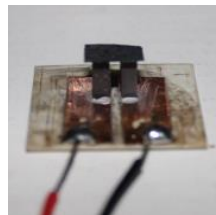
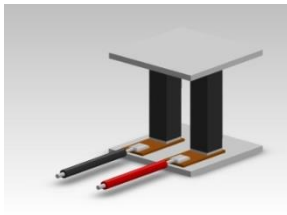
# Synthesis and Thermoelectric Properties

$\text{CaCo}_3 + \text{MnO}_2$  (n-type)

$\text{CaCo}_3 + \text{Co}_3\text{O}_4$  (p-type)

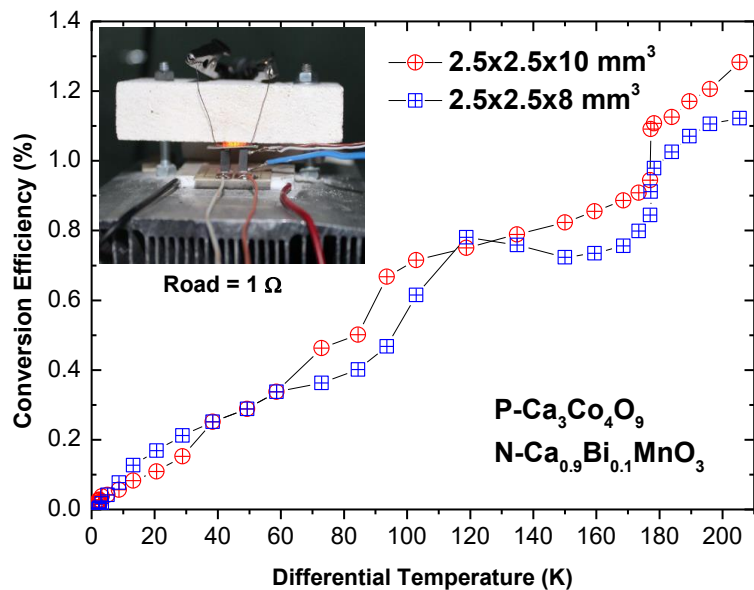


**Crystallography (XRD)**  
**Thermoelectric properties**  
**Thermoelectric cell**

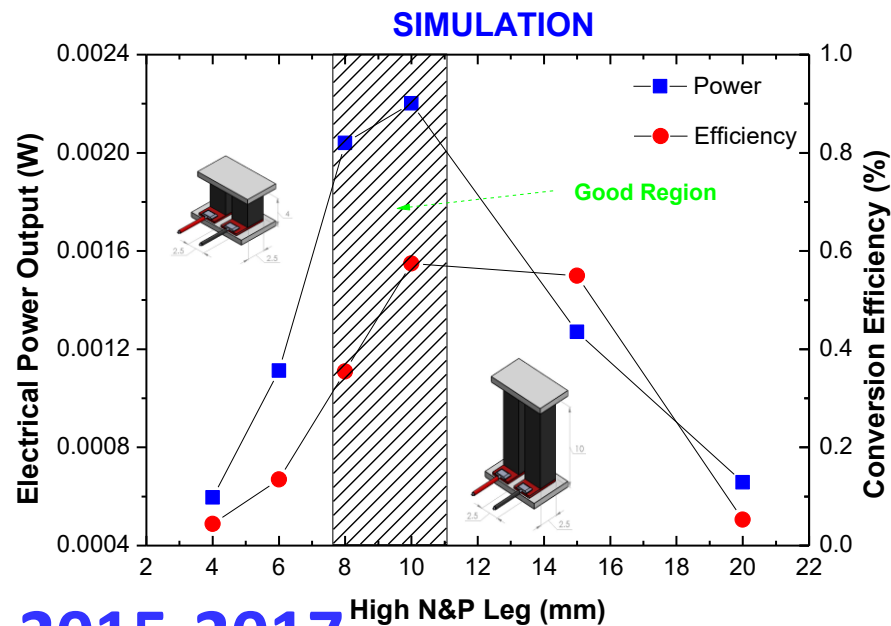


Thermoelectric oxide cell of long column, drawing long column, long thin, and drwing long thin are fabricated.

