2009 Thermoelectrics Applications Workshop
Oct. 1, 2009 @Hotel Del Coronado, San Diego, CA

Oxide thermoelectric power generation

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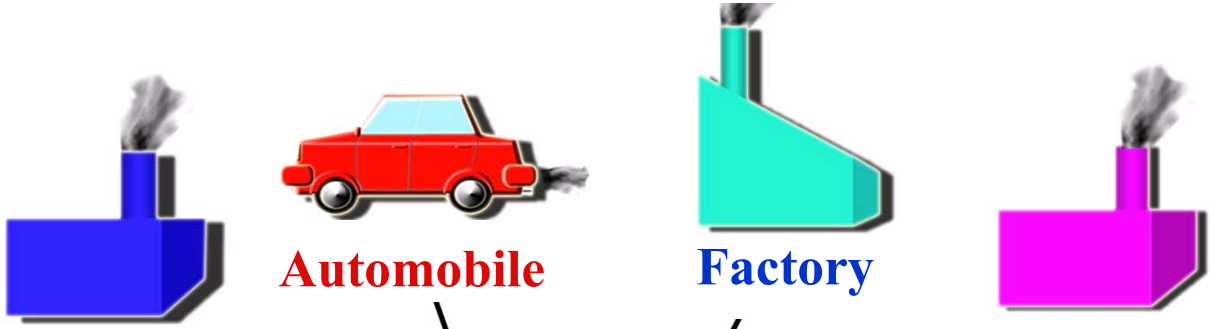
National Institute of Adv. Ind. Sci. & Tech.

Waste heat

Total primary energy
(Several 100 mil. kl/year in Japan)

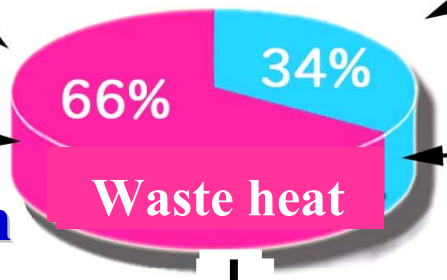


Automobile

Factory

Thermal power plant

Incinerator



Energy loss

Dilute distribution

Used energy

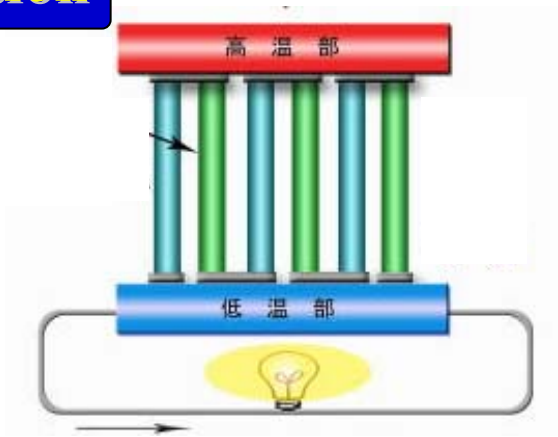
Thermoelectric conversion

Electrical energy

Contribution to energy & environmental problems

Problems in TE generation

Heat energy



Electrical energy

Conventional TE materials

Bi_2Te_3

Pb-Te alloy

$CoSb_3$

Zn_3Sb_4

Si-Ge alloy

→ Toxic element
→ Rare element
→ Melting
→ Oxidation

↓

Limitation on public application → **Oxide**

At high temperature in air
Safety, Relief & Cheapness

Oxide material

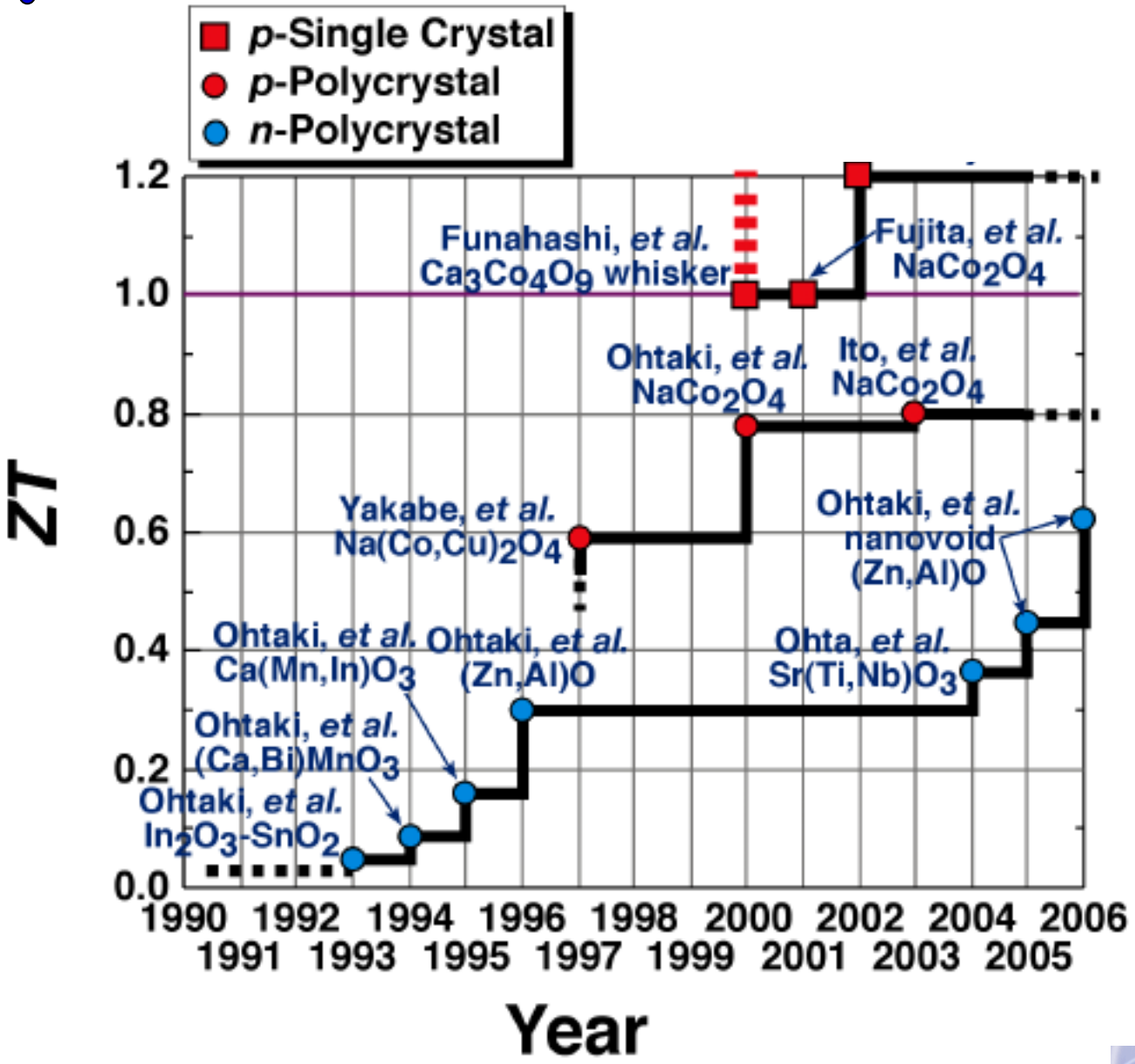
Ancient times
Earthenware
Clay image
Pigments

