COMPOSITES FOR MULTI-ENERGY CONVERSION & WASTE HEAT RECOVERY

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ACKNOWLEDGEMENTS

NSF

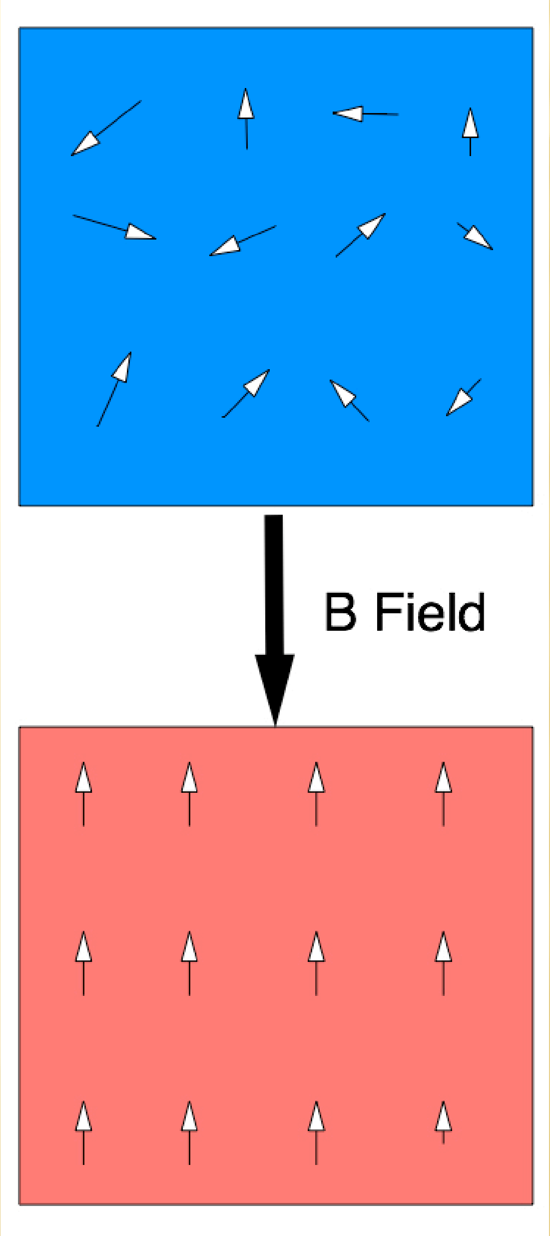
TEXAS A&M UNIVERSITY 1876

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

TEES
TEXAS ENGINEERING EXPERIMENT STATION
THE ENGINEERING AGENCY OF THE STATE OF TEXAS

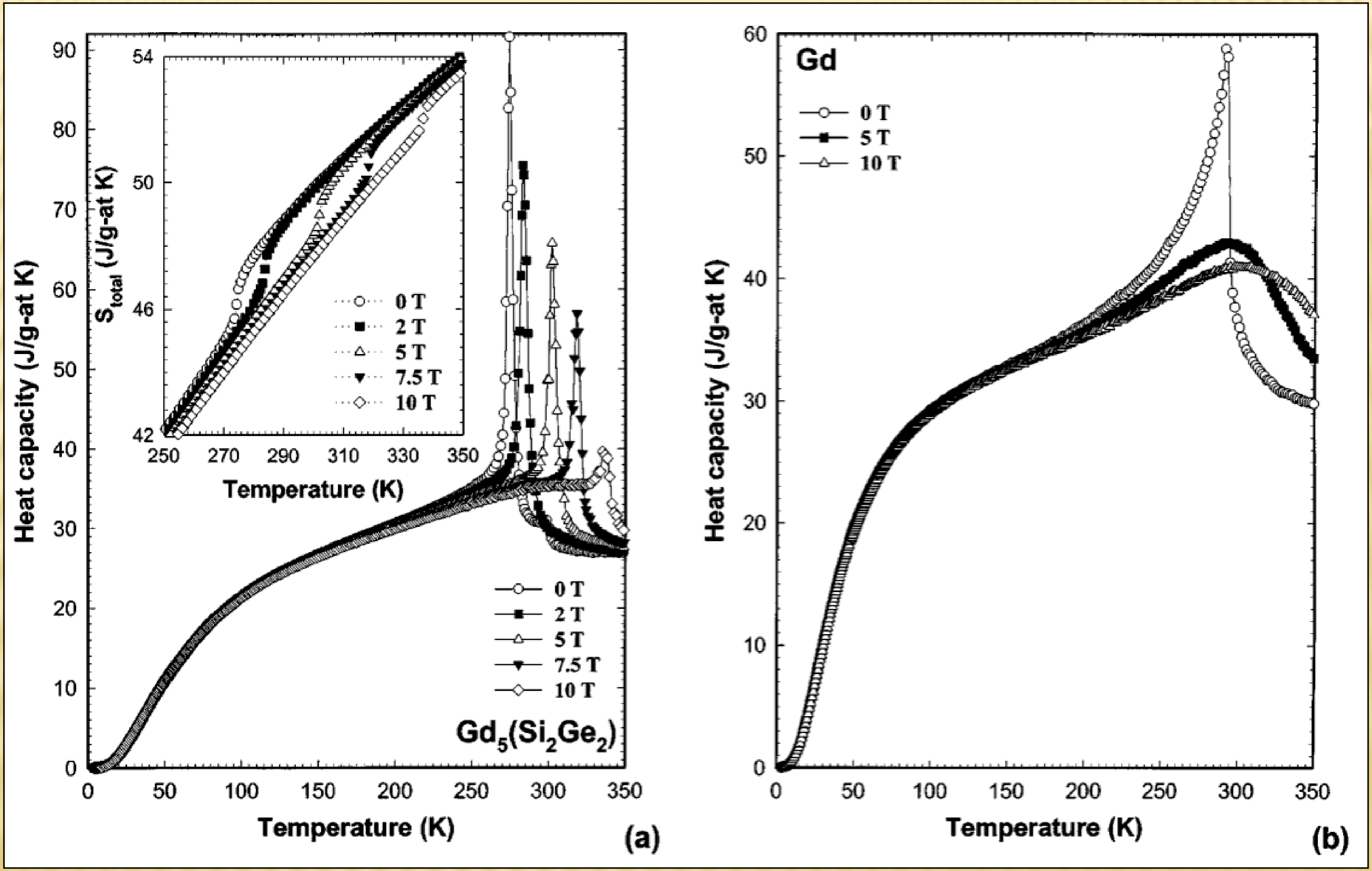
MAGNETOCALORIC EFFECT

- Discovered in 1881 by Emil Warburg in iron
- Changes heat capacity depending on its applied magnetic field
- Alignment of the magnetic dipoles and subsequent relaxation