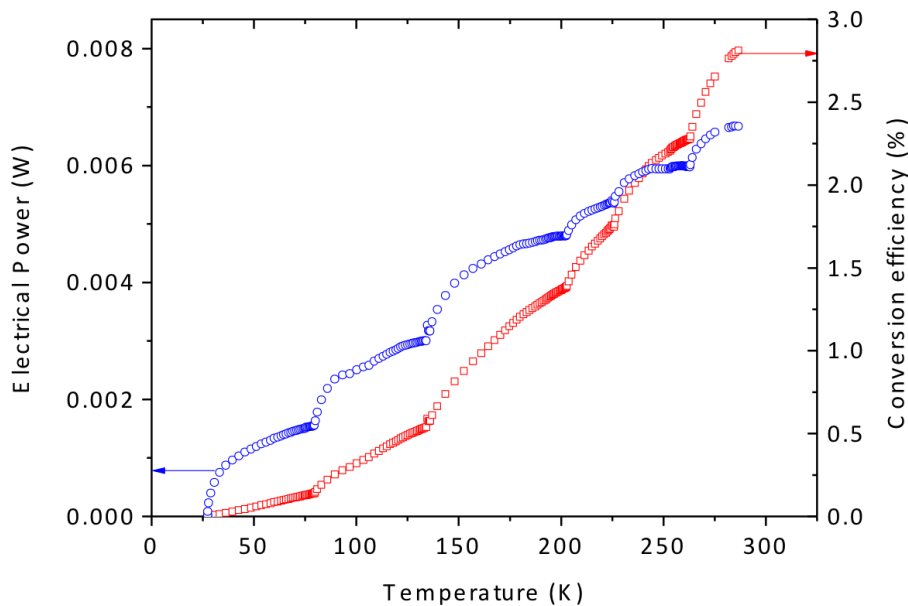
# TE Cell-2012



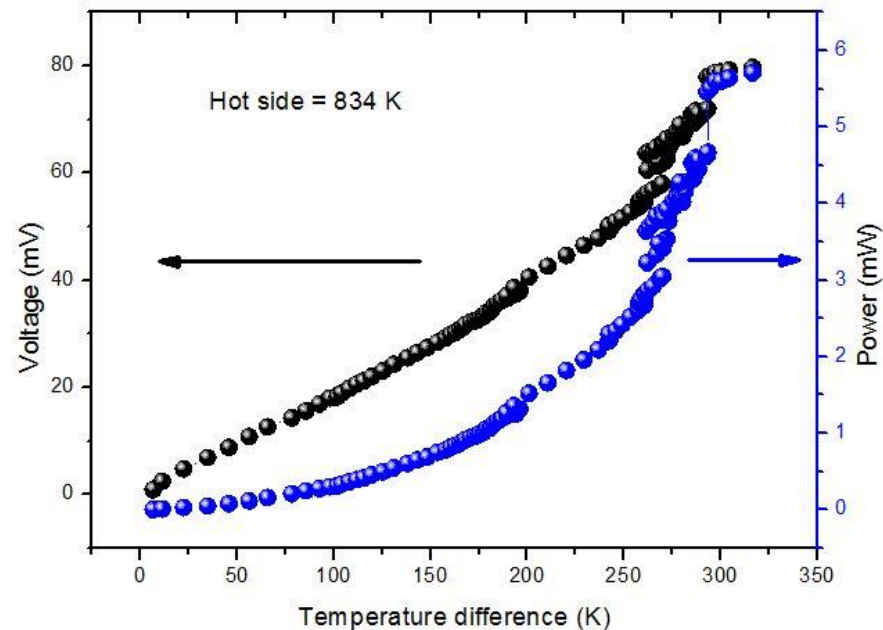
# TE Cell-2013-2014



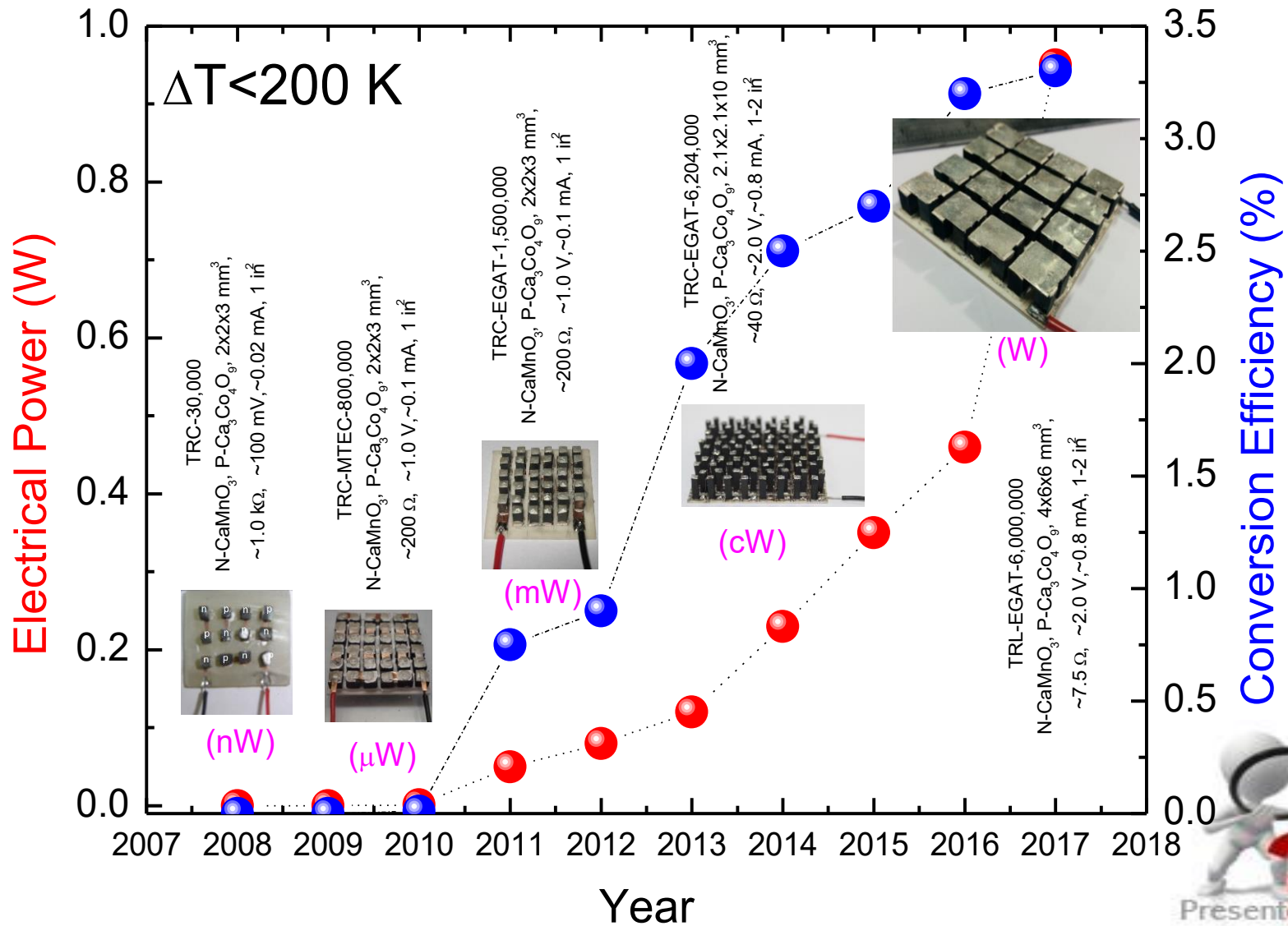
# TE Cell-2014-2015



# TE Cell-2015-2017



# Development of TEG at TRC to TRL, SNRU

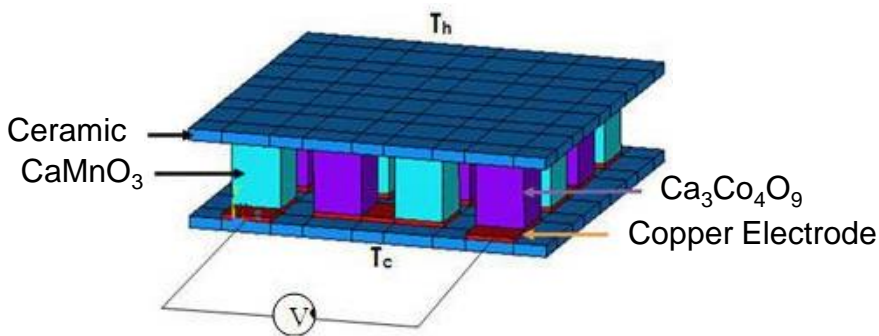
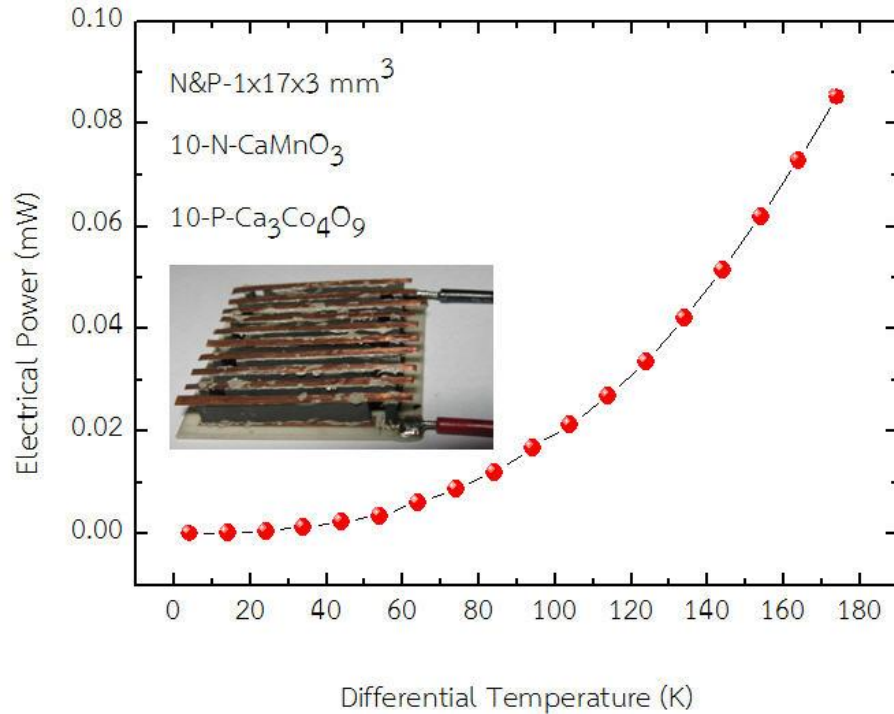
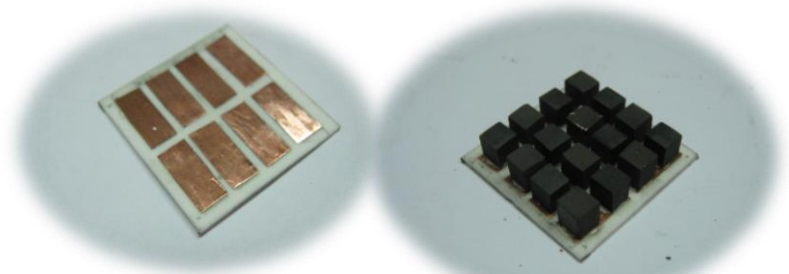
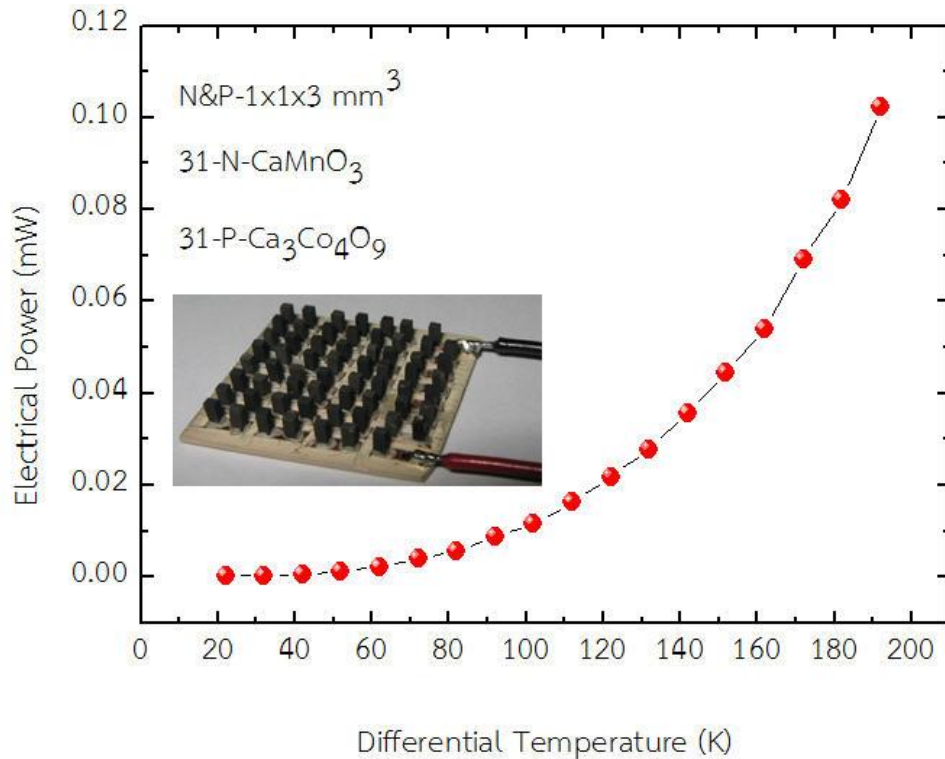


Goal : 1 W/Module



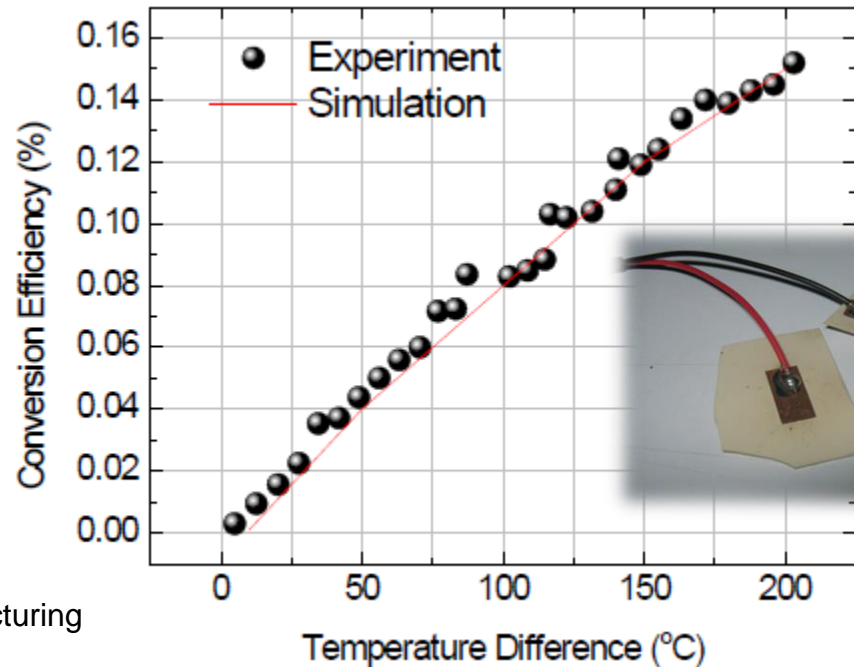
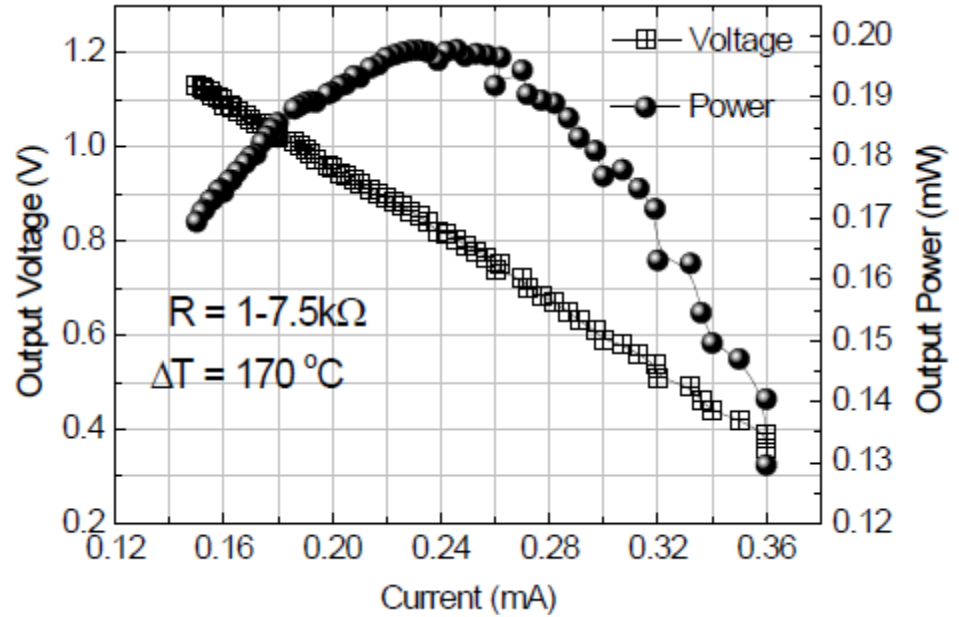
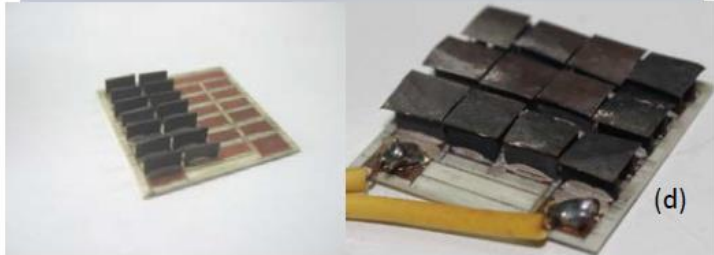
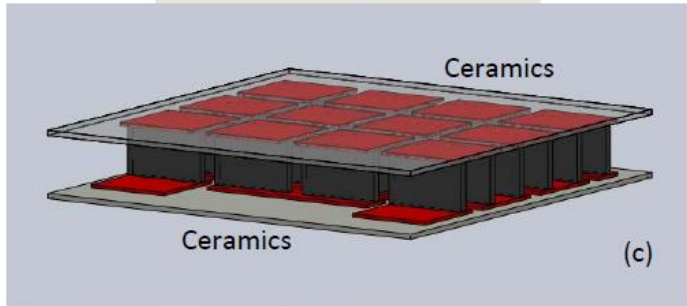
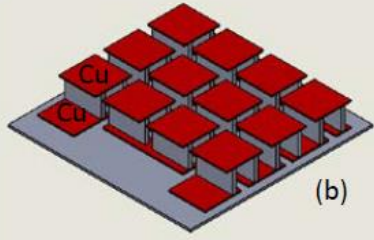
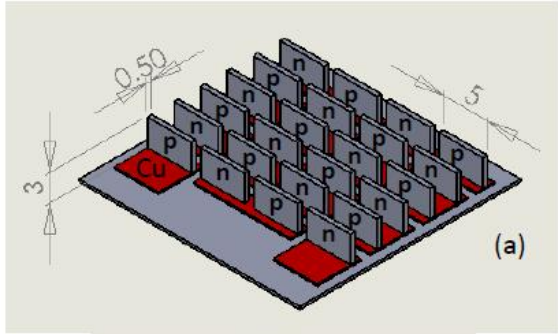
# Thermoelectric Modules

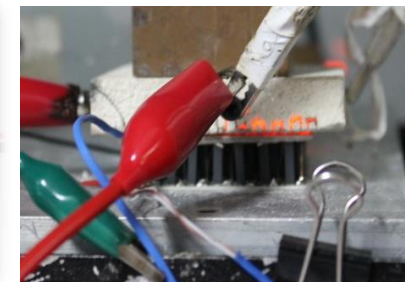
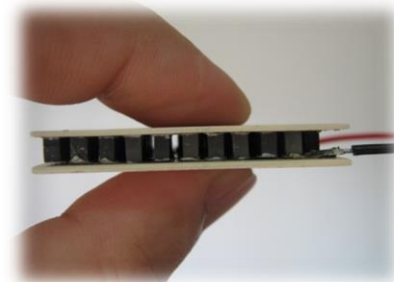
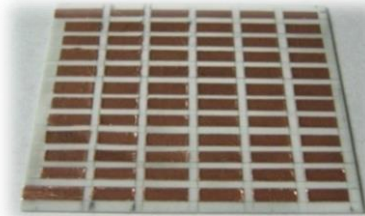
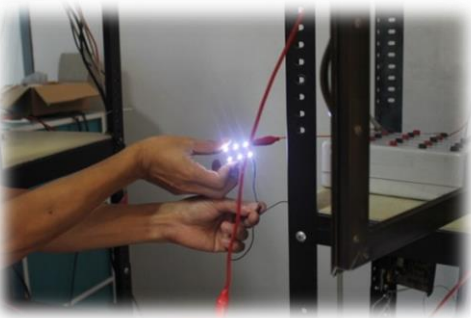
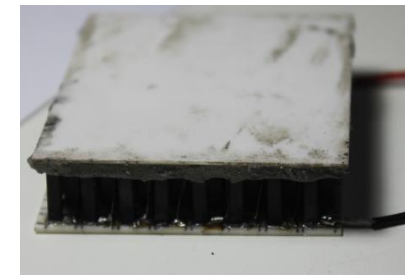
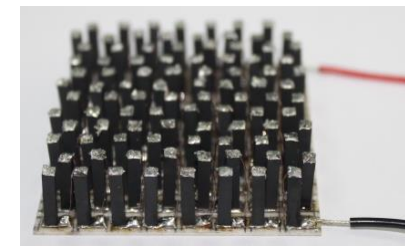
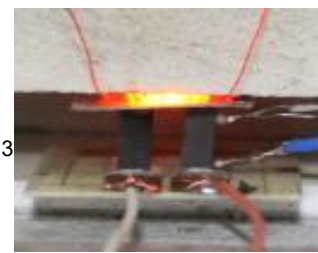
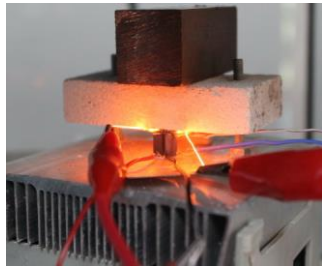
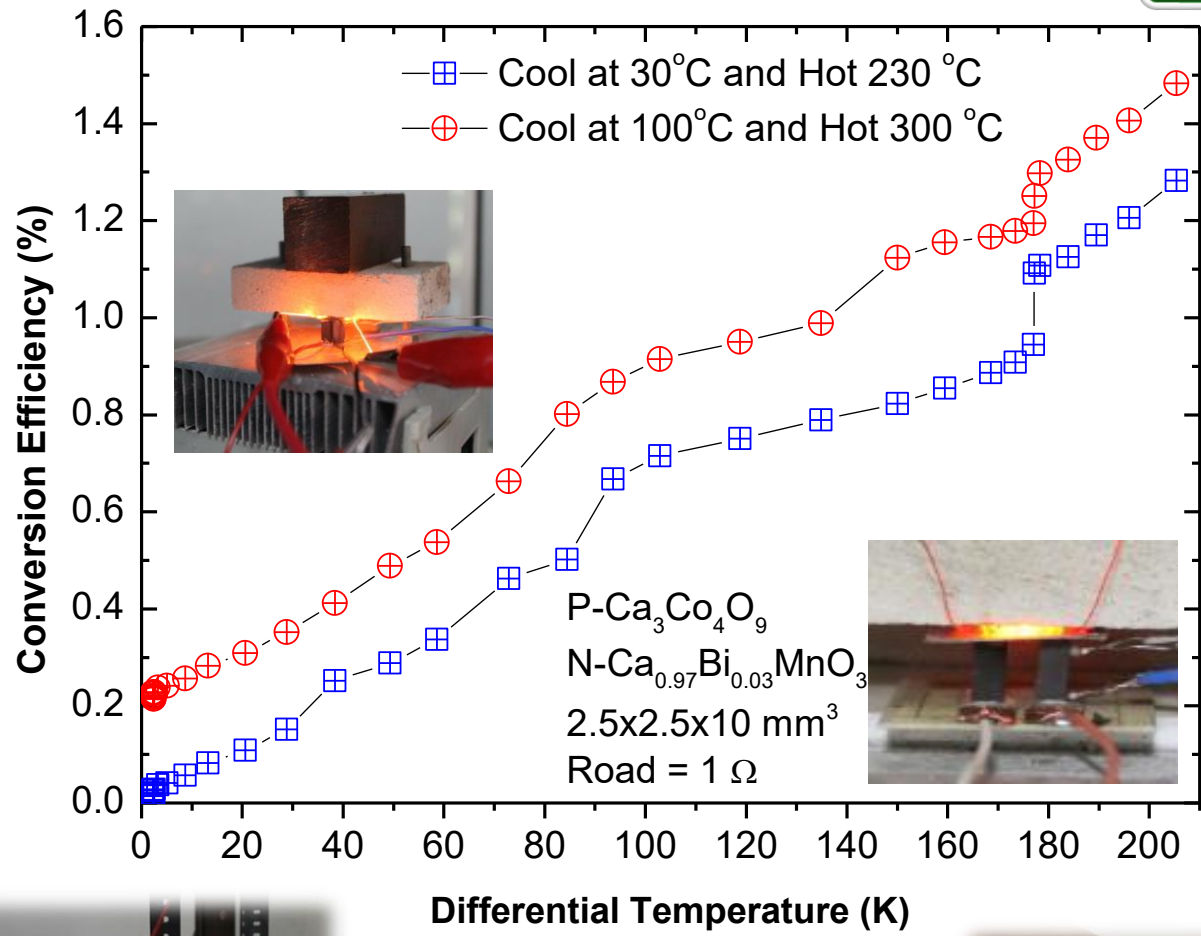
**TE Module-2012**