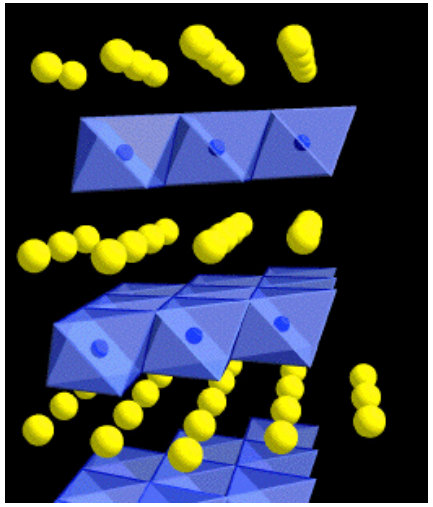
Middle ages
Ceramic ware
Brick
Glass

Present
Conducting materials
heating element ・transparent film
Insulating materials
transistor・insulator
Ionic conductors
Magnetic materials
Sensing materials
Catalysis
Superconductors

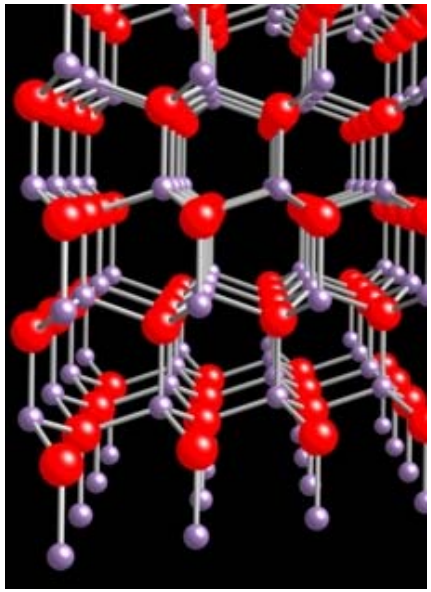
Classical, Advanced & Human friendly

Oxide TE material





$NaCoO_4$



ZnO

http://ohtaki.cube.kyushu-u.ac.jp/Ohtaki_Lab/index.html

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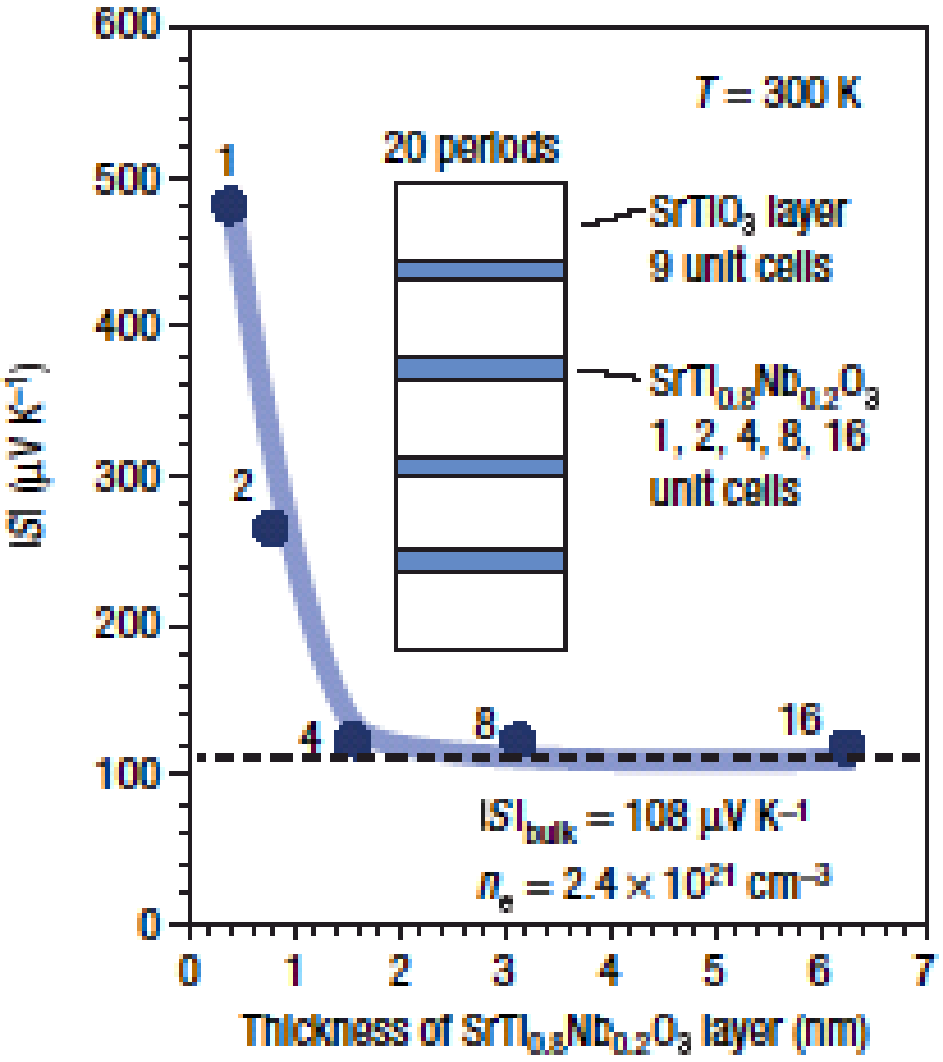
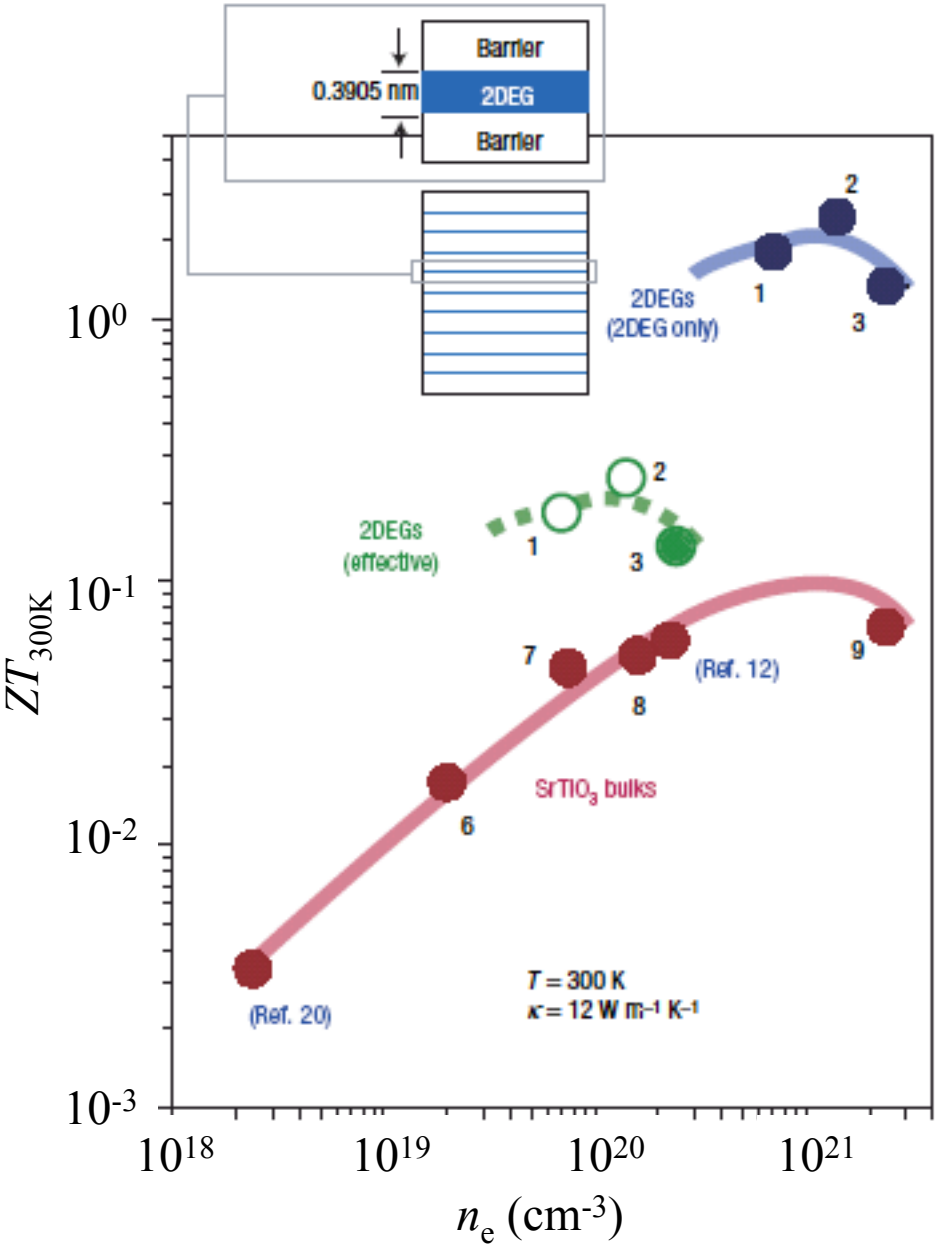
SL oxide TE film





