Composite Silicide Thermoelectric Materials for Power Generation

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TE Materials

TE - Si/Ge Alloys, Silicides, Ceramics
Temperature Range - 500 - 1000 °C
Environment - O₂, NO₂, CO, CO₂, H₂O

- Phonon Scattering
- Nano inclusions
- Alloyed Si/Ge matrix
- Mingo et al.
- 2-10 nm - optimum size
- WSi₂ Best Silicide!

Si-TiSi₂/(Si,Ge)-TiSi₂

Hypersonic Vehicle

Directional Solidification Systems

Systmes
YSi₂, VSi₂, TaSi₂, ZrSi₂, MoSi₂, Mg₃Si
TiSi₂, CrSi₂, MoSi₂, WSi₂, CoSi

Advantages
- Stable High Temperature Interfaces
- Unique microstructures
- Coherent Interfaces

Si-TiSi₂/(Si,Ge)-TiSi₂

Solidification Microstructures

- Increasing Ge addition creates larger precipitates
- Ge segregation observed
Melt Derived WSi$_2$-Si/Ge

Resistivity

- Higher resistivity at 4-8% Ge
- Lower resistivity at 15-25% Ge

Seebeck

- Higher Seebeck voltages at 4-8% Ge
- Lower Seebeck voltages at 15-25% Ge

Ge Content

+(Si,Ge)-MoSi$_2$

Sil-MoSi$_2$, 200 mm/hr

Si-MoSi$_2$, 200 mm/hr

Seebeck

Resistivity

Power Factor

- Large power factors > nano SiGe
- High power factors at low temperatures
- High power factors at lower Ge content

Thermal Conductivity

- Si-MoSi$_2$ & Si-WSi$_2$-High κ
- Ge important in reducing κ
- Si-MoSi$_2$ more dependent on Ge content than Si-WSi$_2$
- Si-WSi$_2$ system gives ZT of 0.6
- Further reduction in κ will enhance ZT

Spark Plasma Sintering

Melt Solidification vs Spark Plasma Sintering

Parameter | Value
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Temperature | 200-1050 °C
Heating/Cooling Rate | 200 °C/min
Applied Pressure | 70-80 MPa
Hold Time | ~10 min
Si/Ge-WSi
Melt Solidification vs Spark Plasma Sintering

W, Mo & Ti systems gave high power factors (more than twice the nano-SiGe).
W, Mo & Ti - large power factors at low temperatures.
ZT = 0.55 for WSi2-SiGe eutectic is demonstrated.
WSi2-SiGe - Potential higher ZT - reducing thermal conductivity
SPS - Have not achieve good TE properties.