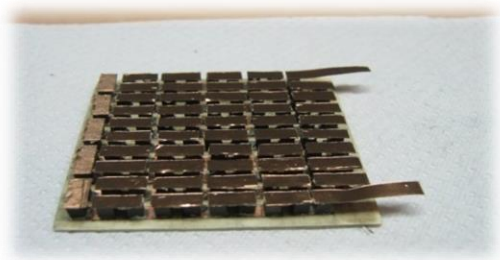
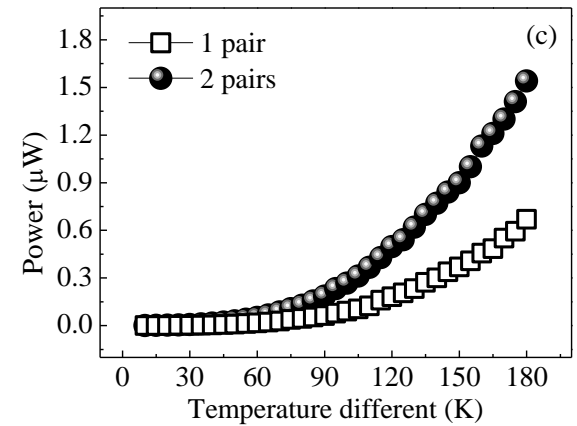
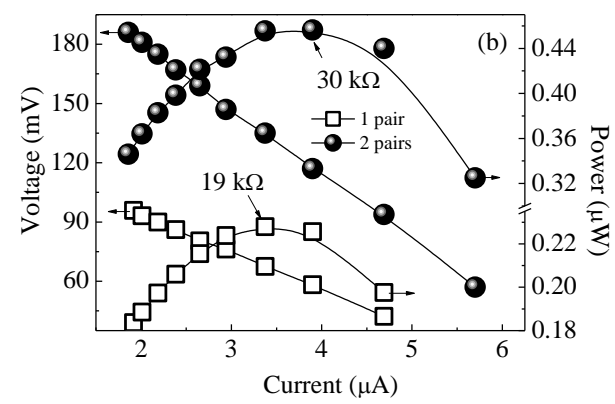
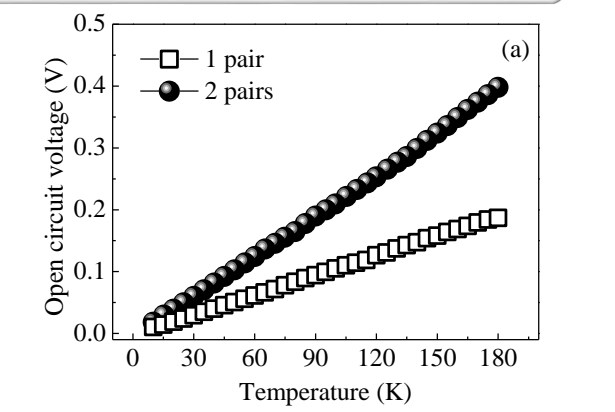
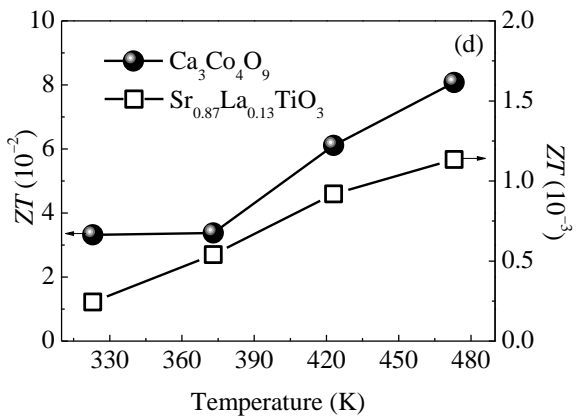
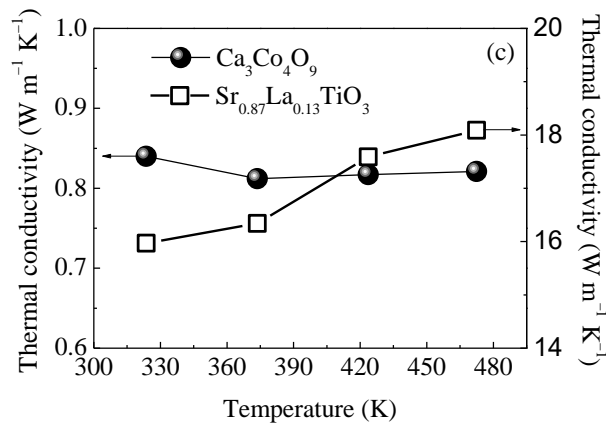
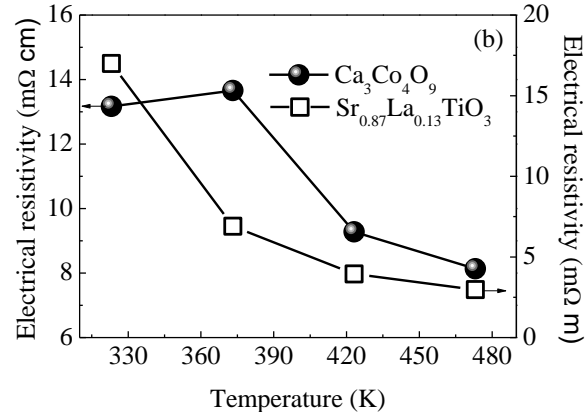
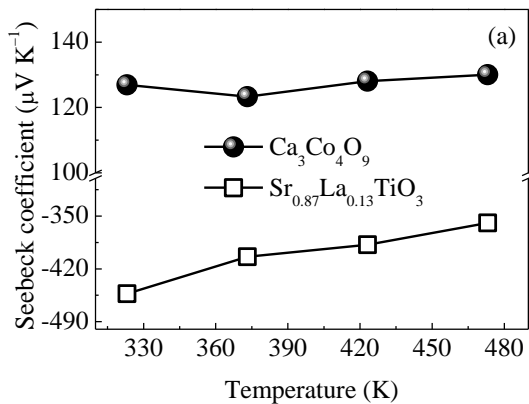
# TE Module-2013

**TEG-Dimensions of p-type and n-type legs are  $0.5 \times 5 \times 3 \text{ mm}^3$ ,  $\Delta T < 200 \text{ K}$**



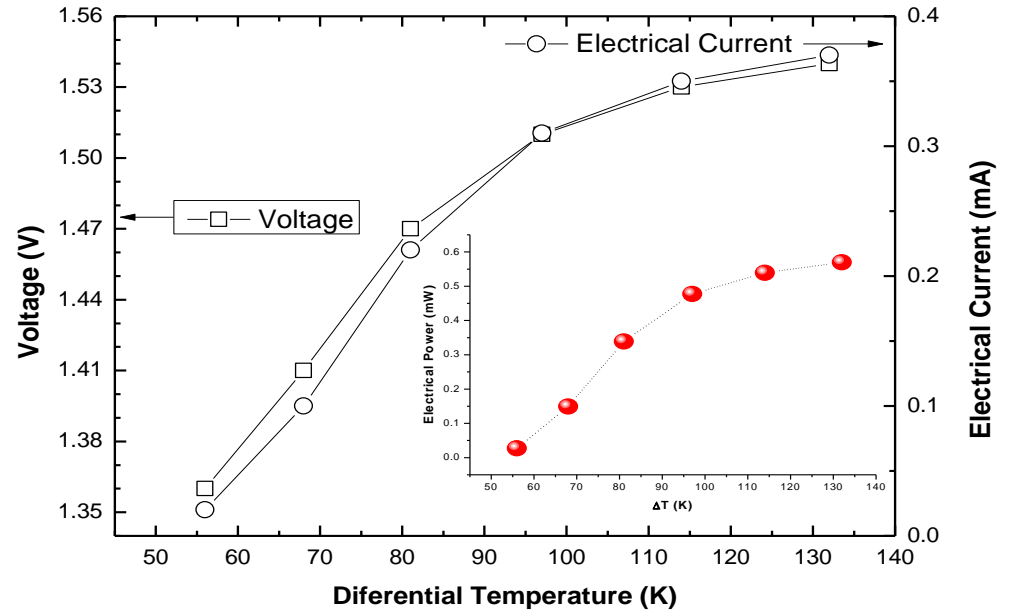
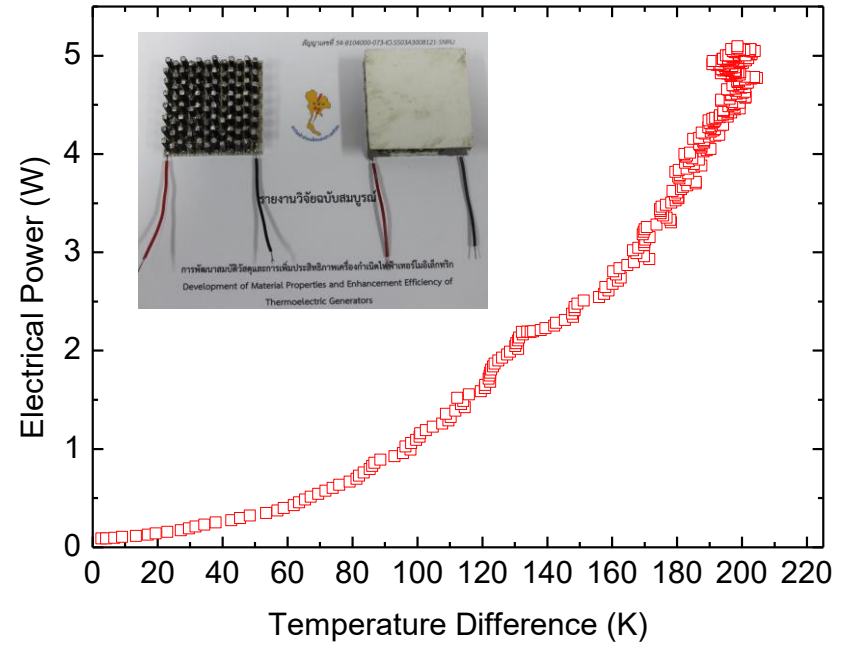
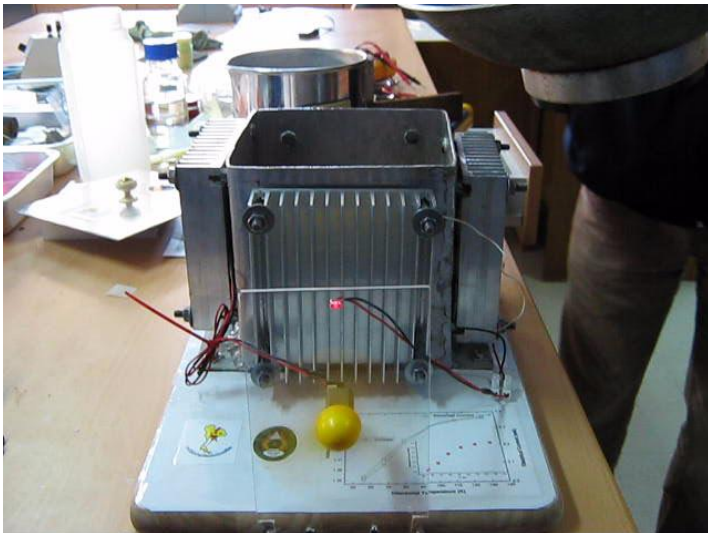
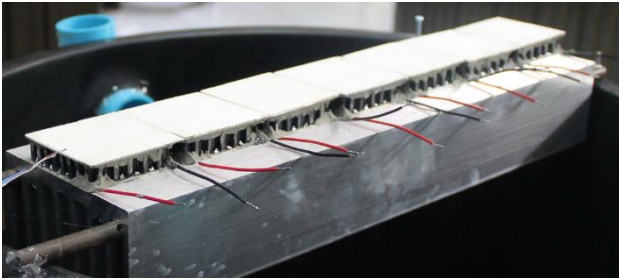


## Thermoelectric Properties and Power Generation of p-Ca<sub>3</sub>Co<sub>4</sub>O<sub>9</sub> and n-Sr<sub>0.87</sub>La<sub>0.13</sub>TiO<sub>3</sub> Thermoelectric Modules