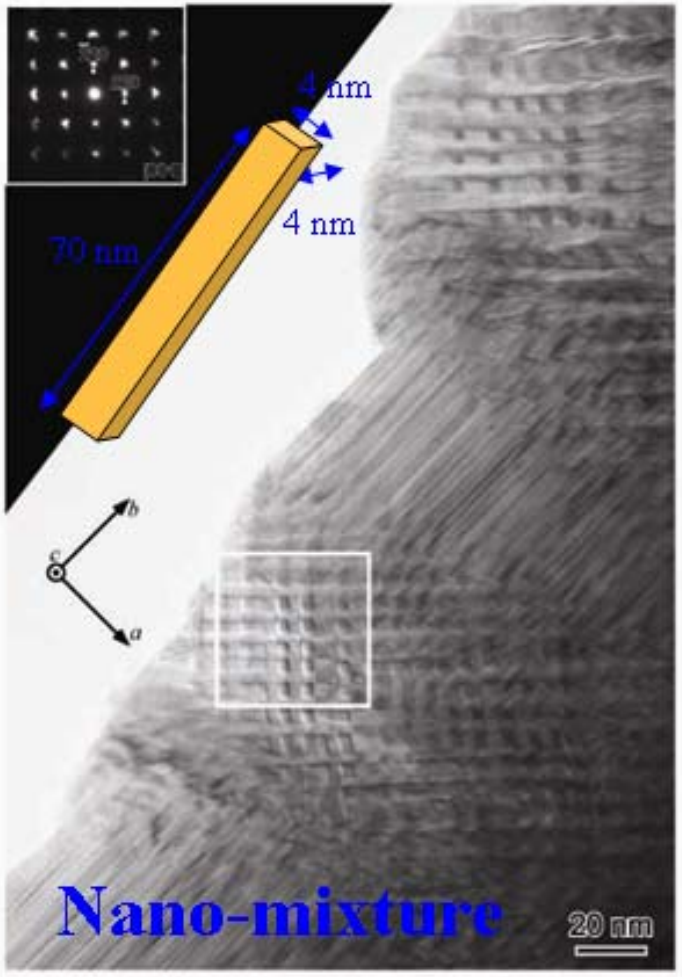
H. Ohta et al, NATURE MATERIALS 6, 129 (2007).

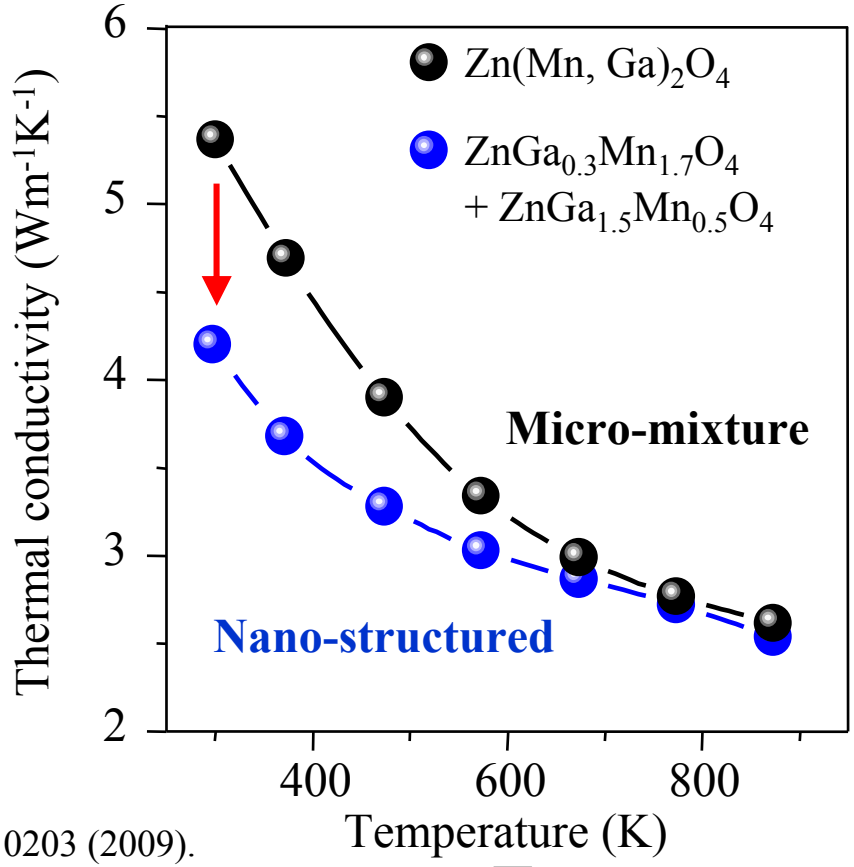
Phase separation

ZnO, Mn_2O_3, Ga_2O_3 → **Heating** → **Slow cooling** →

Phase separation in grains
$ZnGa_{0.3}Mn_{1.7}O_4$ (Cubic)
$ZnGa_{1.5}Mn_{0.5}O_4$ (Tetragonal)
Phase Separation in Nano-scale