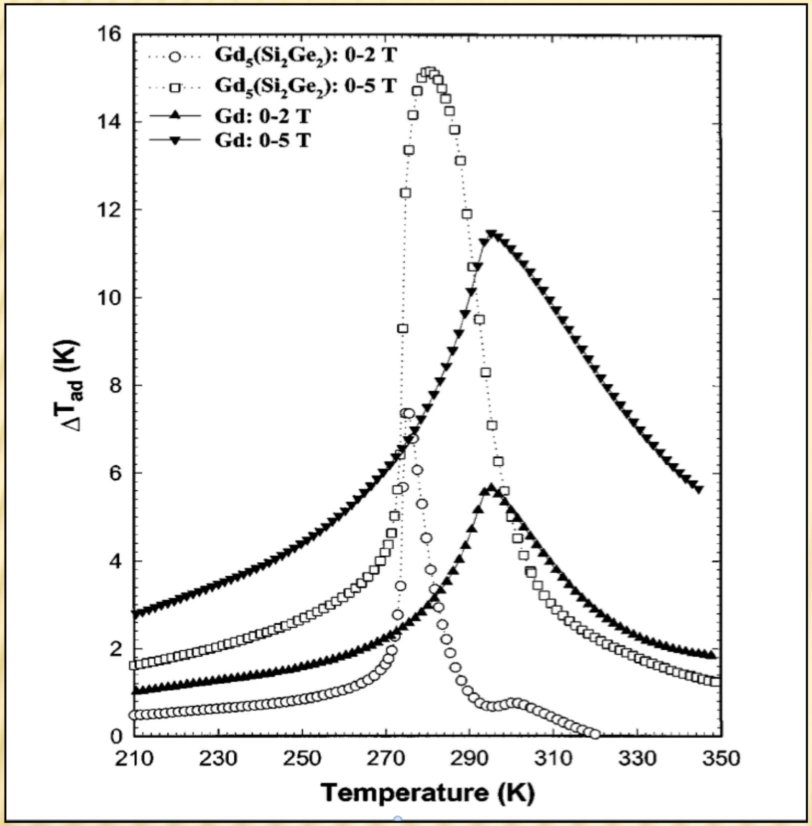
E. Warburg, Ann. Phys **13, 1441 (1881)**

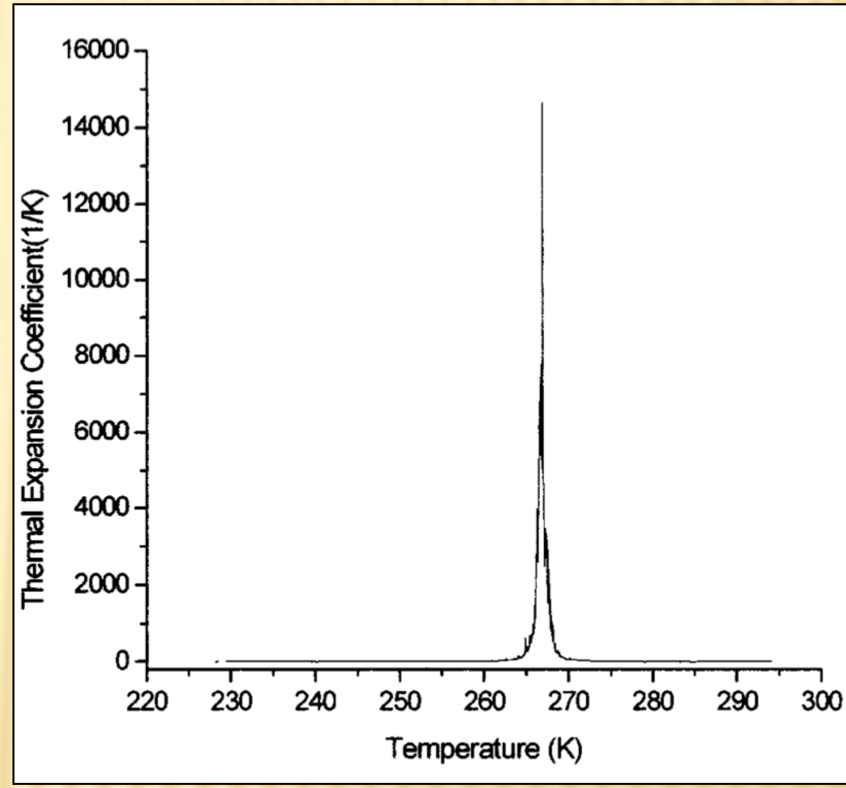
MAGNETOCALORIC EFFECTS



V. K. Pecharsky, and K. A. Gschneider, Journal of Alloys and Compounds **260, 98 (1997).**

MAGNETOCALORIC EFFECTS





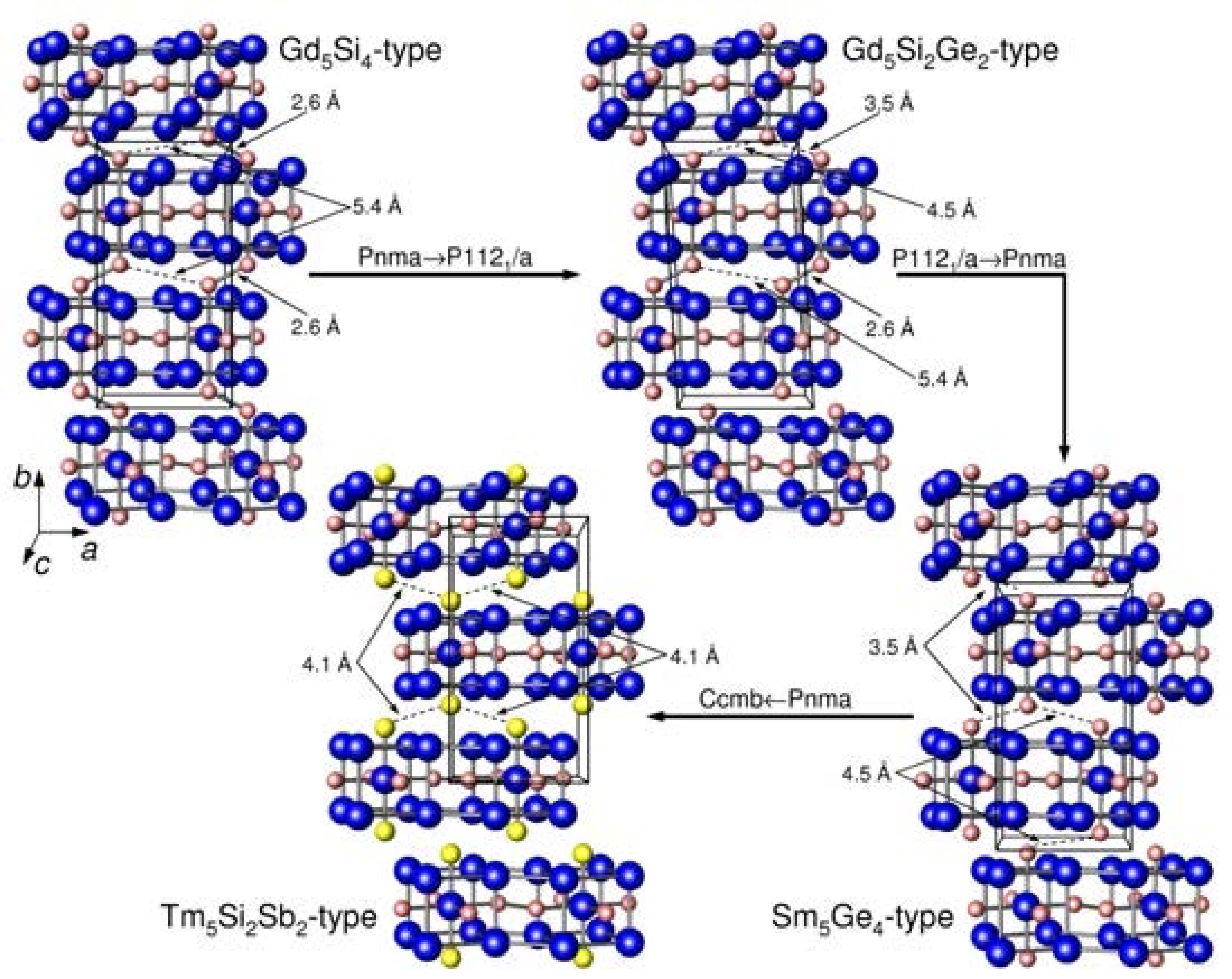
Possible applications

- Refrigerant
- Heat Transfer Agent

V. K. Pecharsky, and K. A. Gschneider, Journal of Alloys and Compounds **260, 98 (1997).**

- Large Thermal Expansion around 270K
- Ferromagnetic Orthorhombic
- Paramagnetic Monoclinic