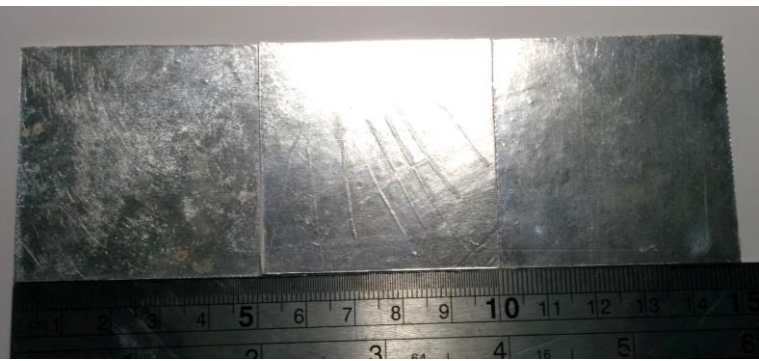




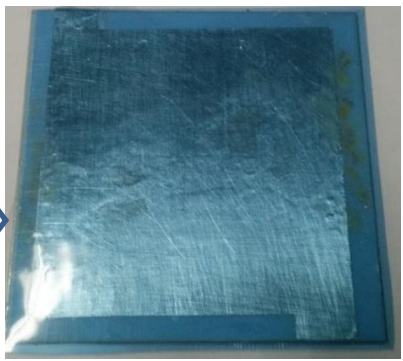
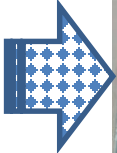
# TE Module-2015



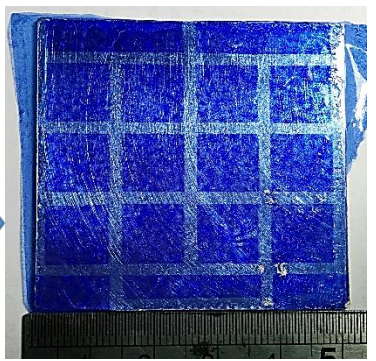
# Etching Substrate Process



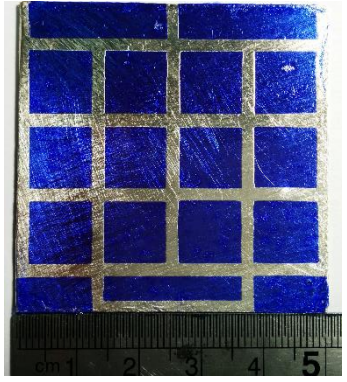
1. Silver metalized substrate



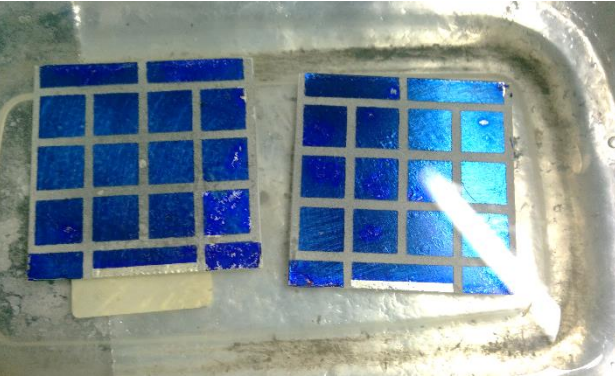
2. Film covered on substrate



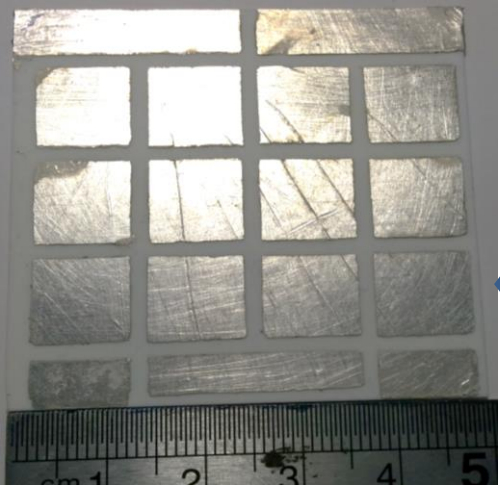
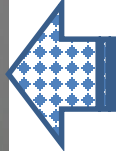
3. Substrate illuminated by UV



4. Film removed by developer



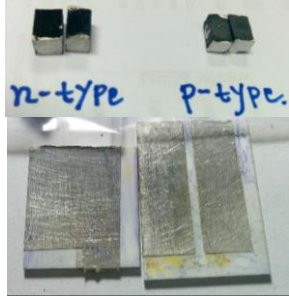
5. Silver etched by nitric acid



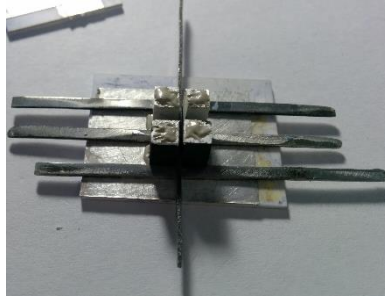
6. Substrate for fabrication module

# Fabrication of Oxide TE Cell & Module

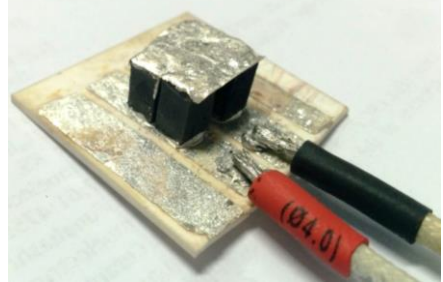
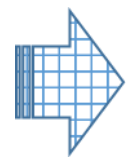
## TE Module-2016



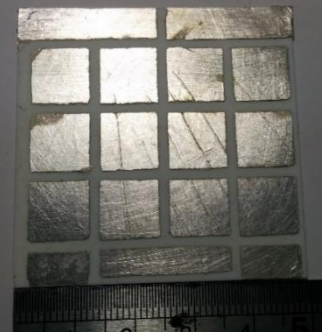
Substrate and p, n legs



The p and n legs attached to substrate by silver paste



Thermoelectric cell connected red and black wire



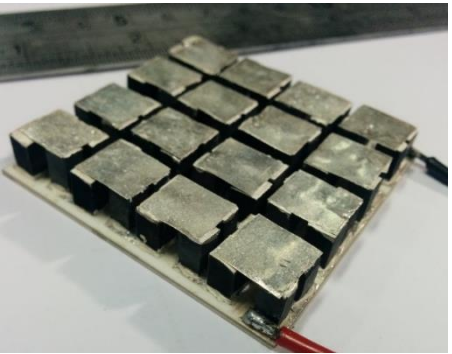
Silver etched substrate



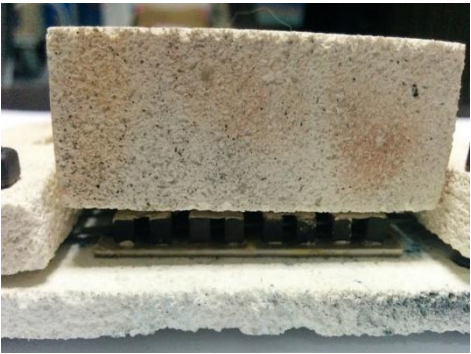
Egg crate for TE legs



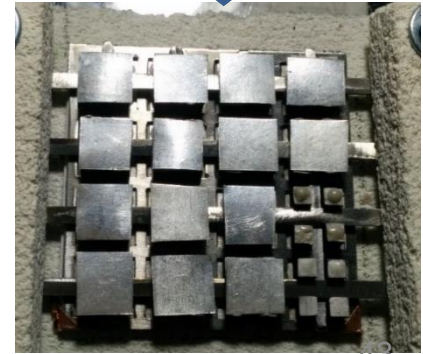
TE legs installed in egg crate



TE connected red and black wire

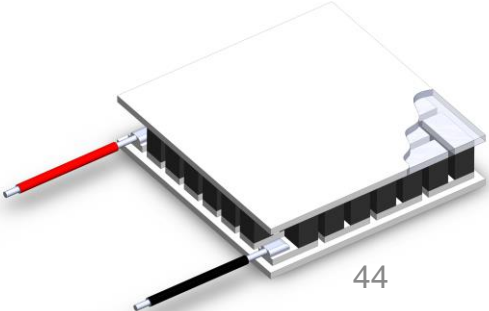
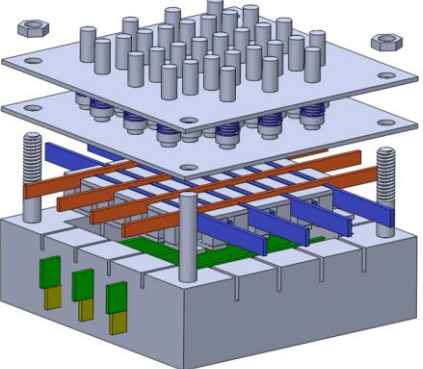
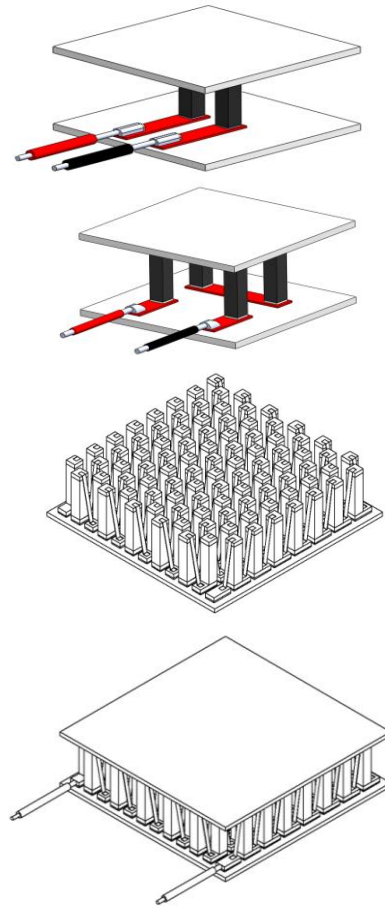
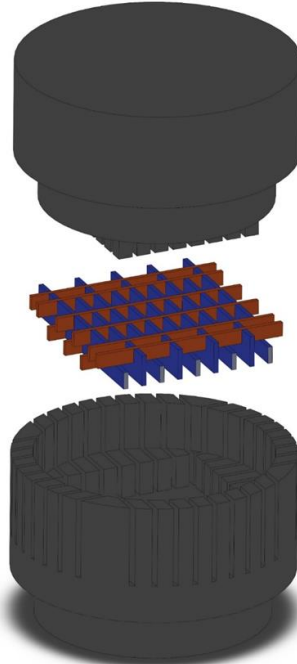
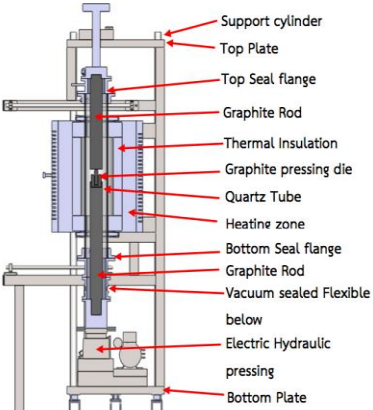
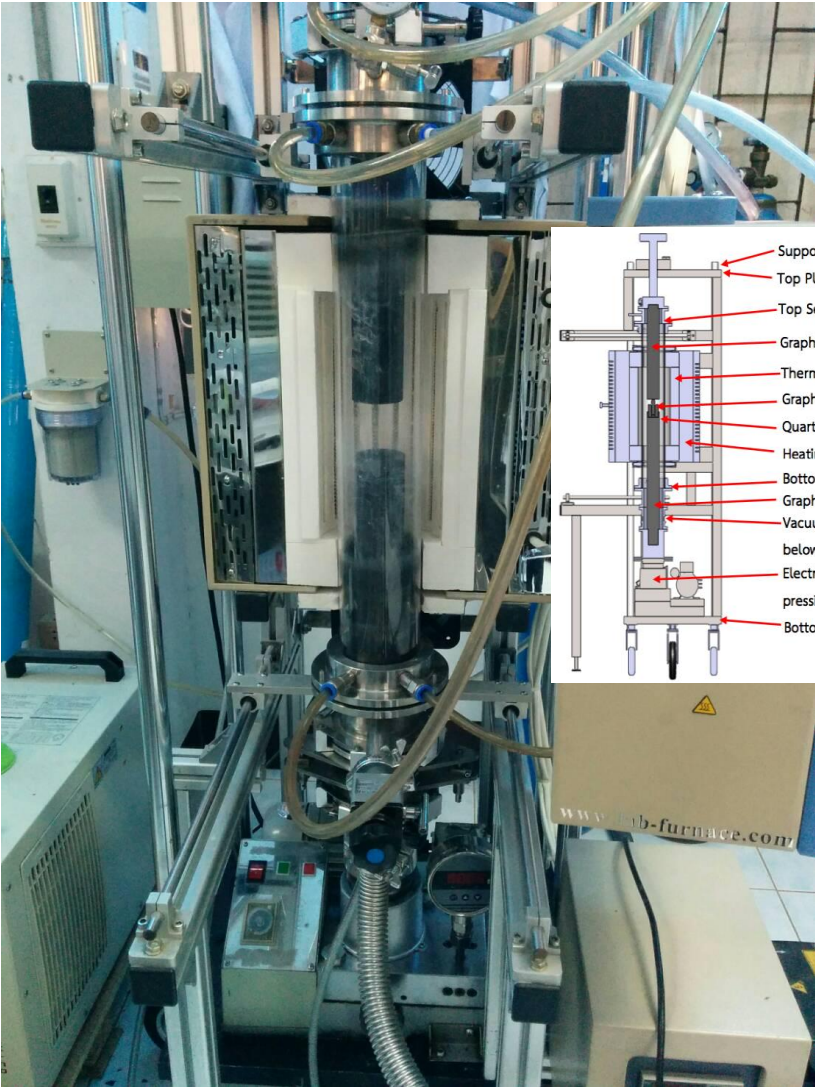