S. Yeo et al,APL 89, 233120(2006)

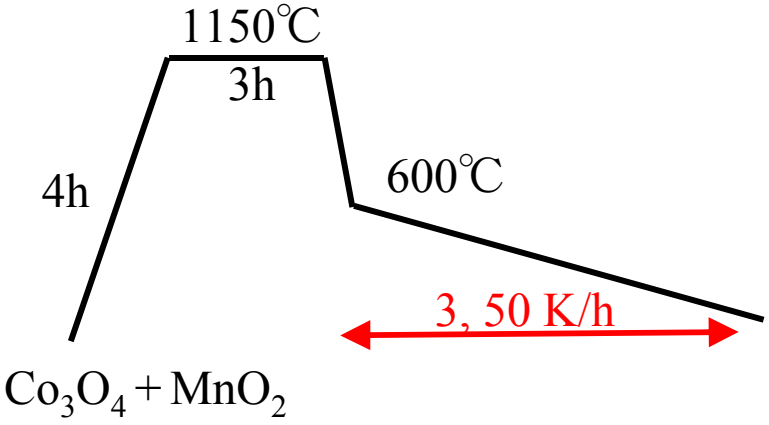


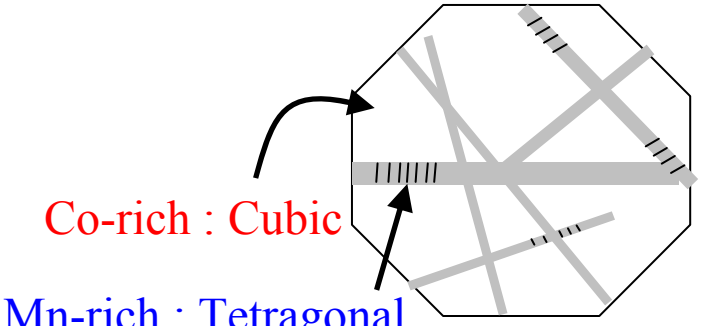


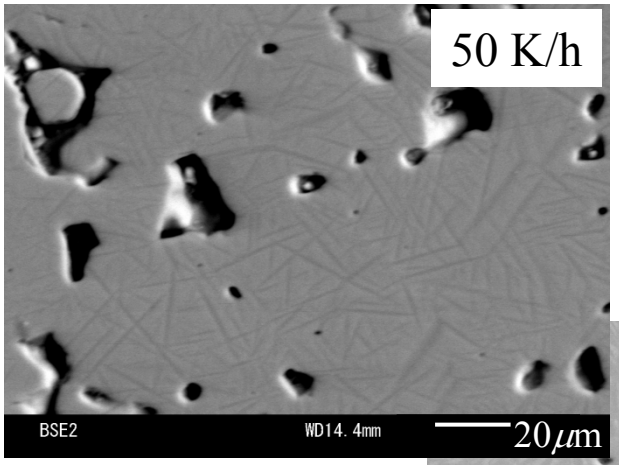
A. Kosuga, *et al*., Jpn. J. Appl. Phys., Vol. 48, 010201-010203 (2009).

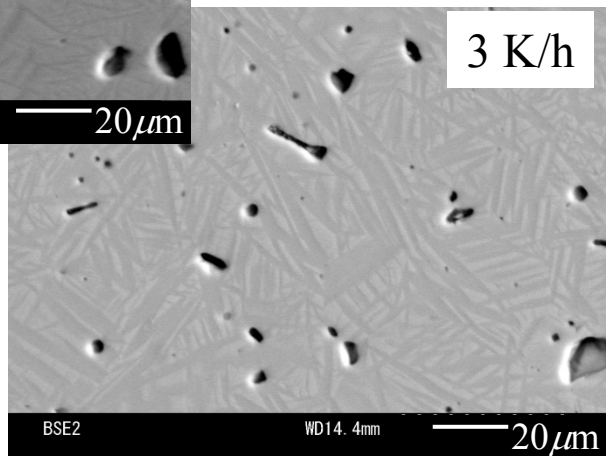
Conductive nano-structured oxide

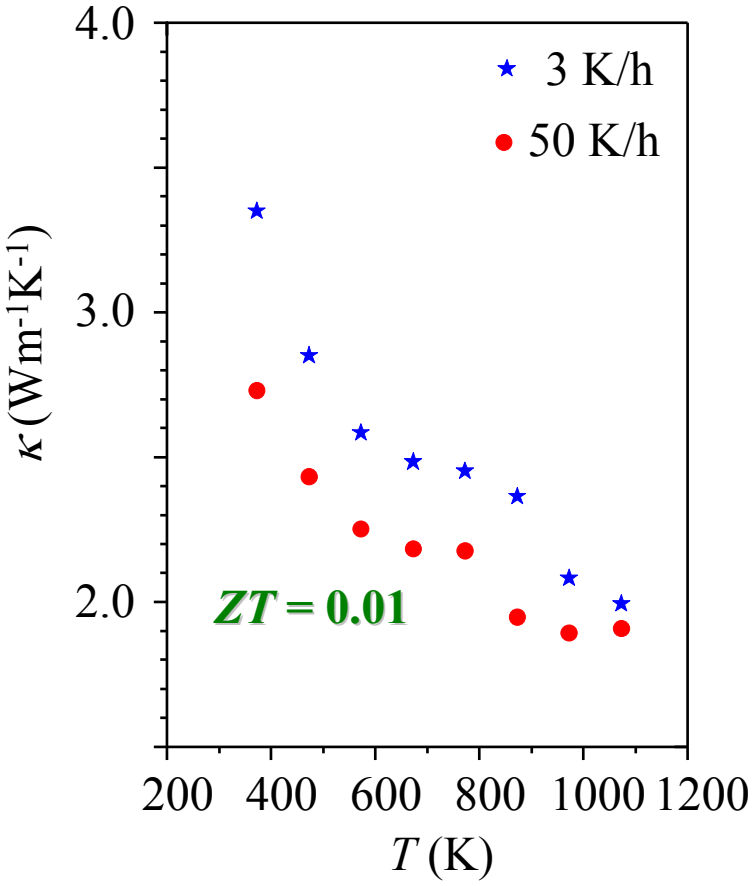
$Co_{1.5}Mn_{1.5}O_4$









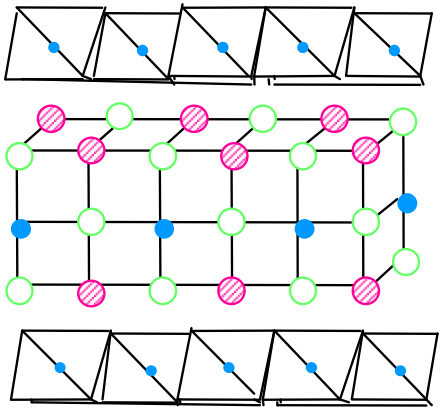


TE properties oxides

p-type

$Ca_3Co_4O_9$

(Co-349)