M. Han *et al.*, *(Ieee-Inst Electrical Electronics Engineers Inc, 2002), pp. 3252.*



Gd_5Si_4-type
2.6 Å
5.4 Å
2.6 Å
Pnma→$P112_1/a$
$Gd_5Si_2Ge_2$-type
3.5 Å
4.5 Å
2.6 Å
5.4 Å
$P112_1/a$→Pnma
b
a
c
4.1 Å
4.1 Å
Ccmb←Pnma
3.5 Å
4.5 Å
$Tm_5Si_2Sb_2$-type
Sm_5Ge_4-type

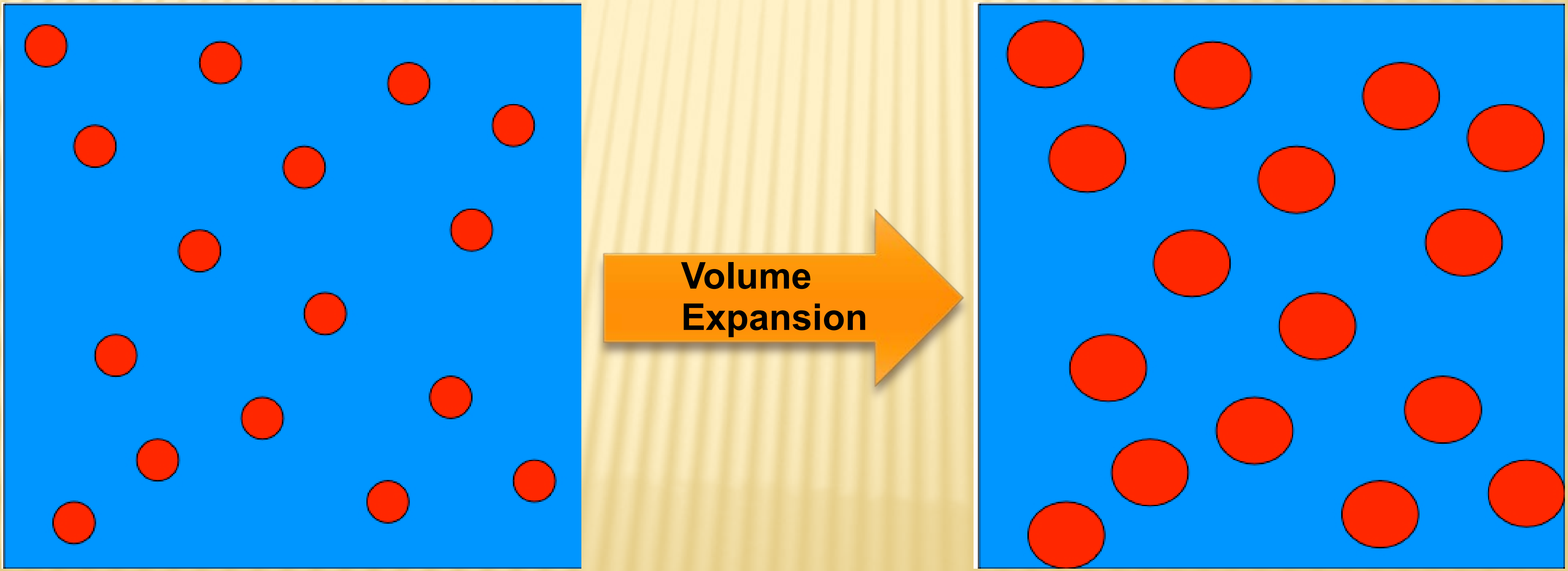
OBJECTIVES

- Develop a composite that transfers energy between thermal, electrical, magnetic, and mechanical types.

- Develop a composite material that improves performance through in situ strengthening

DESIGN CONCEPT

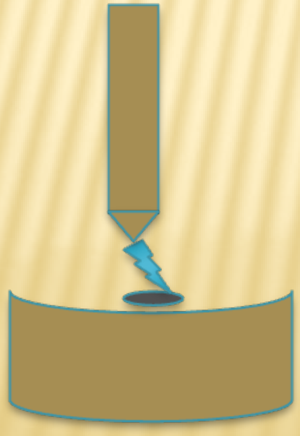
- Maximize contact between GSG and matrix material.