TE compressed and annealed in furnace

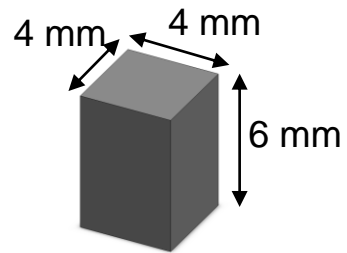


TE legs installed in egg crate

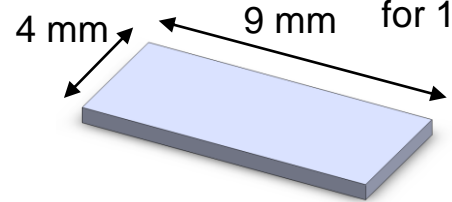
# Thermoelement & Compact Module by Hot-press method



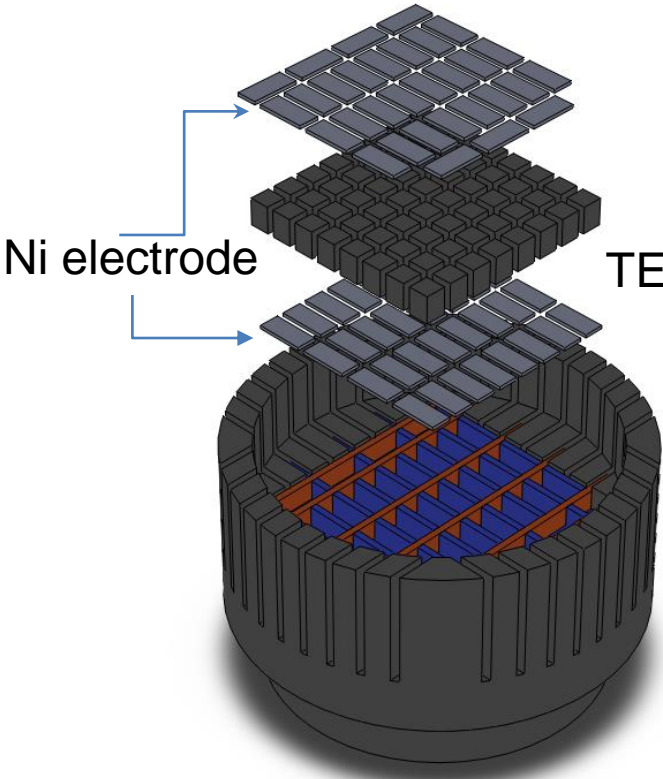
# Fabrication of Alloy TE Cell & Module



1. Materials are cut in size of  $4 \times 4 \times 6 \text{ mm}^3$ .



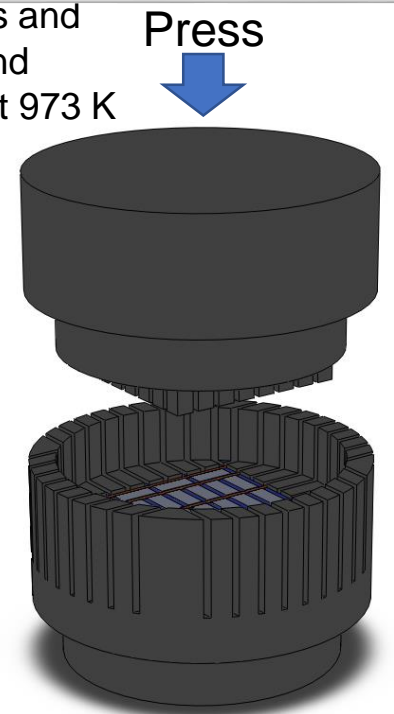
2. Ni thickness 0.5 mm is cut in size of  $9 \times 4 \text{ mm}^2$  for using electrode



TE Materials

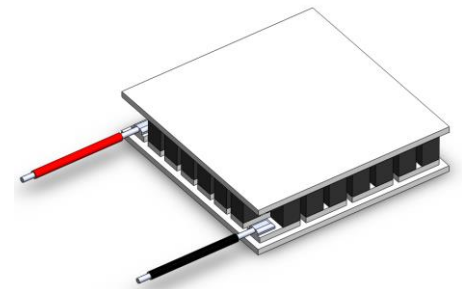
3. The p and n materials and Ni electrode are load in material fix block, which connect together by silver paint and heat at 473 K for drying silver paint.

4. The p and n materials and Ni electrode are melt and compact by hot press at 973 K for 1 h in a vacuum.



Press

Press

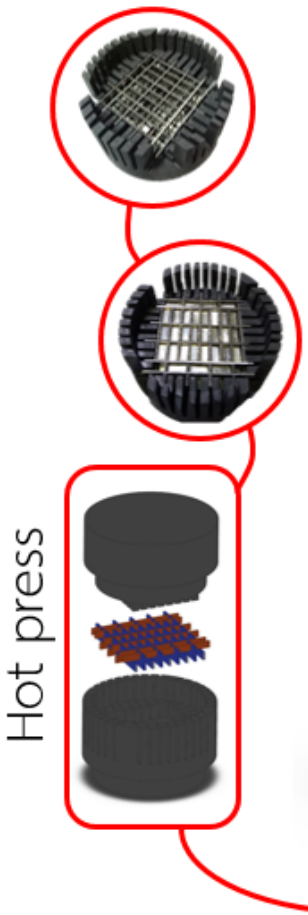


5. Alumina substrate size of  $50 \times 50 \times 1 \text{ mm}^3$  is setup on top and bottom side of p-n pairs+Ni by silver paint and heat at 773 K for 1 h in a vacuum.

# Commercial Thermoelectric Module

**TE Module-2017**

## ASSEMBLY



### SPECIFICATION

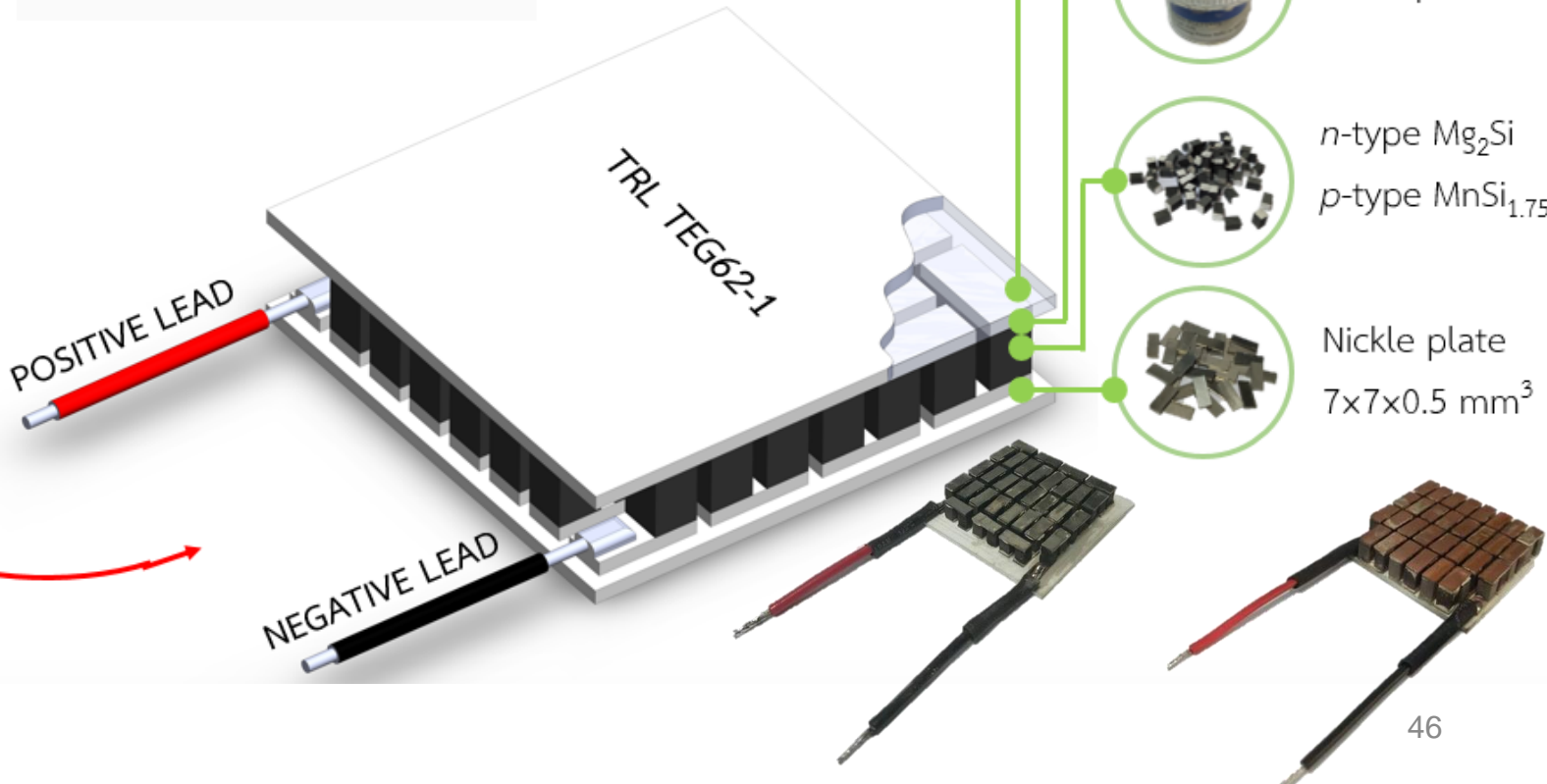
- Dimension: 37x37x7 mm<sup>3</sup>
- Maximum temp: 600 °C
- Power: 1 W, V<sub>OC</sub> 5 V at  
T<sub>h</sub>: 600 °C, T<sub>c</sub> 50 °C
- Efficiency: 2%

### FEATURES

- Al<sub>2</sub>O<sub>3</sub> Substrate
- Ni Electrode
- Ag interface
- Si-base Materials

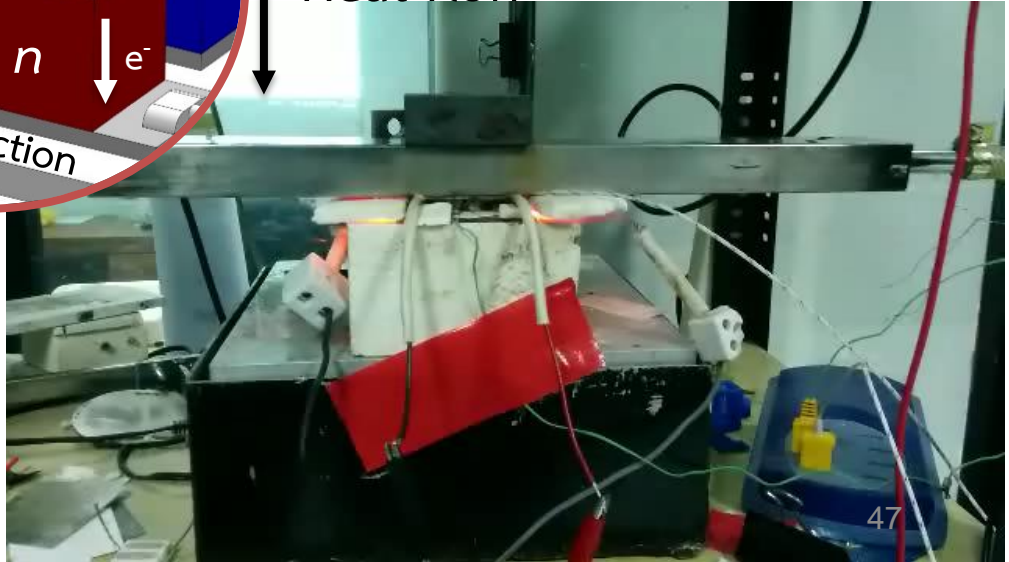
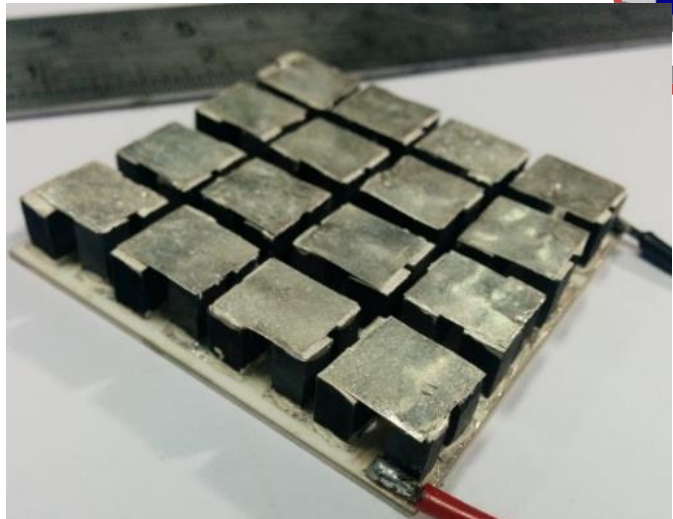
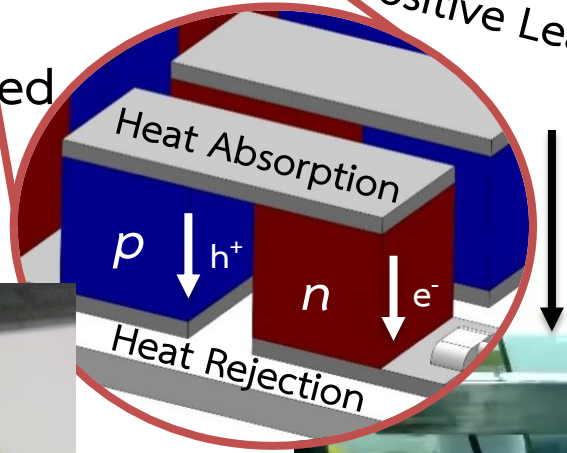
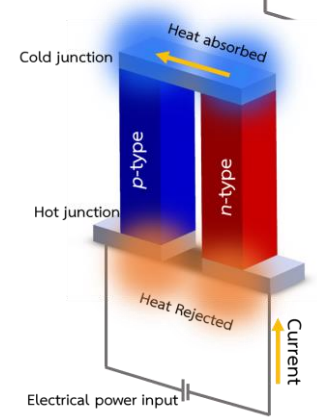
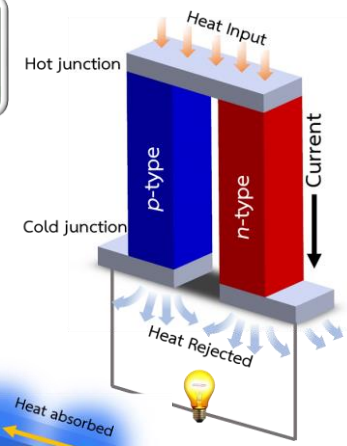
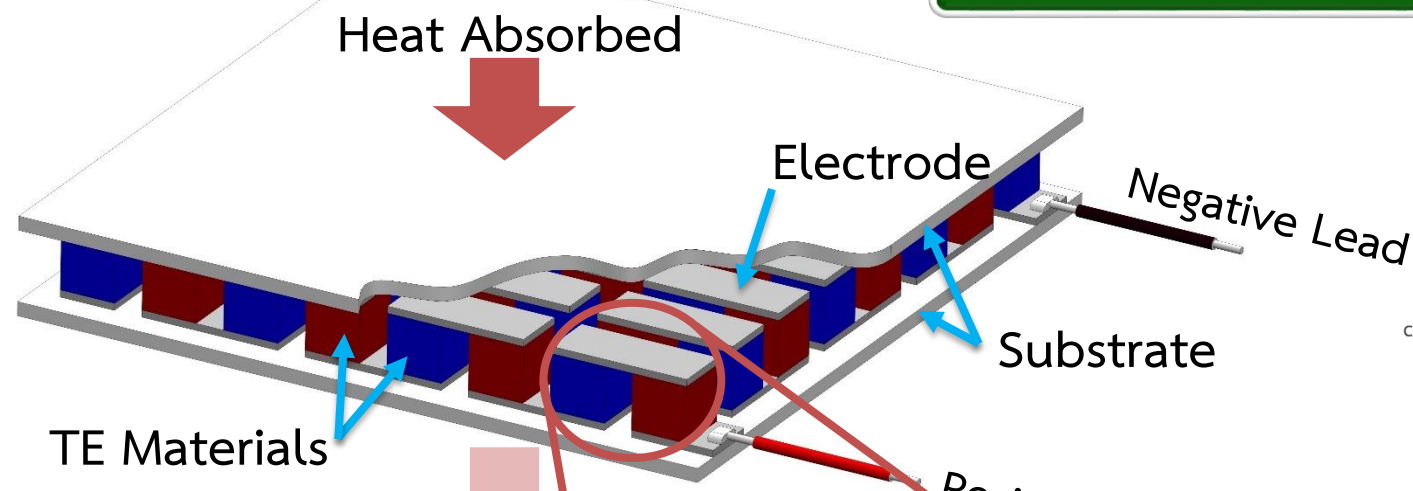
## MATERIALS