Co

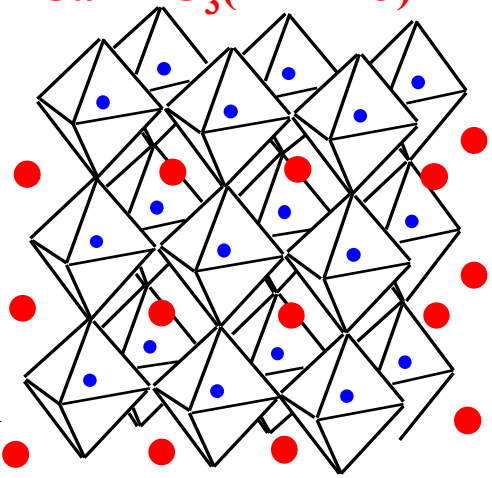
Ca

O

n-type

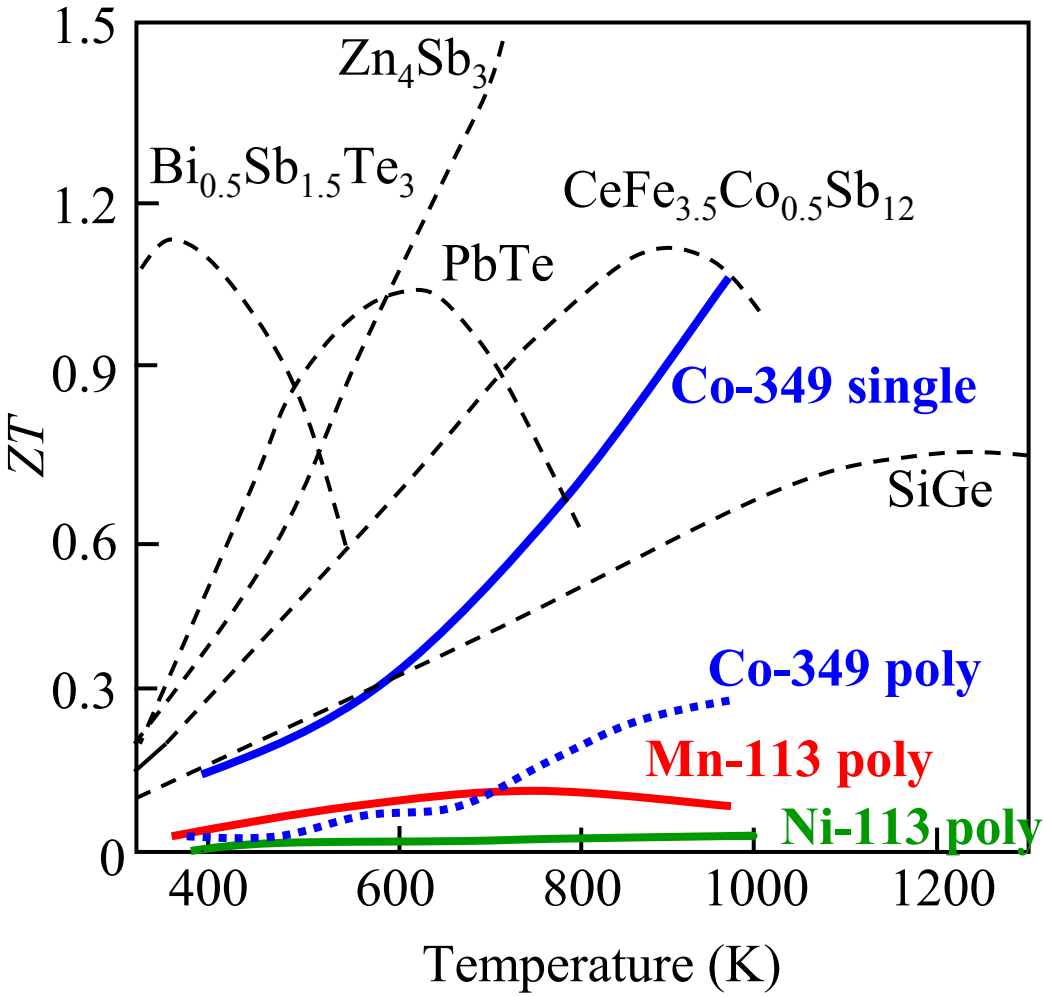
$LaNiO_3$(Ni-113)

$CaMnO_3$(Mn-113)



La, Ca

Ni, Mn



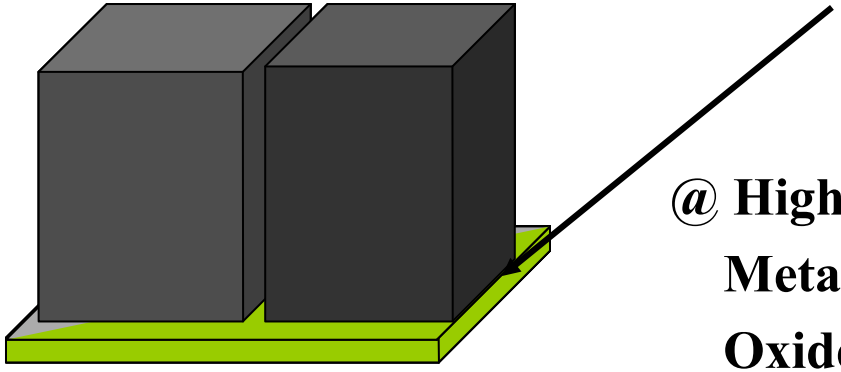
Modules

Junction

Mechanical strength

Contact resistance

p-type oxide n-type oxide



electrode metal

@ High temperature

Metal・・・great thermal expansion

Oxide・・・small thermal expansion

Exfoliation

Ag paste (commercially available)