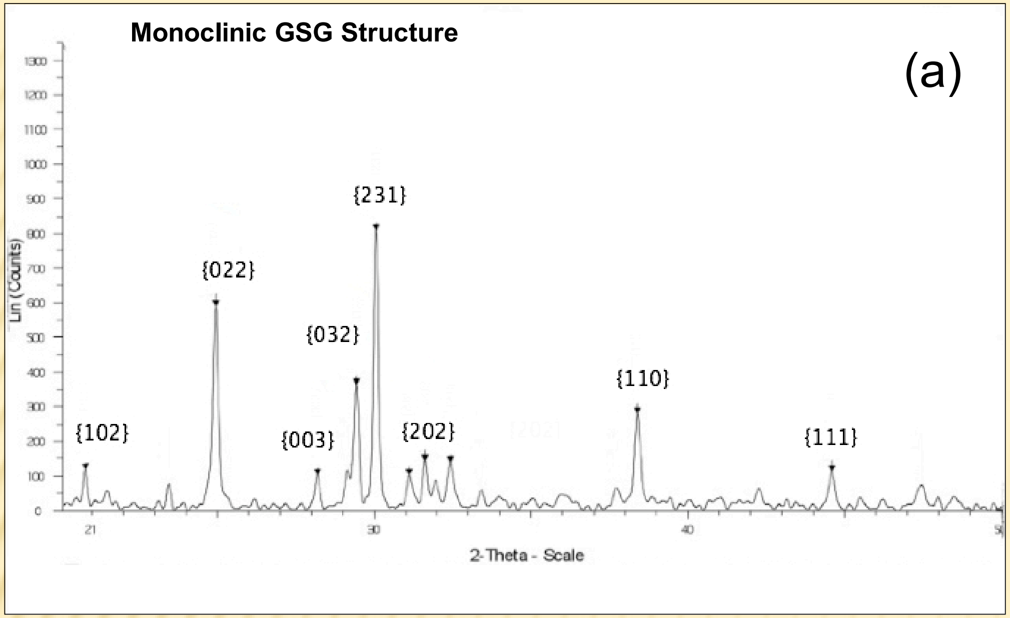


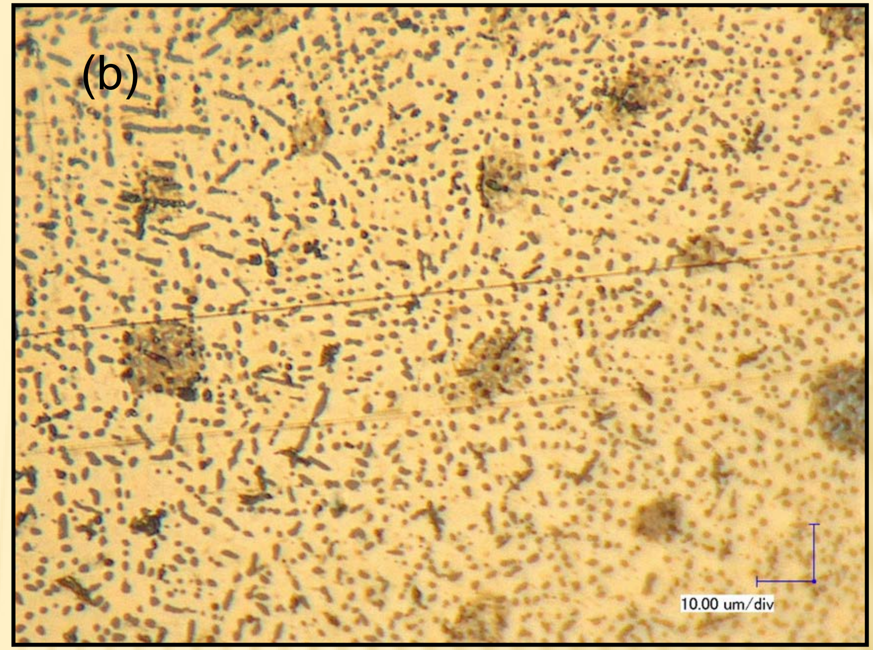
MATERIALS SYNTHESIS

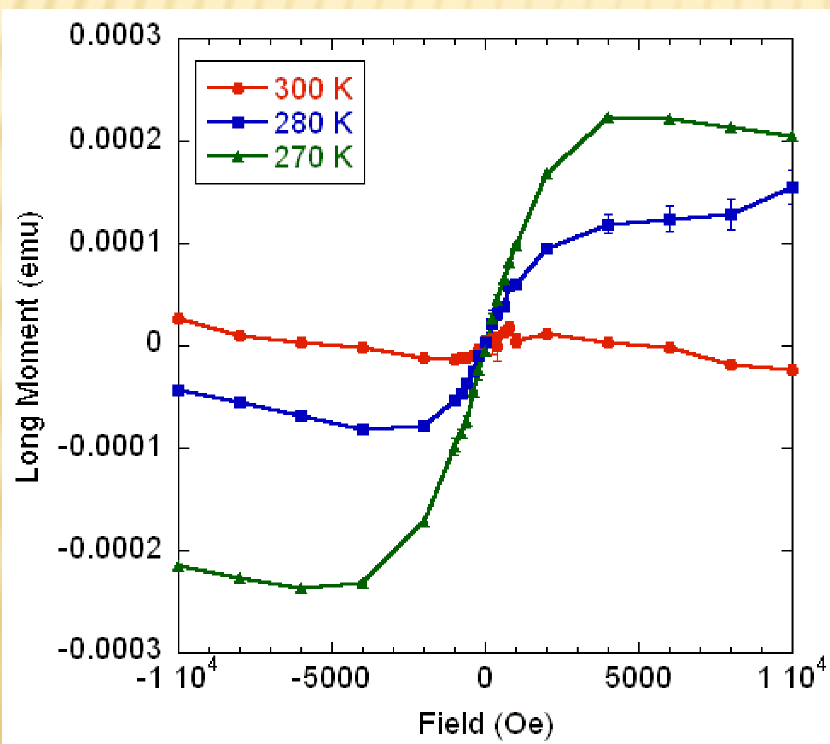
Conditions:

Materials
Gd 99.9%, Si 99.9999%, Ge 99.999% purity
Current - 150 Amps
Argon Environment
Circular Heating Pattern
Melt time - 30 to 45 seconds
Melted 4x flipped each time







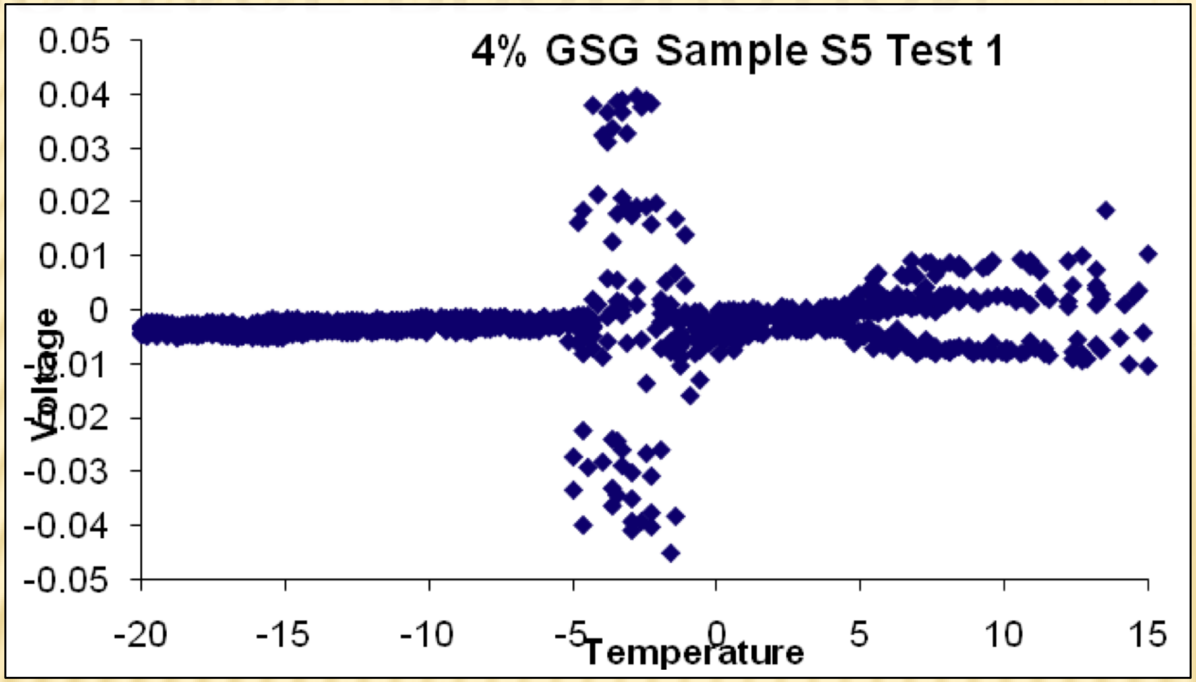


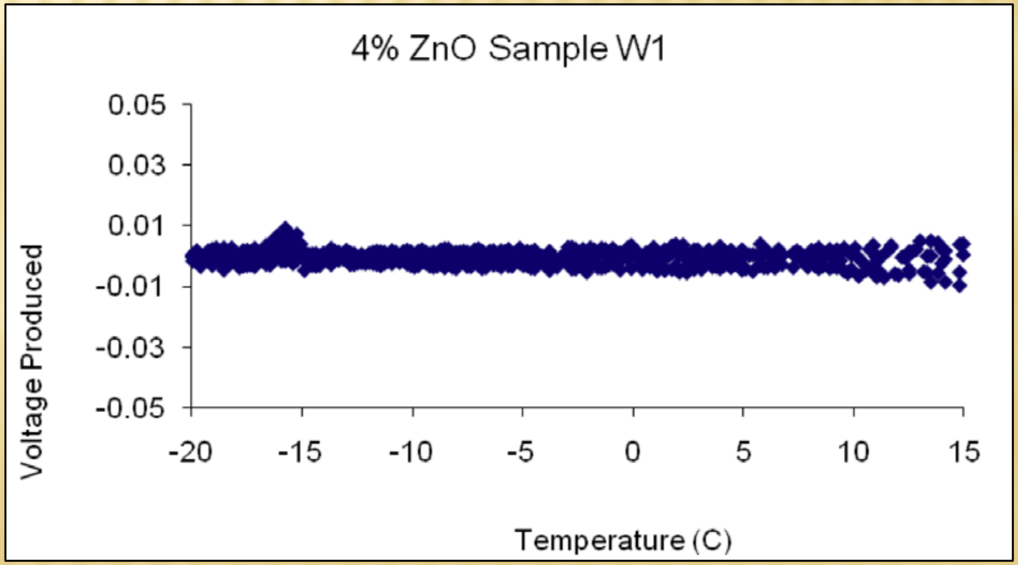
a, Microstructure analysis of the composite material. a, X-ray diffraction showing the monoclinic structure of GSG;