-  Alumina substrate  
37x37x1 mm<sup>3</sup>
-  Silver paste
-  n-type Mg<sub>2</sub>Si  
p-type MnSi<sub>1.75</sub>
-  Nickle plate  
7x7x0.5 mm<sup>3</sup>



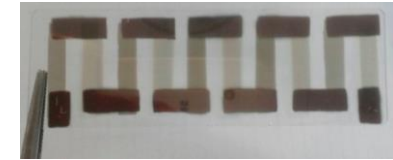
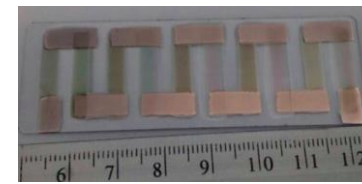
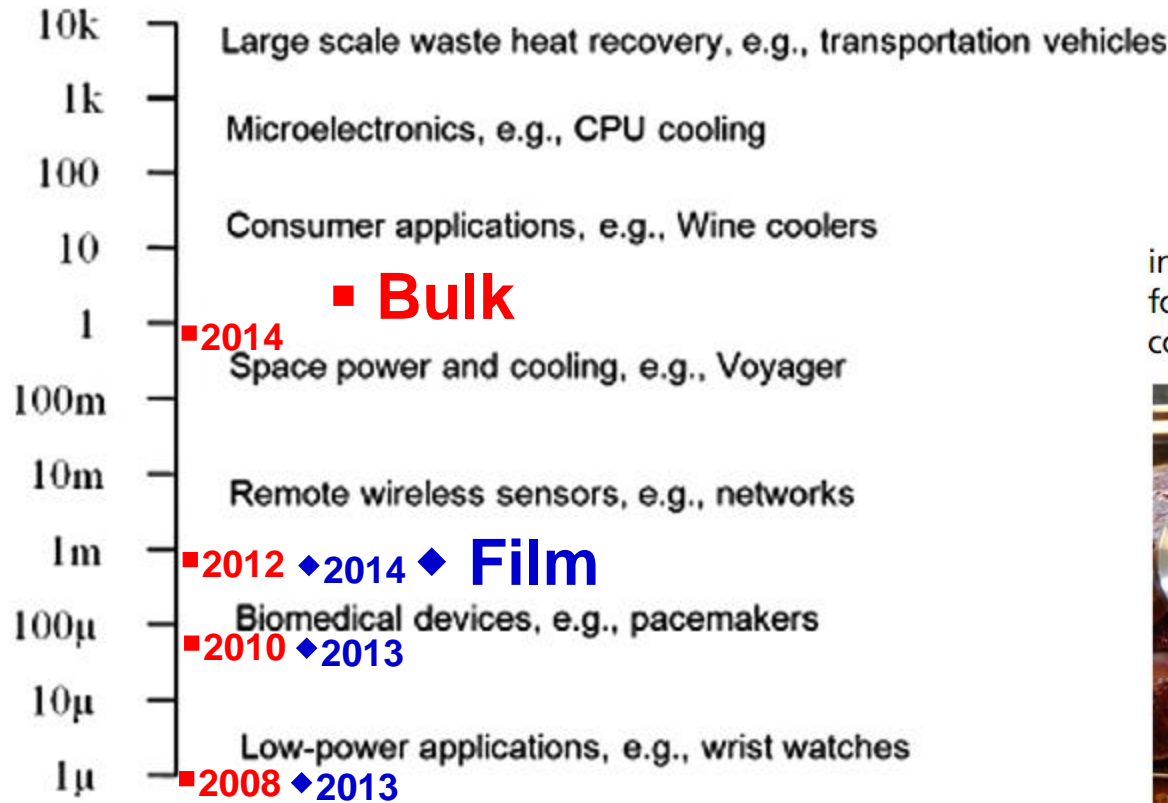
# Thermoelectric Applications

## TE Module-2017

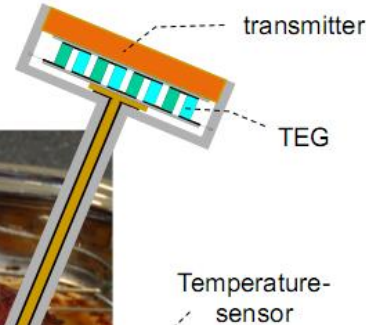
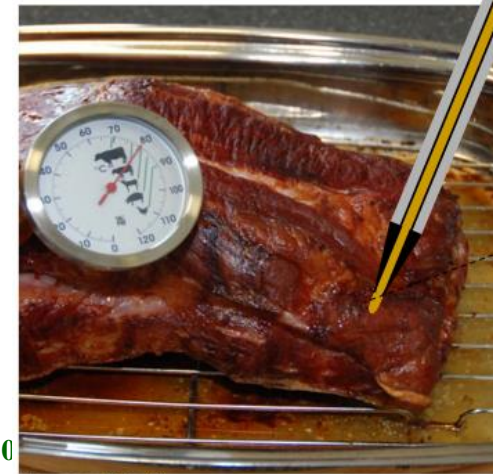


Power (Watts)

# TE Bulk and Film Applications



insertion thermometer for cooking and food control



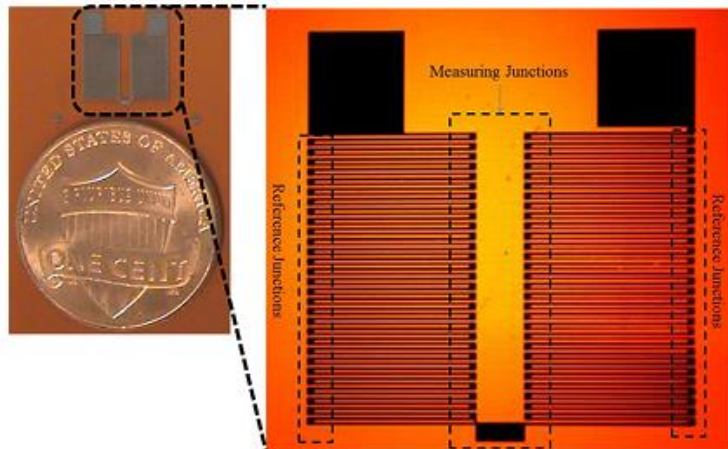
Pichanusakorn P, Bandaru P. Nanostructured thermoelectrics. Mater Sci Eng R: Rep 2010

## Thermoelectric microfluidic sensor for bio-chemical applications

Kopparthy VL, Tangutooru SM, Nestorova GG, Guilbeau EJ. Sensors and Actuators B 166–167 (2012) 608–615

## Thermoelectric oxygen sensors

Frank R, Ralf M. Sensors and Actuators B 145 (2010) 685–690



Source: E.G.O.

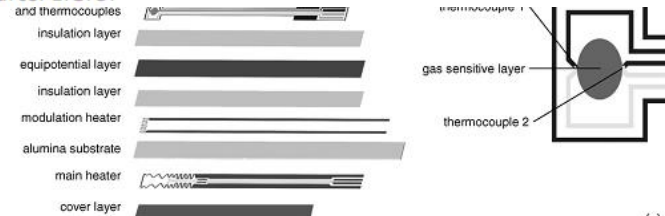


Fig. 3. Sensor set up (a), detailed view of the sensor tip (b) and a photograph of a complete  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>-sensor (c).



# Outline

Presentation

ง่าย

Imitation

การเลียนแบบ

Improvement

การปรับปรุง

Innovation

การคิดขึ้นใหม่

ยาก

Invention

การประดิษฐ์ใหม่

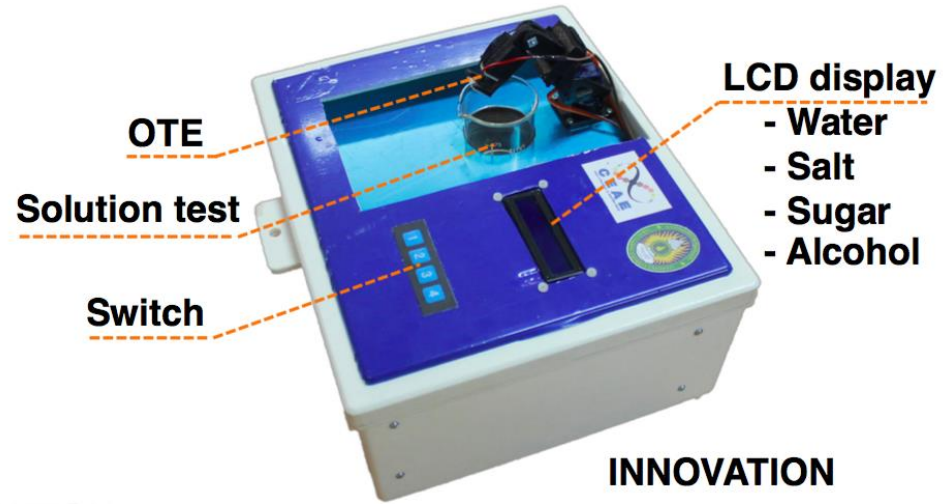
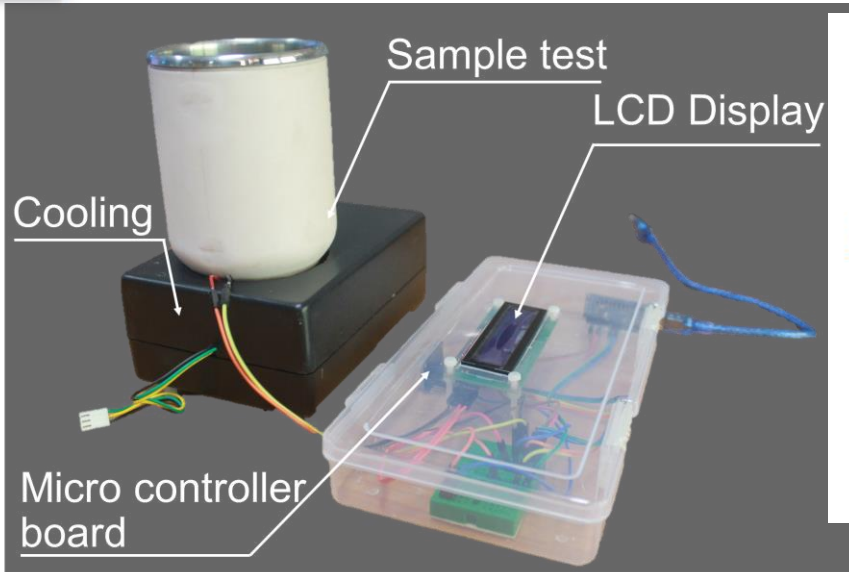
5