+

p-type oxide powder

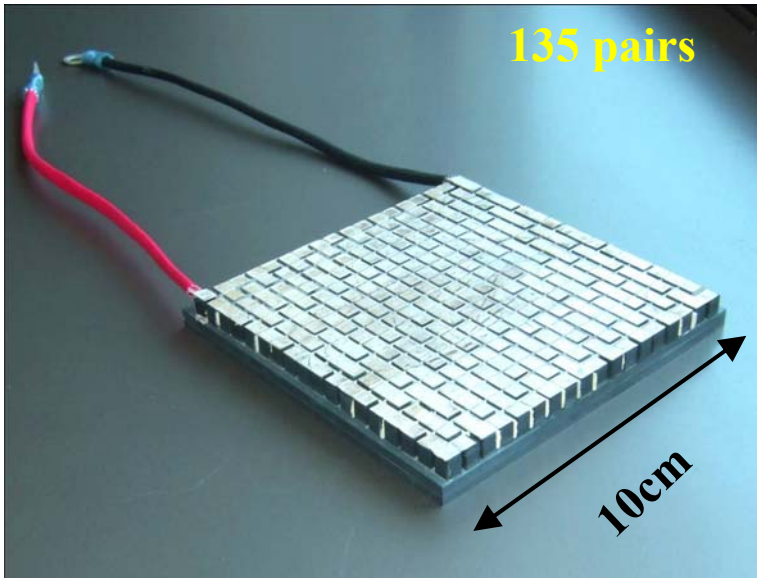
Good junctions

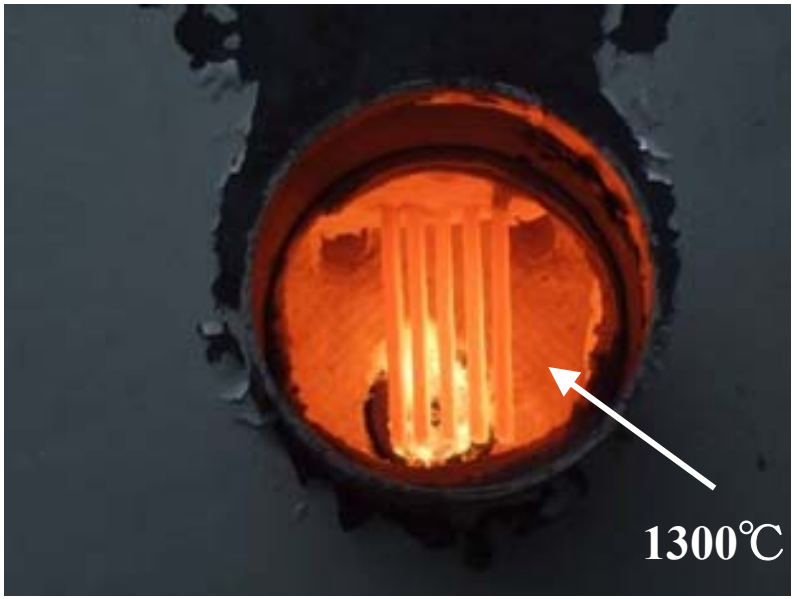
Metal vs. Oxide

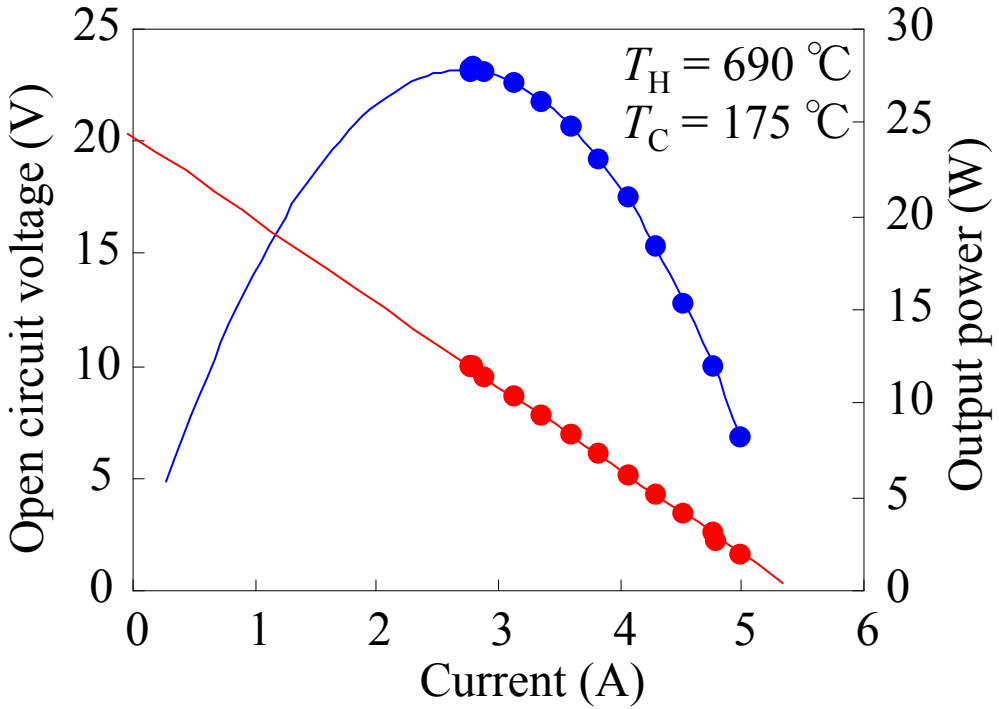
・・・Different electronic properties

High contact resistance

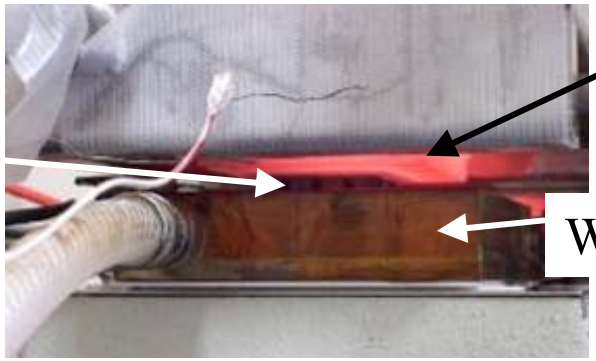
TE oxide module

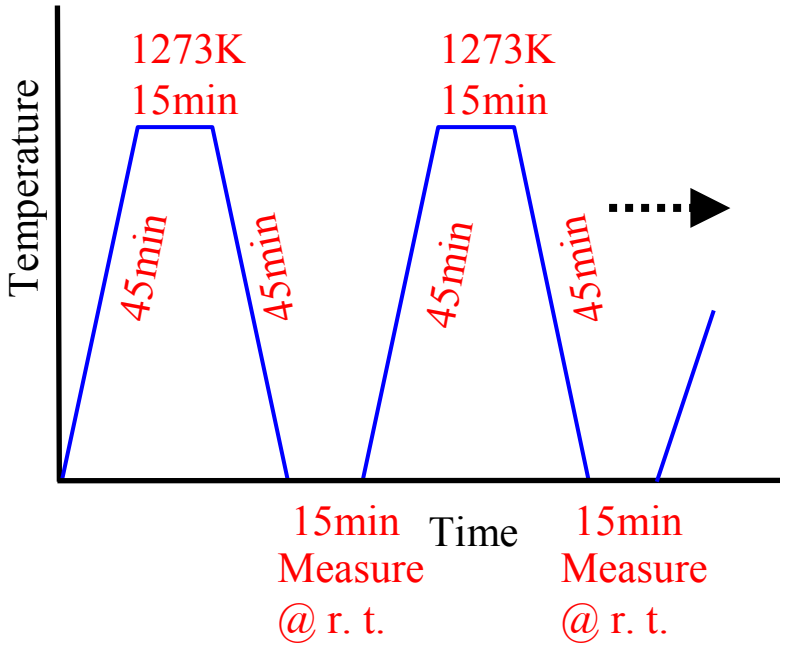


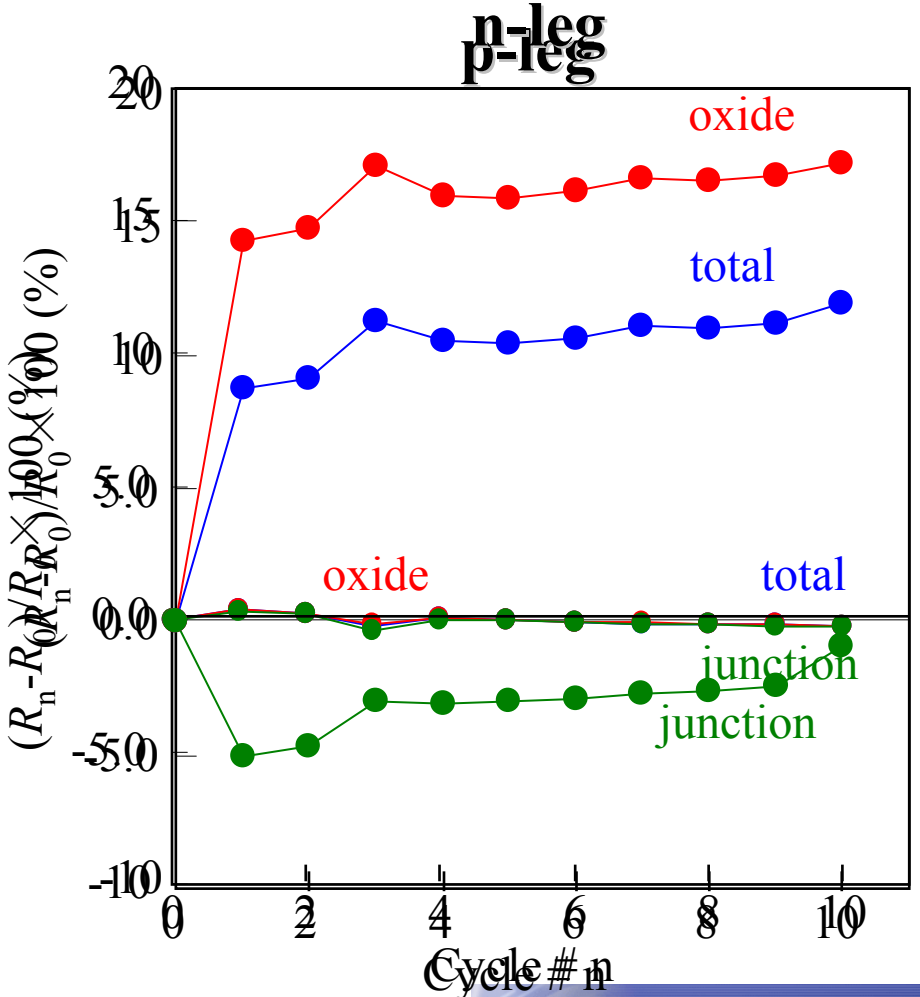




Durability







Power density

Space between devices

: Dead space

Space : 1.2 mm

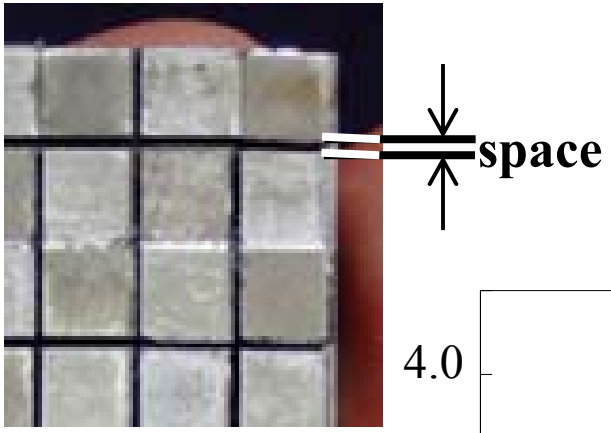