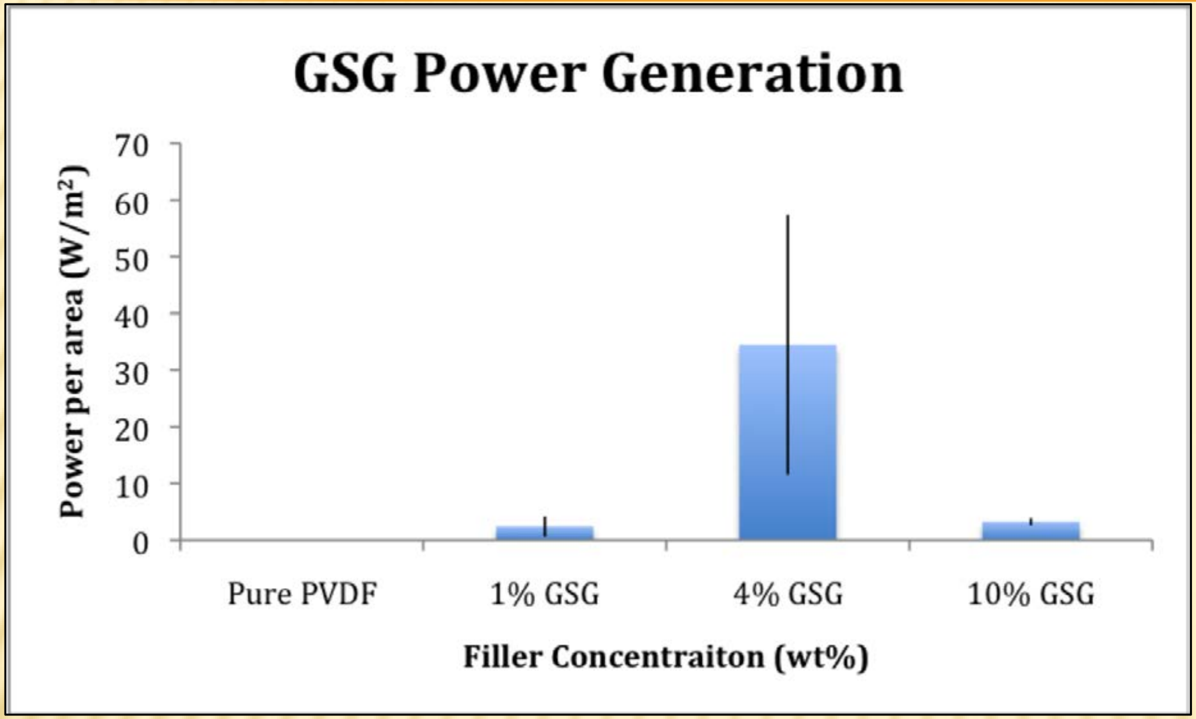
b, optical micrograph showing dark spots of GSG distributed in the PVDF;

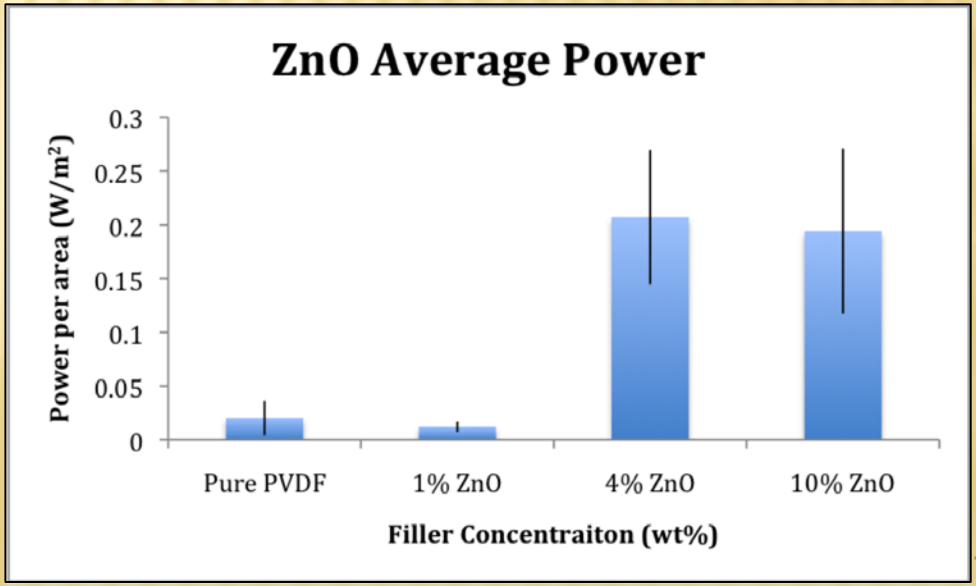
c, magnetic test showing order at 270K.