Invention 2017

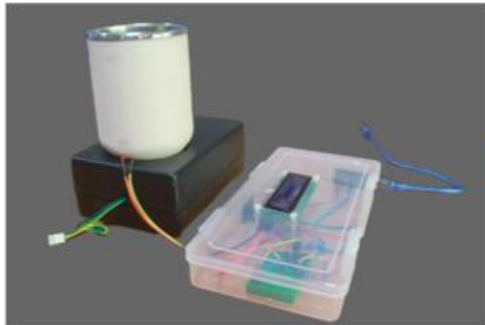


# Prototype of Thermoelectric Sensor Smart Bulk Sensor 2017

INST2015



GENEVA2016



Separate by boiling point

Separate by heat solution

Separate and specify concentration

**1<sup>st</sup> generation**

**2<sup>nd</sup> generation**

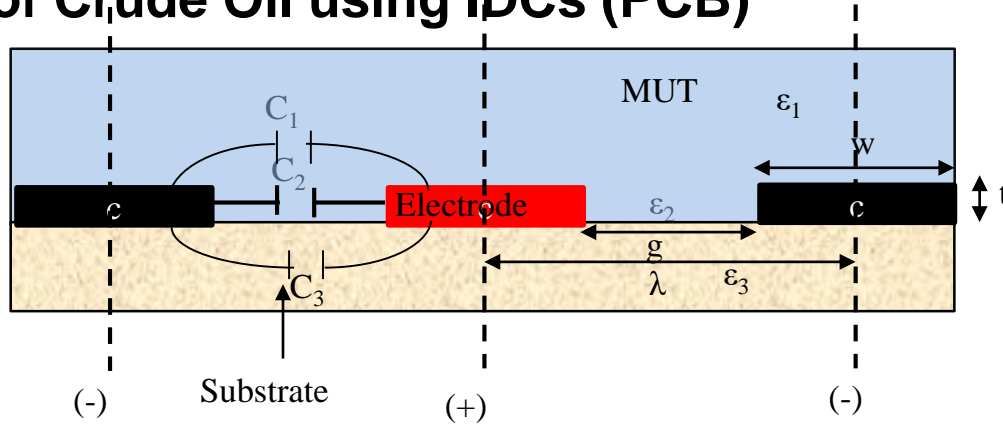
**New generation**



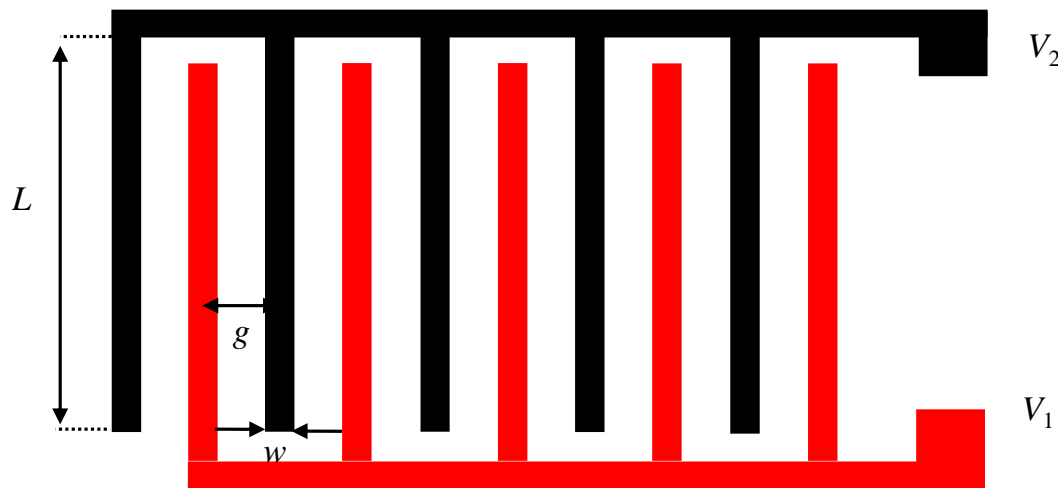
# Invention of Interdigital Capacitors (IDCs)

## Smart Film Sensor 2017

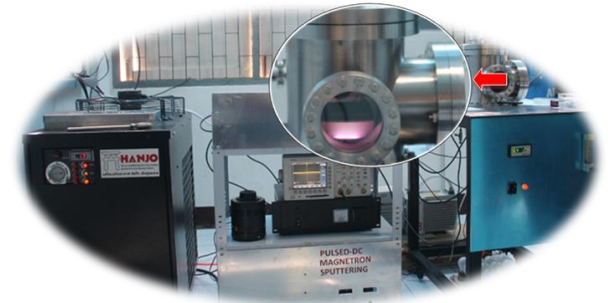
### Permittivity Measurement System of Crude Oil using IDCs (PCB)



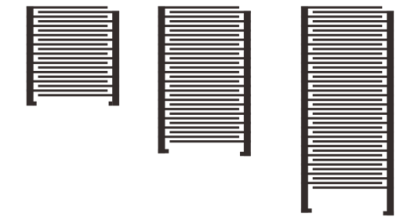
Configuration IDCs (across section)



Configuration of IDCs (from above)



(a) (b) (c) (d)



(e) (f) (g)

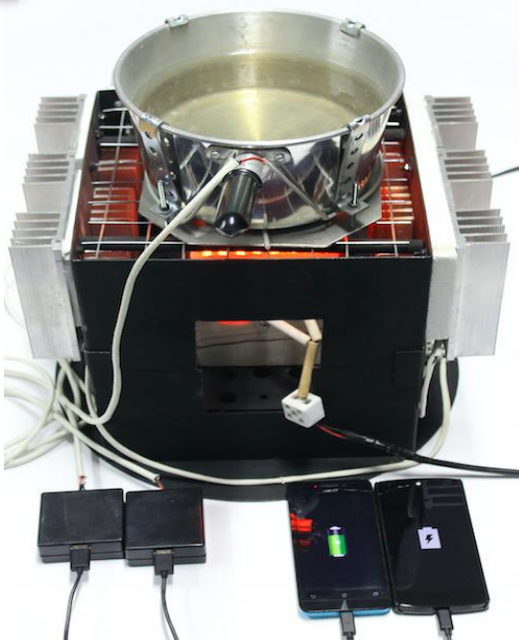


(A) (B) (C)

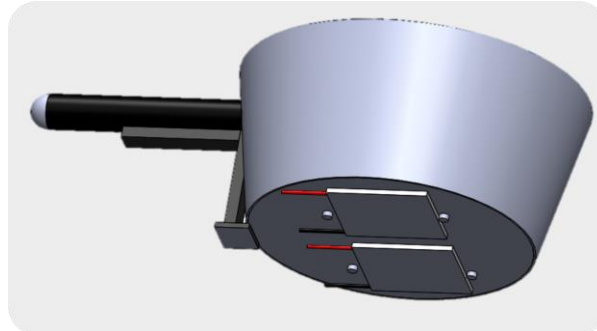


# Invention of Thermoelectric Generator Smart Generator 2017

GENEVA 2015



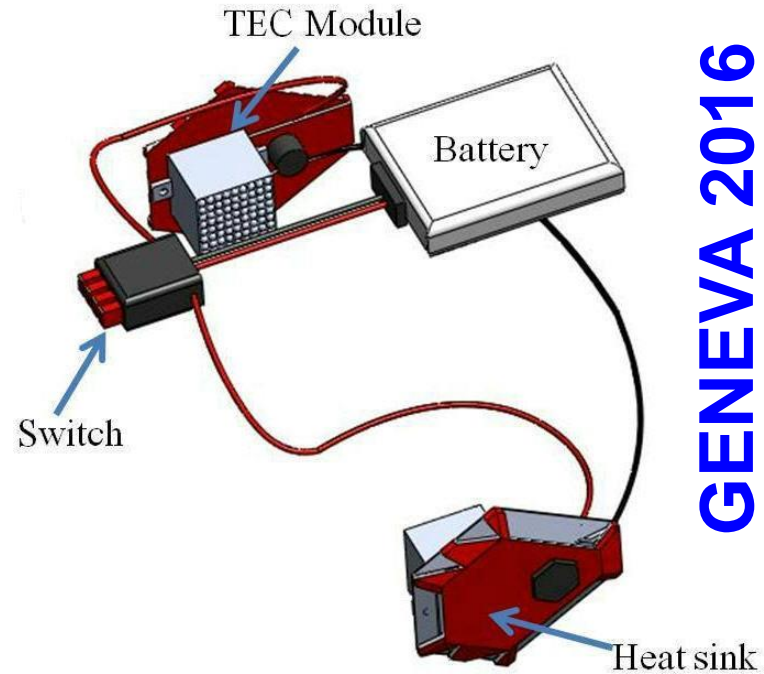
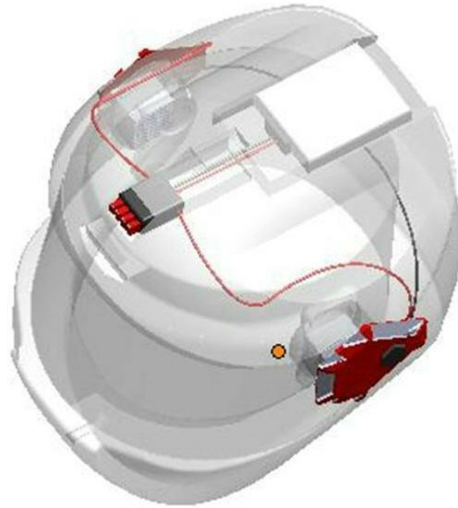
BIXPO2015





# Invention of Helmet Temperature Control

## Smart Helmet 2017



GENEVA 2016



1<sup>st</sup> generation

### DEVELOPEMENT



2<sup>nd</sup> generation



New generation

# Invention of Personal Temperature Control Smart Shirt 2017



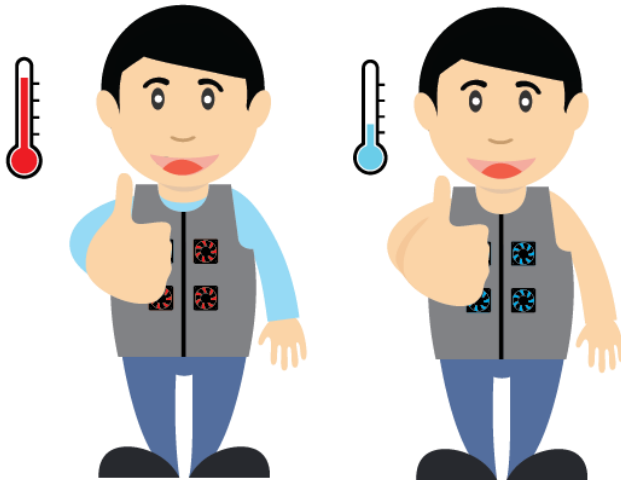
1<sup>st</sup> TEC-water cooling



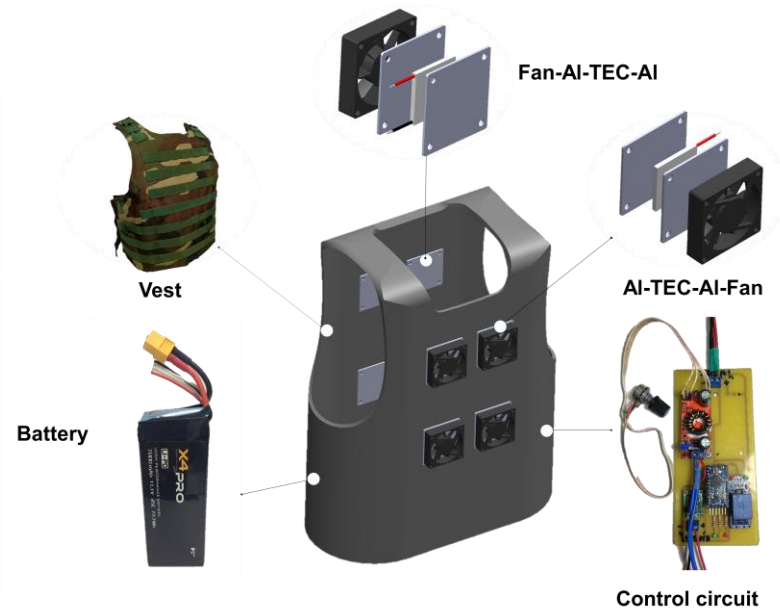
2<sup>nd</sup> TEC-warming & cooling



SIIF2016

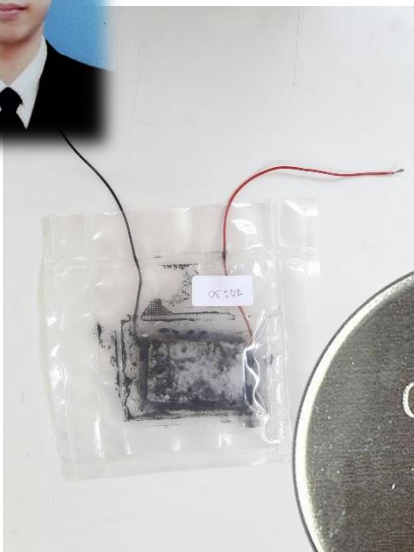


Warming & Cooling



# Invention of Coin Cell-Battery

## Smart Battery 2017



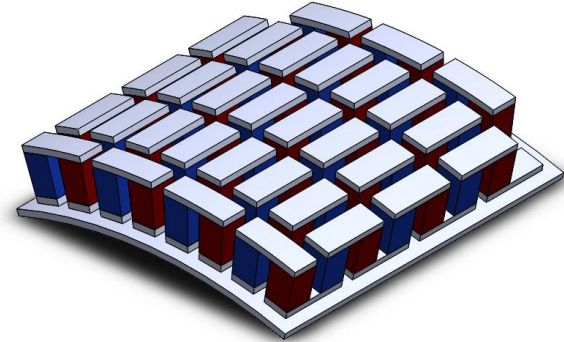
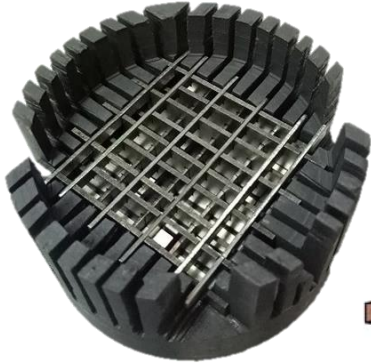
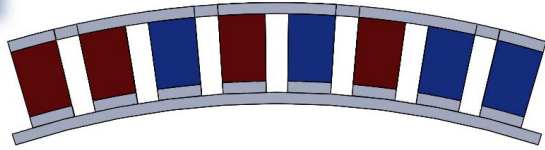
**Metrohm Autolab Modules**