Device area/Total area : 49 %

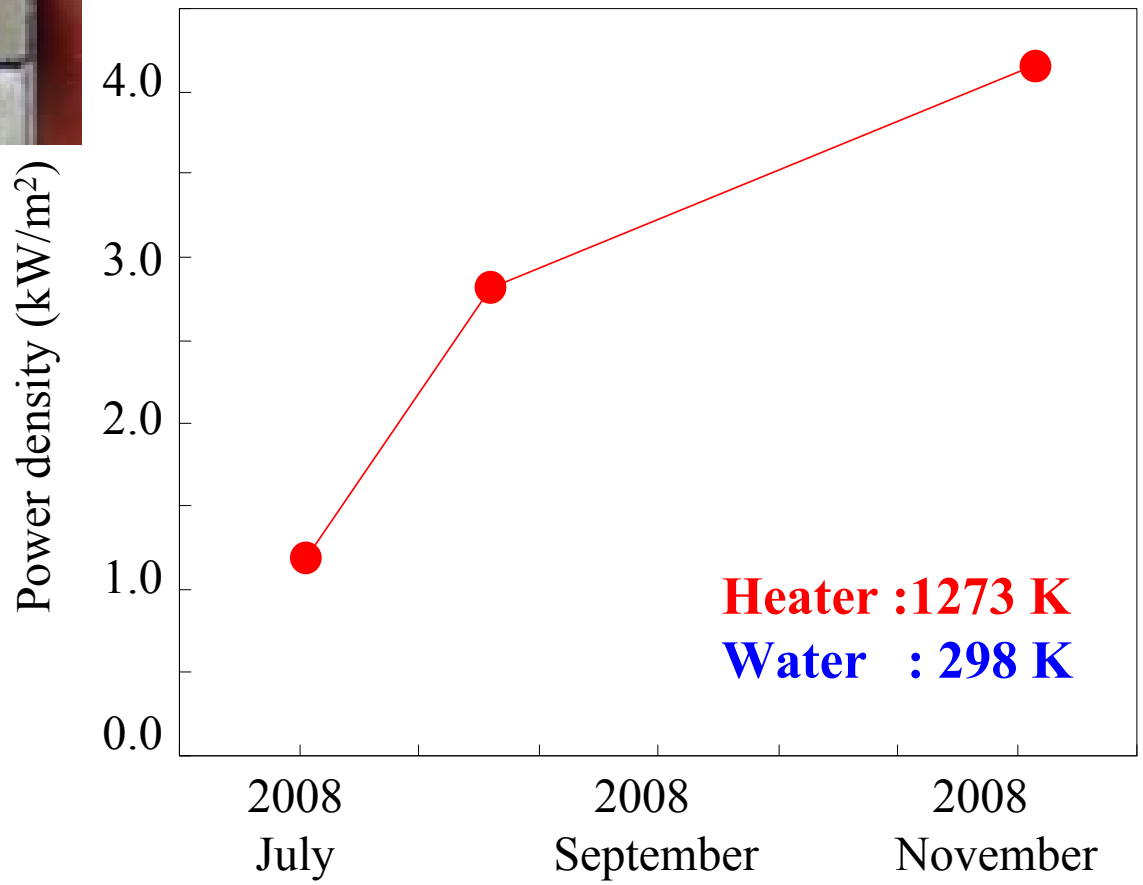
0.8 mm

62 %

0.5 mm

83 %



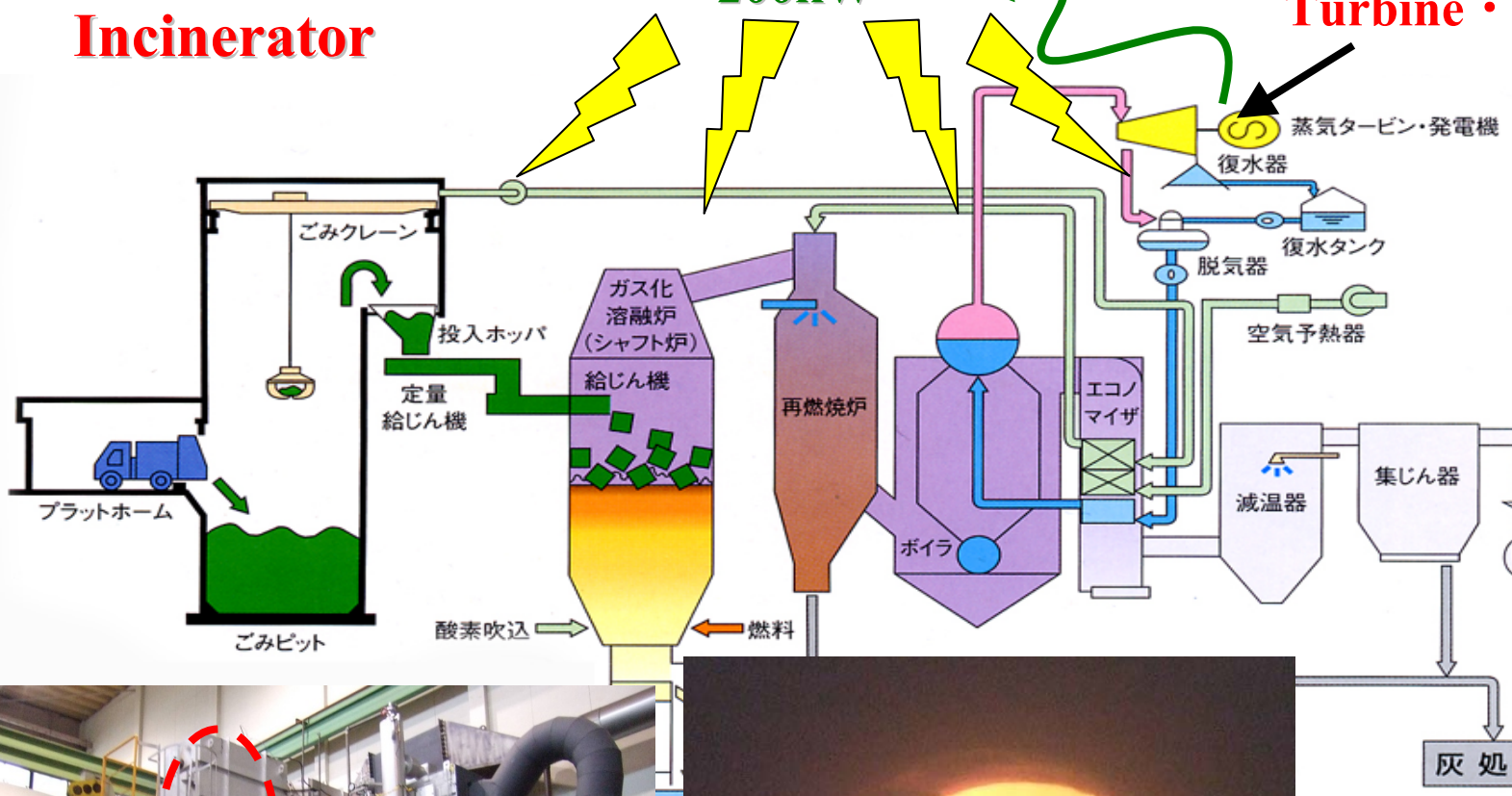


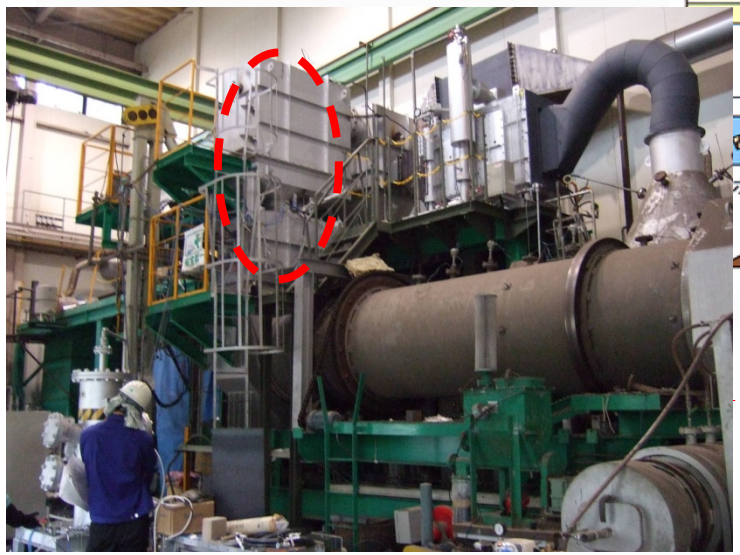
Application

Incinerator

Self-conclusion
200kW

Turbine・・・Expensi





n turbine

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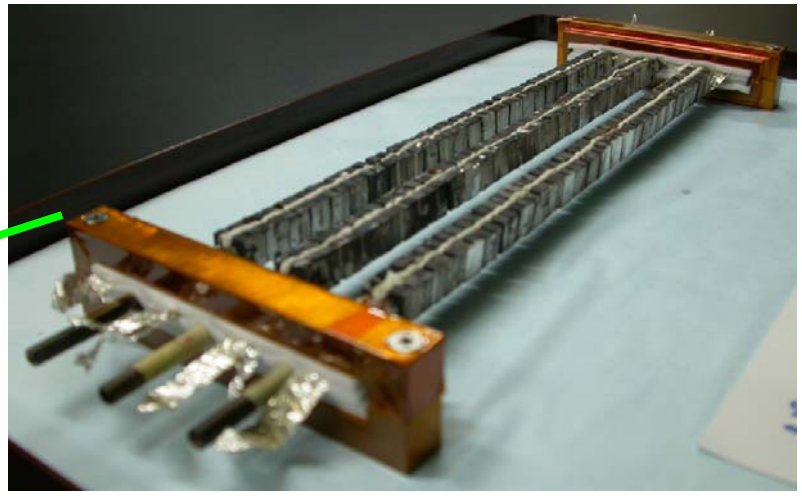
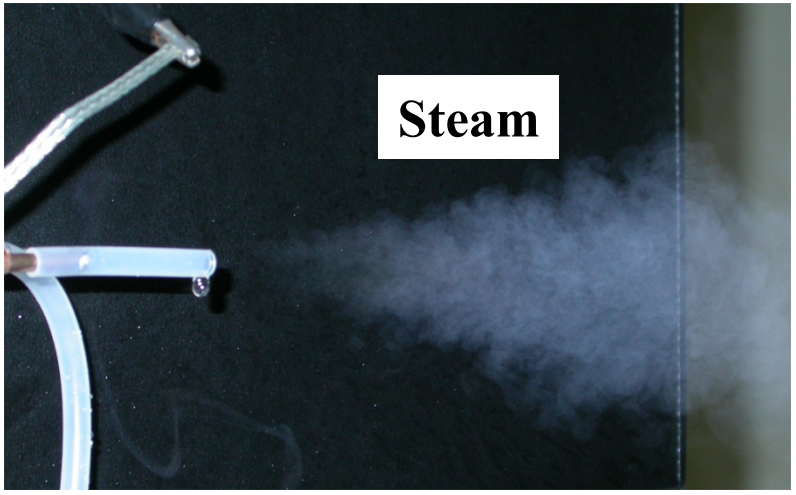
Topping heat recovery





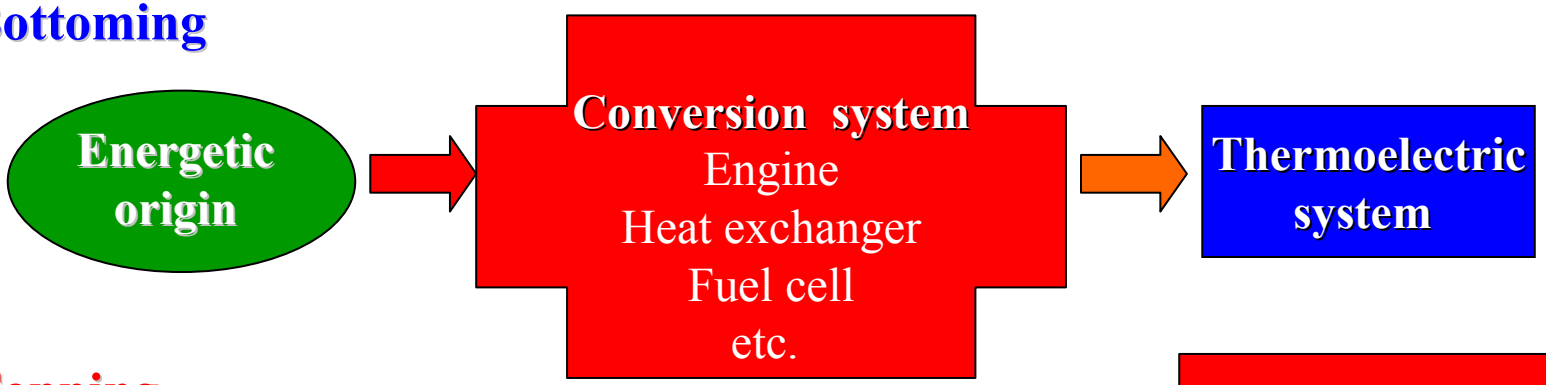
New concept of TE power generation

Oxides

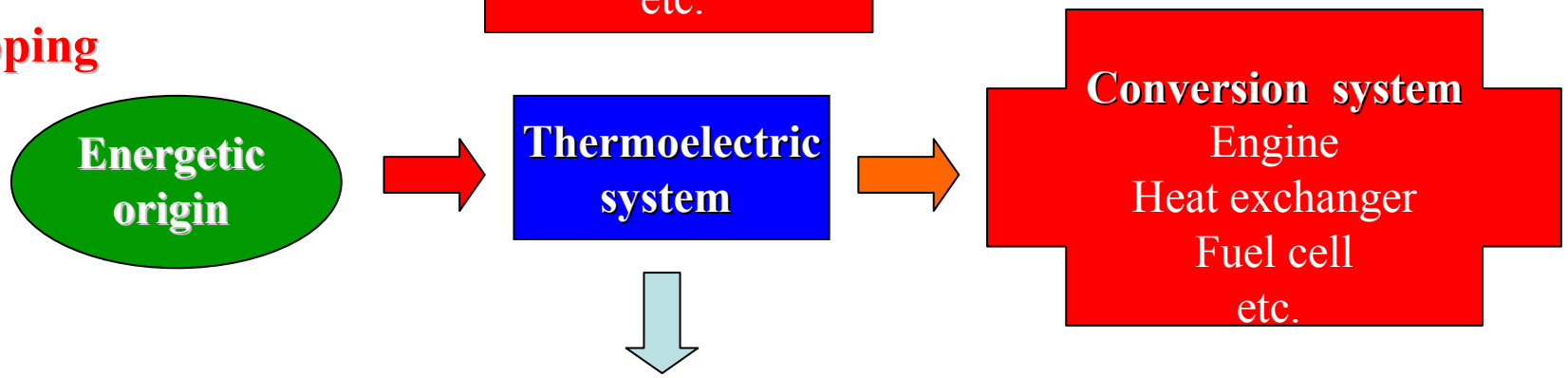
High Temperature Use

Topping Recovery of Waste Heat

Bottoming



Topping



Establish New Concept for Conversion Systems

Conclusion

Oxide TE

Strong points

-High durability against high temperature and oxidation

-No secure elements

-No toxic elements

-Mass production

-Light weight

-Small thermal expansion

⇩

Reliable, Safe, and Cheap system

Weak points

-Low ZT

-High ZT_{max} temperature

-Brittle

⇩

New material

Thank you very much

http://staff.aist.go.jp/funahashi-r

/english/Index.htm