VOLTAGE PRODUCTION

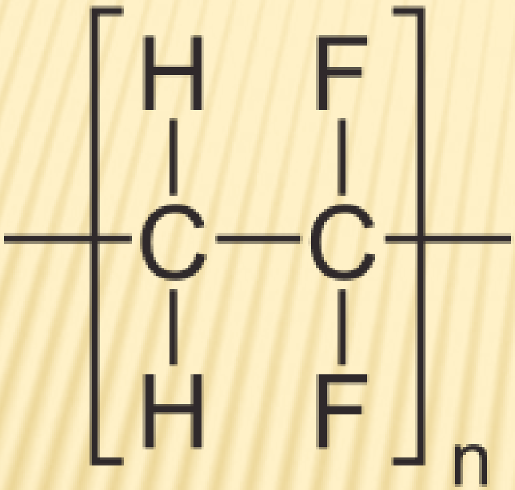


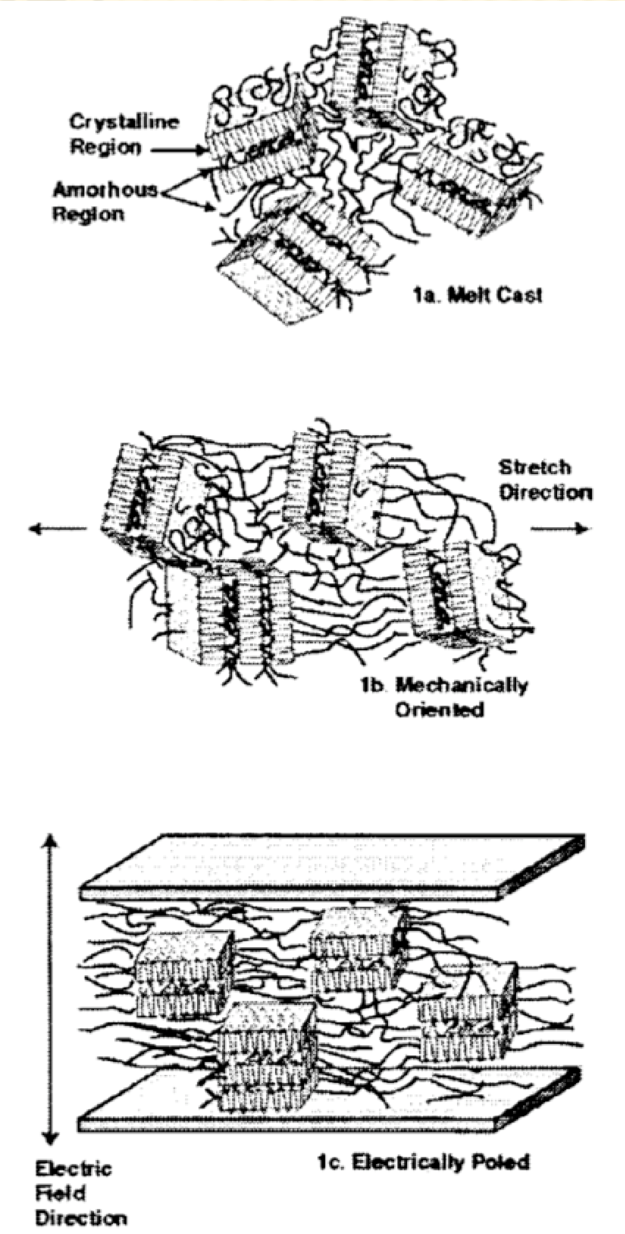



GSG Power Generation
Power per area (W/m²)
70
60
50
40
30
20
10
0
Pure PVDF
1% GSG
4% GSG
10% GSG
Filler Concentraiton (wt%)


ZnO Average Power
Power per area (W/m²)
0.3
0.25
0.2
0.15
0.1
0.05
0
Pure PVDF
1% ZnO
4% ZnO
10% ZnO
Filler Concentraiton (wt%)

POLY (VINYLIDENE FLUORIDE)