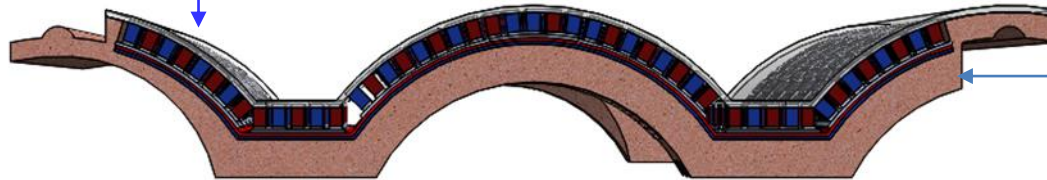


# Invention of Roof Tiles

## Smart Roof Tiles 2017



TEG

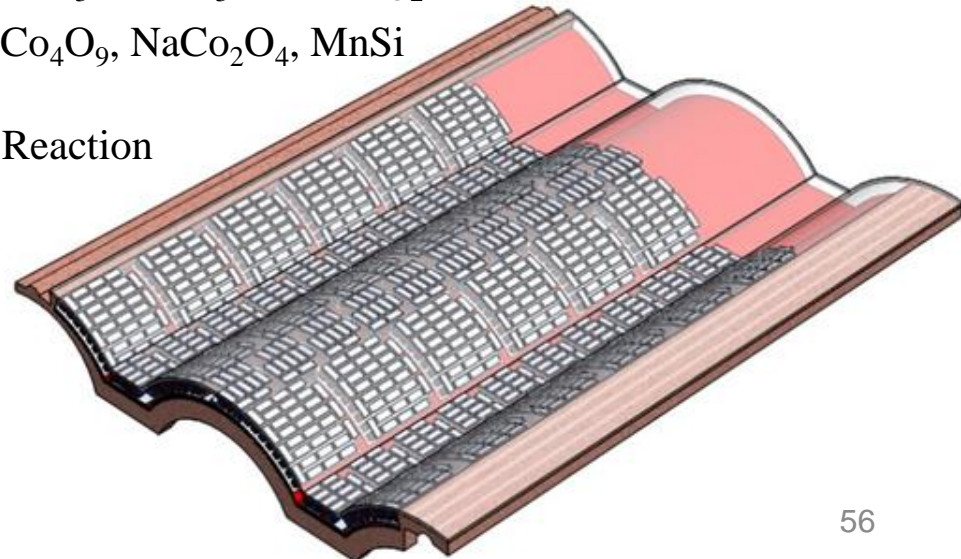
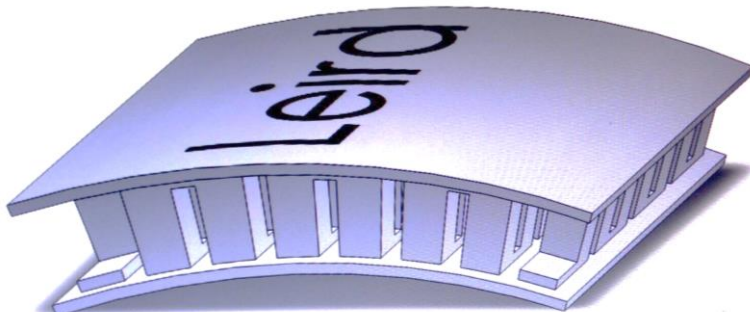


Tile



**Materials** *n*-type:  $\text{CaMnO}_3$ ,  $\text{SrTiO}_3$ ,  $\text{ZnO}$ ,  $\text{Mg}_2\text{Si}$   
*p*-type:  $\text{Ca}_3\text{Co}_4\text{O}_9$ ,  $\text{NaCo}_2\text{O}_4$ ,  $\text{MnSi}$

**Method** Solid State Reaction  
Hot Press

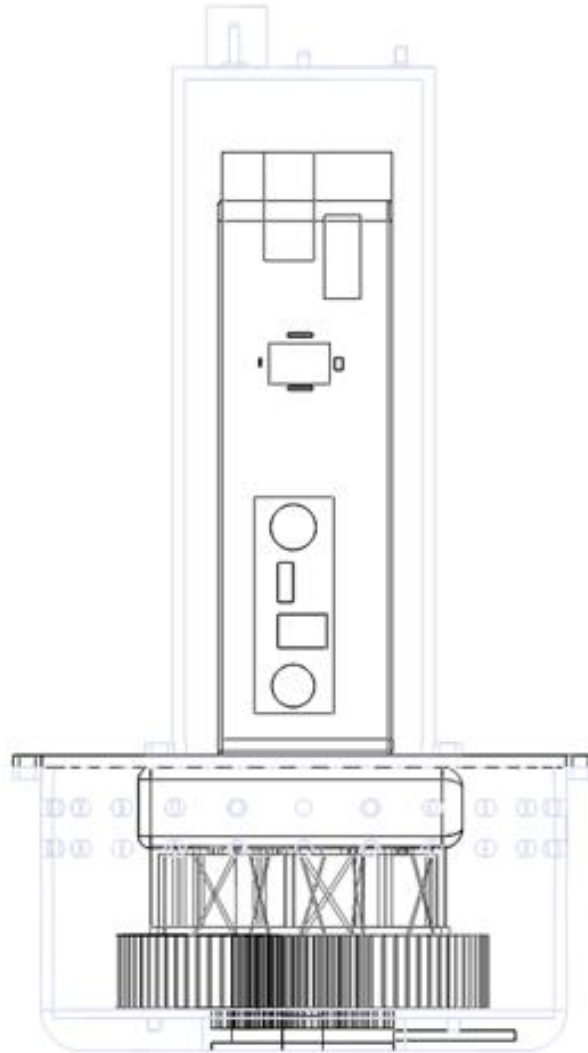
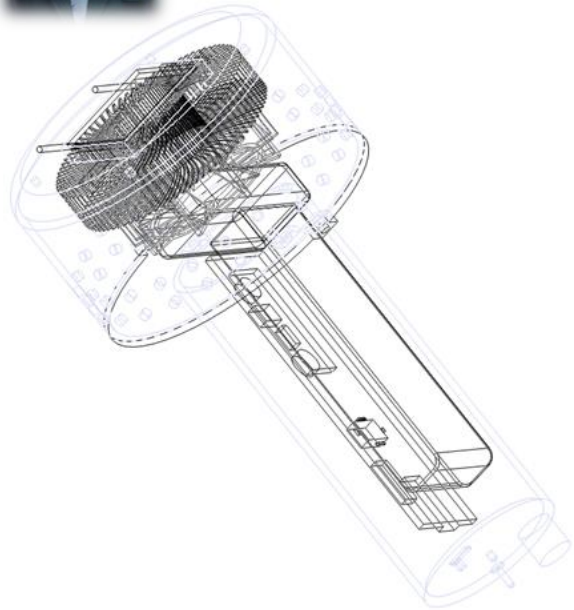




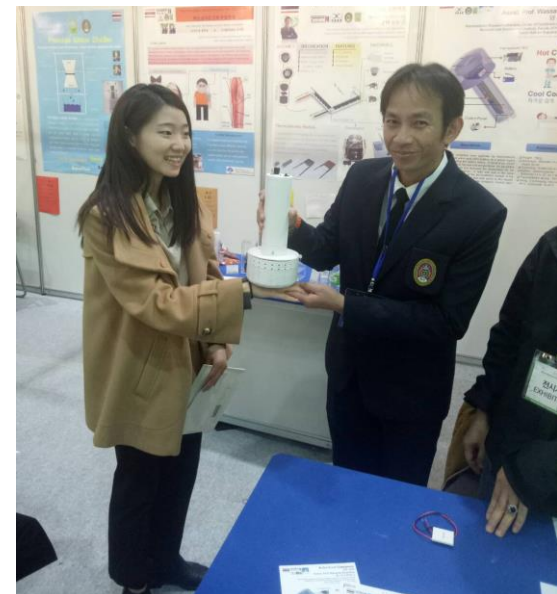


# Invention of Compress Ball

## Smart Compress Ball 2017



**SIIF2016**



# Invention of Portable Water Distiller

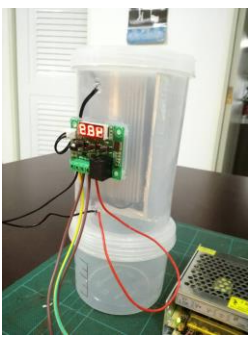
## Smart Water Distiller 2017



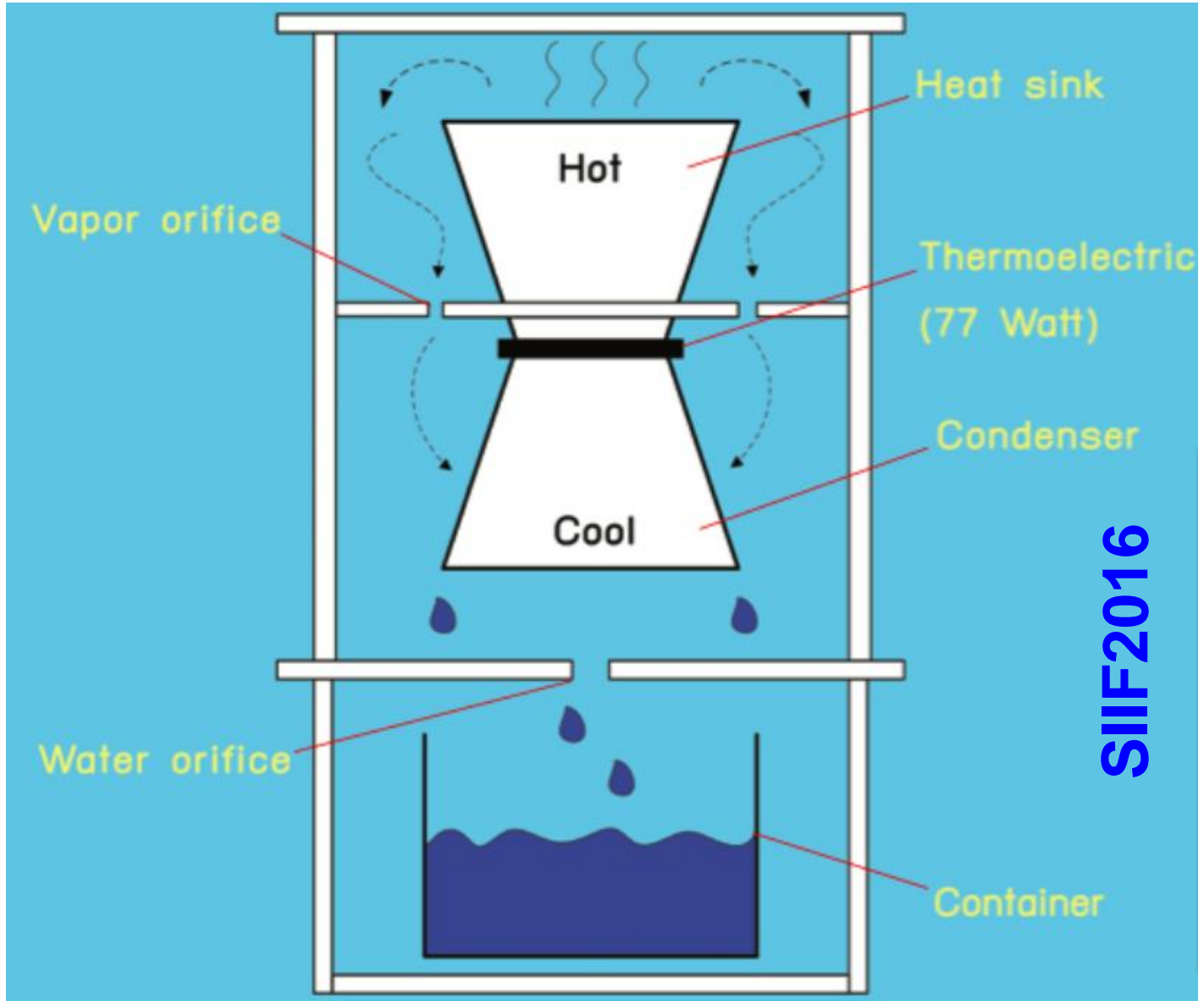
1<sup>st</sup> Generation



2<sup>nd</sup> Generation



3<sup>rd</sup> Generation



SIIF2016



44<sup>e</sup> Salon International des Inventions  
Genève 13>17 avril 2016

**Thai PBS** HD **ชยอ่อนหล้า**  
<http://clip.thaipbs.or.th>

<http://clip.thaipbs.or.th/home.php?vid=6087&action=search&ctype=&pname=489&stype=2&ap=false>

The Awards Ceremony of  
**Seoul International Invention Fair 2016**

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**nature INDEX**

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**ขอแสดงความยินดีกับ**  
คณาจารย์มหาวิทยาลัยราชภัฏสกลนคร

คว้ารางวัล 1 เหรียญทอง 3 เหรียญเงิน 2 เหรียญทองแดง รางวัลพิเศษ 4 รางวัล  
ในงาน **Seoul International Invention Fair 2016**  
ระหว่างวันที่ 1-4 ธันวาคม 2559 ณ Coex exhibition hall กรุงโซล สาธารณรัฐเกาหลีใต้

**เทคโนโลยีเทอร์โมอิเล็กทริก**  
Thermoelectric Technology

ทศวรรษ อีอีเอ็ม

Institution	AC~	FC~	WFC~
1. Chulalongkorn University (CU)	79	5.98	5.74
2. Mahidol University (MU)	36	5.60	4.74
3. Suranaree University of Technology (SUT)	21	1.77	1.62
4. Naresuan University	7	1.67	1.61
5. Vidyasirimedhi Institute of Science and Technology (VISTEC)	4	1.43	1.43
6. Chiang Mai University (CMU)	8	1.13	0.95
7. Thailand Center of Excellence in Physics (ThEP Center)	7	1.48	0.84
8. King Mongkut's University of Technology Thonburi (KMUTT)	2	0.67	0.67
9. Sakon Nakhon Rajabhat University (SNRU)	1	0.57	0.57
10. Srinakharinwirot University	4	0.65	0.52

# การอบรมเชิงปฏิบัติการ เทคโนโลยีเทอร์โมอิเล็กทริก



“การประดิษฐ์เทอร์โมอิเล็กทริกเซลล์เบื้องต้น” ระดับประเทศ ปี 2559

**Thank you for your attention**