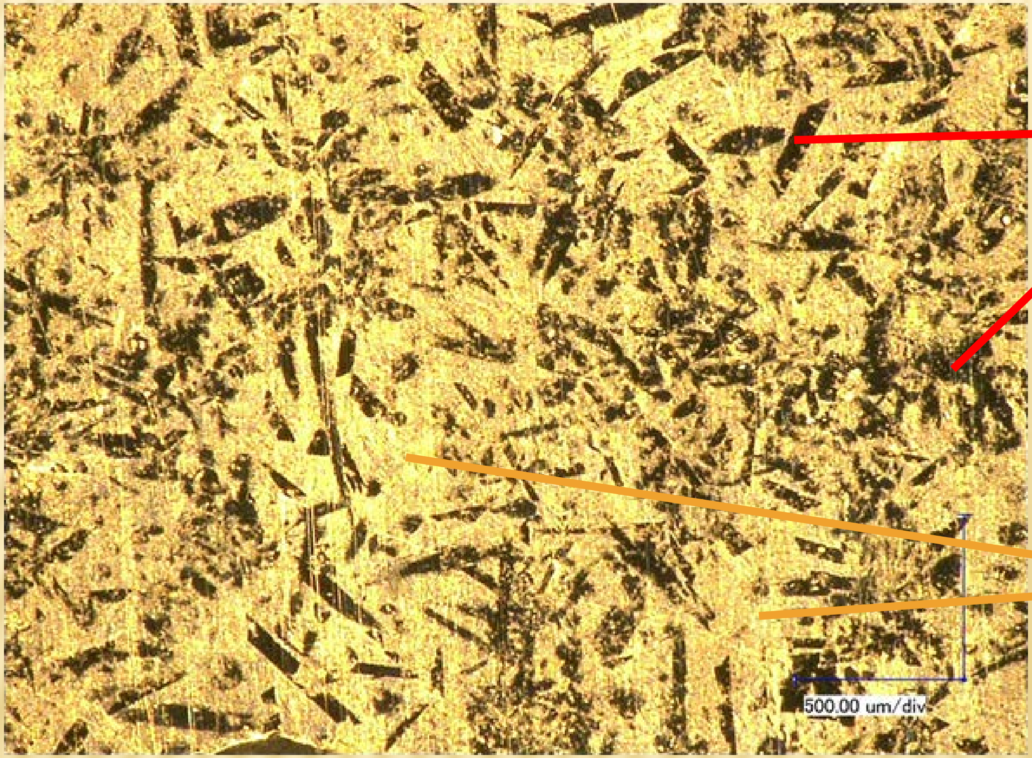




J. S. O. Harrison, Z., in *ICASE-2001-43; NAS 1.26:211422; NASA/CR-2001-211422, edited by NASA2001).*

IN AL MATRIX

Stable structure and no cracking



100X magnification of GSG-Al

Mostly GSG Phase

31%

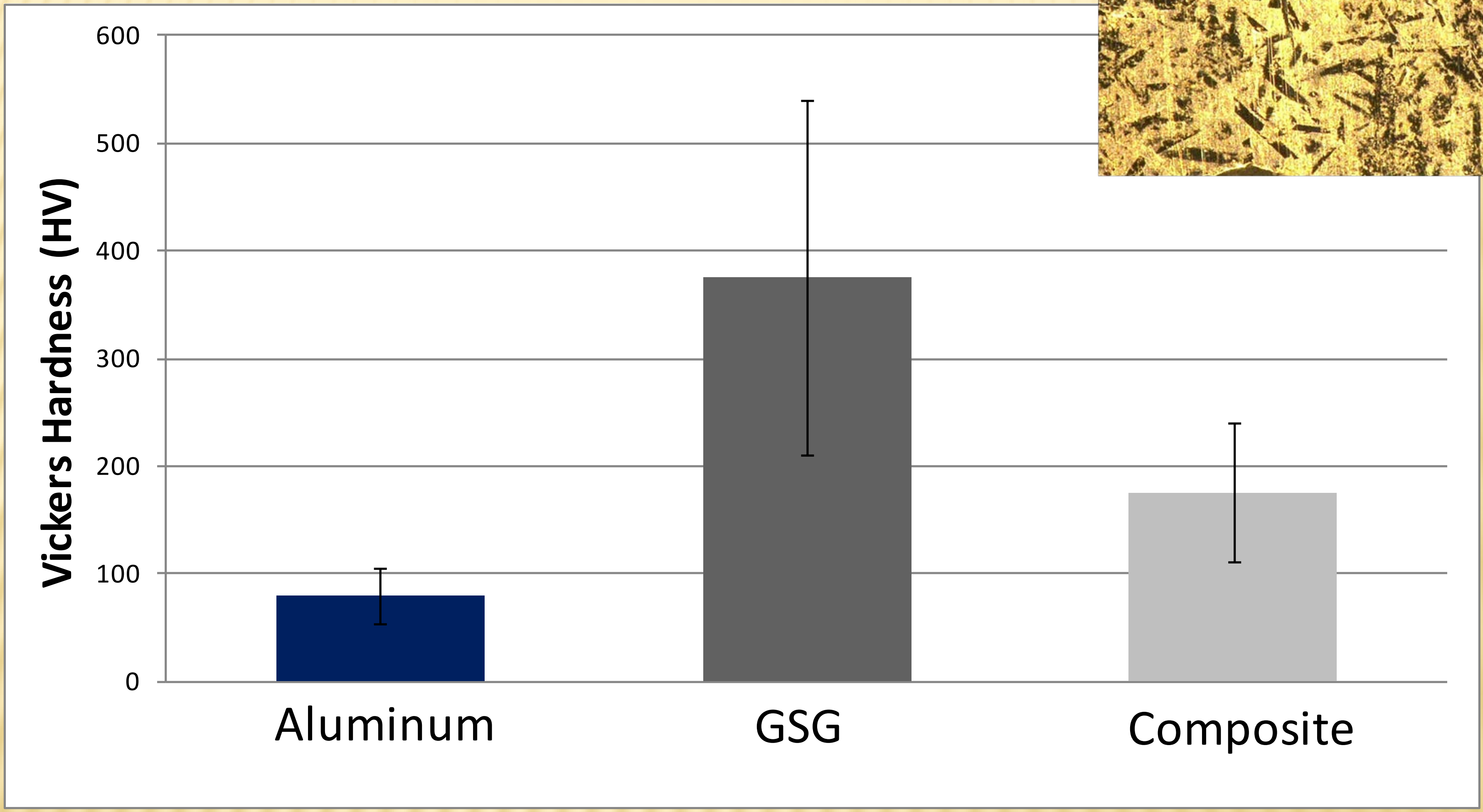
Mostly Al phase

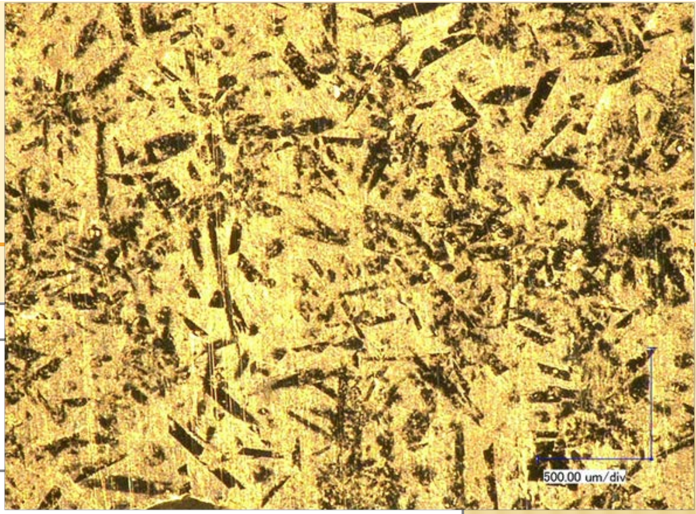
69%

J. Trib., accepted.

MECHANICAL PROPERTIES

MICROHARDNESS OF EACH PHASE

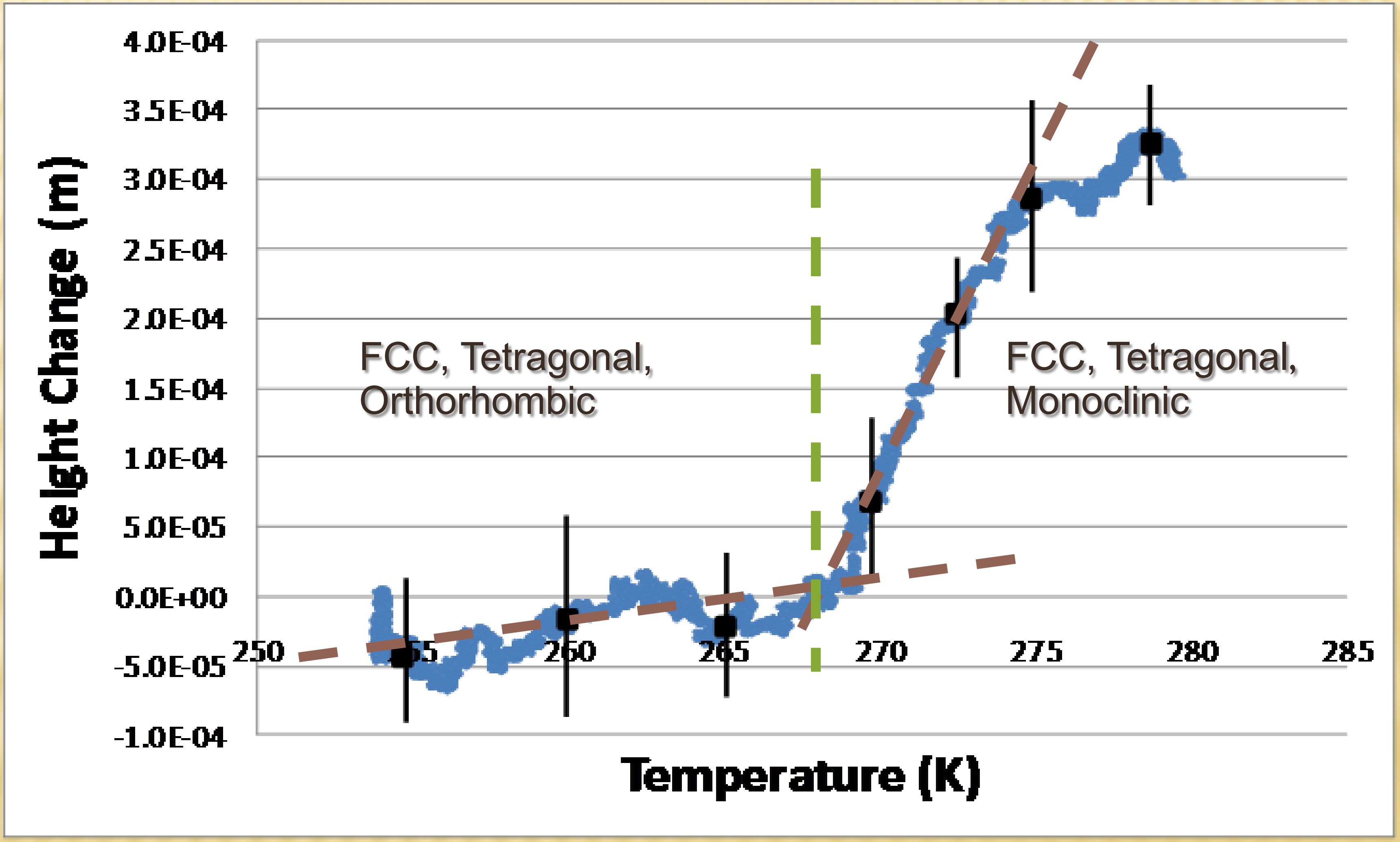




GSG phase is harder than Al phase:
Porous vs. Non-porous, Al naturally more ductile

MECHANICAL PROPERTIES

THERMAL EXPANSION – LOW TEMPERATURES (-18° C TO 8° C (255 K TO 281 K)) - PHASE CHANGE BEGINS AT -5° C (268 K)

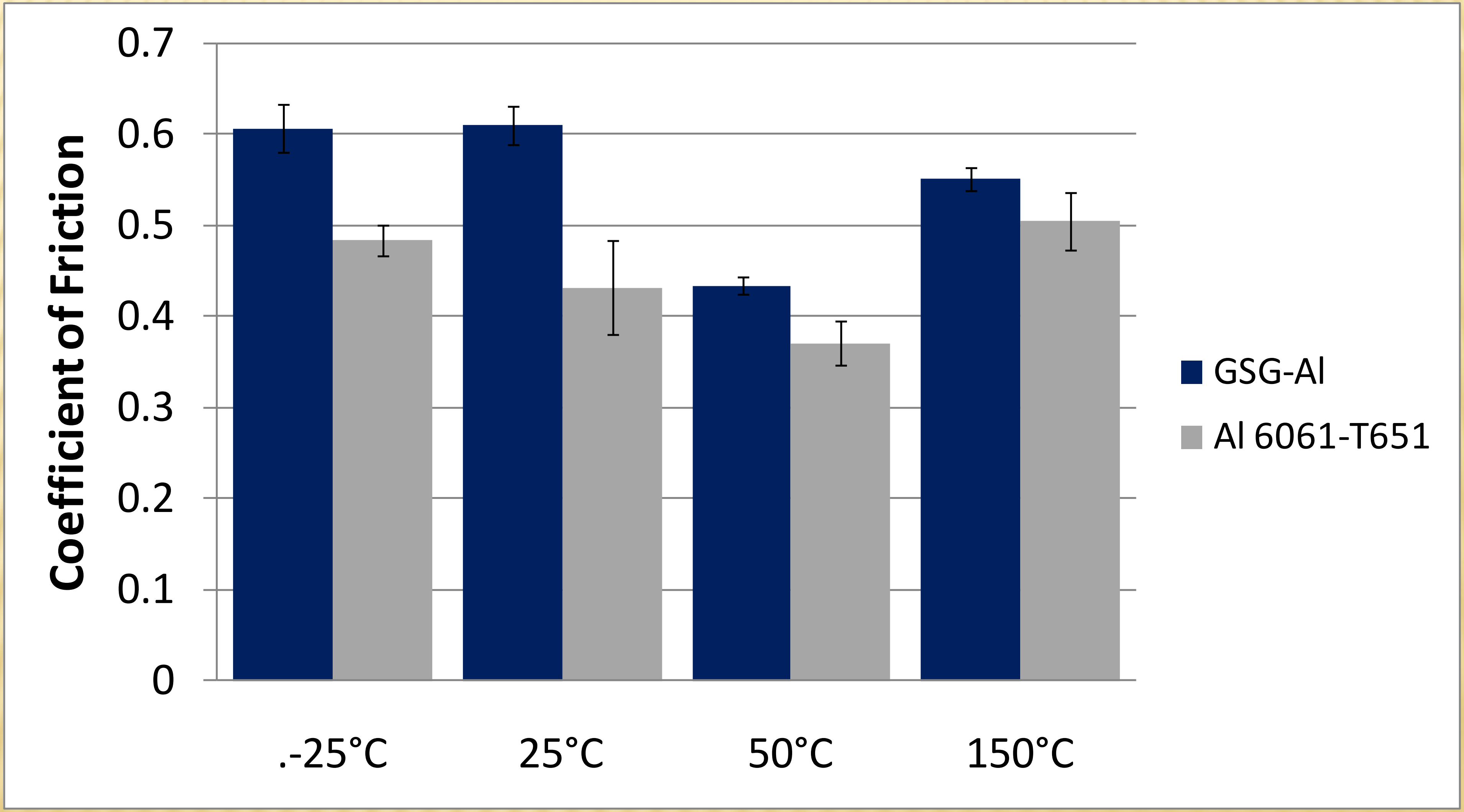


J. Trib., accepted.

TRIBOLOGICAL PROPERTIES

RELATIVELY STABLE COEFFICIENT WITHIN TEMPERATURE RANGE

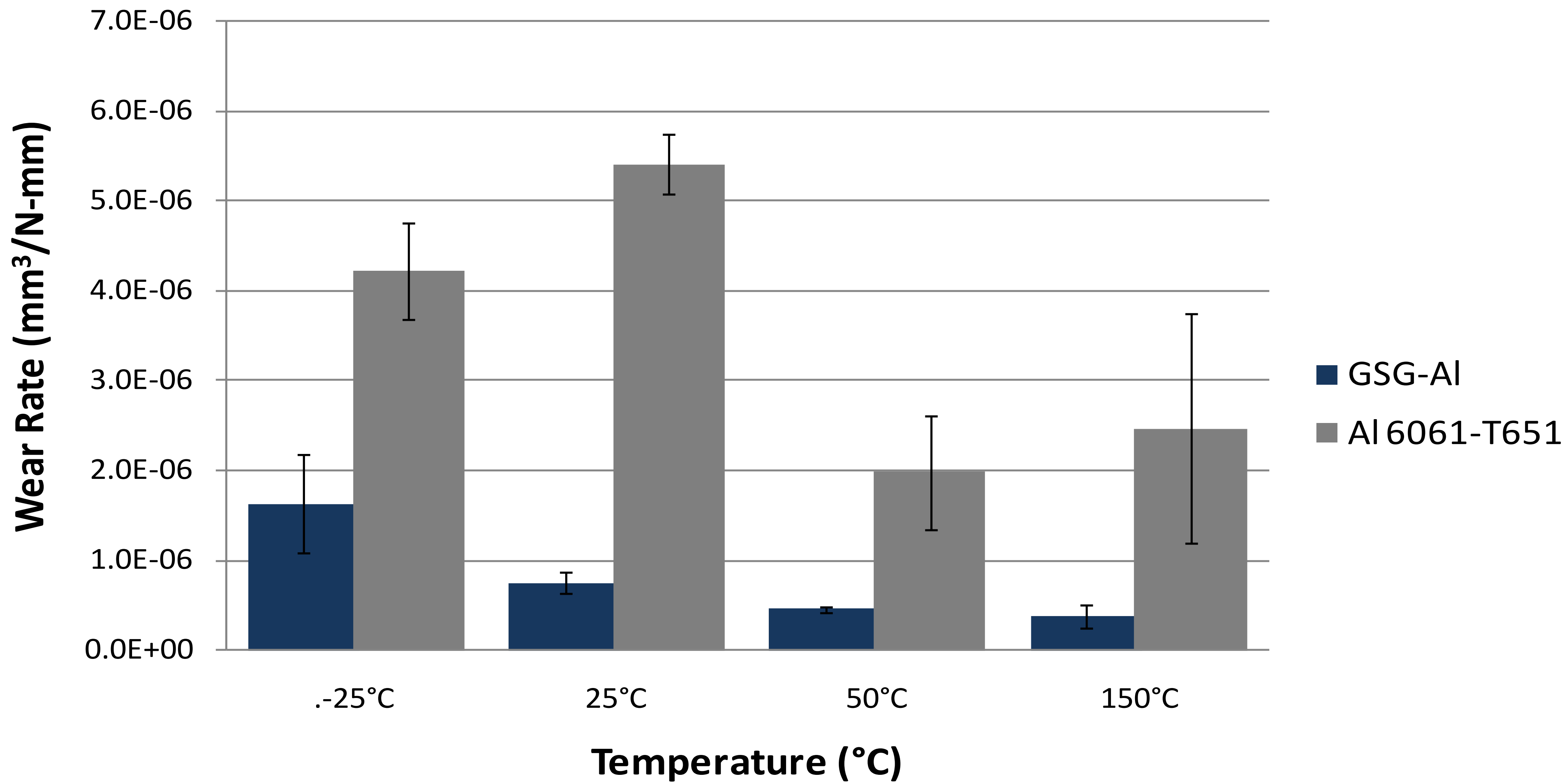
ALUMINUM ALLOY SHOWS LESS FRICTION THAN GSG-AL



Friction behavior is affected by temperature

TRIBOLOGICAL PROPERTIES

GSG-AL IS HIGHLY WEAR RESISTANT FROM -25 TO 150° C



CONCLUSIONS

- Developed a new composite that converts various types of energy
- The new composite is able to improve wear resistance & strength in situ
- The material has potential in waste heat recovery