Reliability of Transport Properties for Bulk Thermoelectrics

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Most Cited Thermoelectric Papers

1. Title: Thin-film thermoelectric devices with high room-temperature figures of merit Author(s): Venkatasubramanian, R; Siivola, E; Colpitts, T; et al. Source: NATURE Volume: 413 Issue: 6856 Pages: 597-602 Published: OCT 11 2001 Times Cited: 1,558

2. Title: Large thermoelectric power in NaCo2O4 single crystals Author(s): Terasaki, I; Sasago, Y; Uchinokura, K, Source: PHYSICAL REVIEW B Volume: 56 Issue: 20 Pages: 12685-12687 Published: NOV 15 1997 Times Cited: 1,217

3. EFFECT OF QUANTUM-WELL STRUCTURES ON THE THERMOELECTRIC FIGURE OF MERIT Author(s): HICKS, LD; DRESSELHAUS, MS Source: PHYSICAL REVIEW B Volume: 47 Issue: 19 Pages: 12727-12731 Published: MAY 15 1993 Times Cited: 1,017

4. Quantum dot superlattice thermoelectric materials and devices Author(s): Harman, TC; Taylor, PJ; Walsh, MP; et al. Source: SCIENCE Volume: 297 Issue: 5590 Pages: 2229-2232 Published: SEP 27 2002 Times Cited: 925

5. Title: Enhanced thermoelectric performance of rough silicon nanowires Author(s): Hochbaum, Allon I.; Chen, Renkun; Delgado, Raul Diaz; et al. Source: NATURE Volume: 451 Issue: 7175 Pages: 163-U5 Published: JAN 10 2008 Times Cited: 909

6. Title: Cubic AgPbmSbTe2+m: Bulk thermoelectric materials with high figure of merit Author(s): Hsu, KF; Loo, S; Guo, F; et al. Source: SCIENCE Volume: 303 Issue: 5659 Pages: 818-821 Published: FEB 6 2004Times Cited: 905

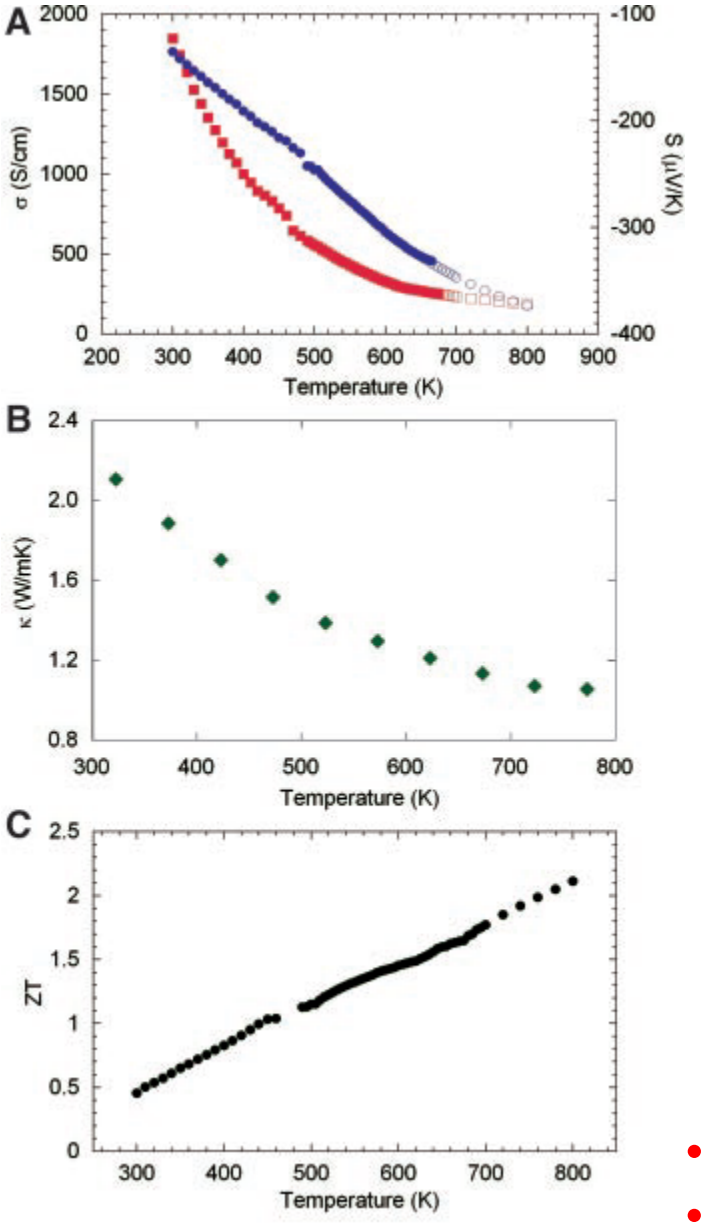
7. Title: Filled skutterudite antimonides: A new class of thermoelectric materials Author(s): Sales, BC; Mandrus, D; Williams, RK Source: SCIENCE Volume: 272 Issue: 5266 Pages: 1325-1328 Published: MAY 31 1996 Times Cited: 833

8. Title: High-thermoelectric performance of nanostructured bismuth antimony telluride bulk alloys Author(s): Poudel, Bed; Hao, Qing; Ma, Yi; et al. Source: SCIENCE Volume: 320 Issue: 5876 Pages: 634-638 Published: MAY 2 2008 Times Cited: 617

9. Title: Skutterudites: A phonon-glass-electron crystal approach to advanced thermoelectric energy conversion applications Author(s): Nolas, GS; Morelli, DT; Tritt, TM Source: ANNUAL REVIEW OF MATERIALS SCIENCE Volume: 29 Pages: 89-116 Published: 1999Times Cited: 287

10. Title: Properties of single crystalline semiconducting CoSb3 Author(s): Caillat, T; Borshchevsky, A; Fleurial, JP Source: JOURNAL OF APPLIED PHYSICS Volume: 80 Issue: 8 Pages: 4442-4449 Published: OCT 15 1996Times Cited: 271

Mystery in Reporting Thermal Conductivity

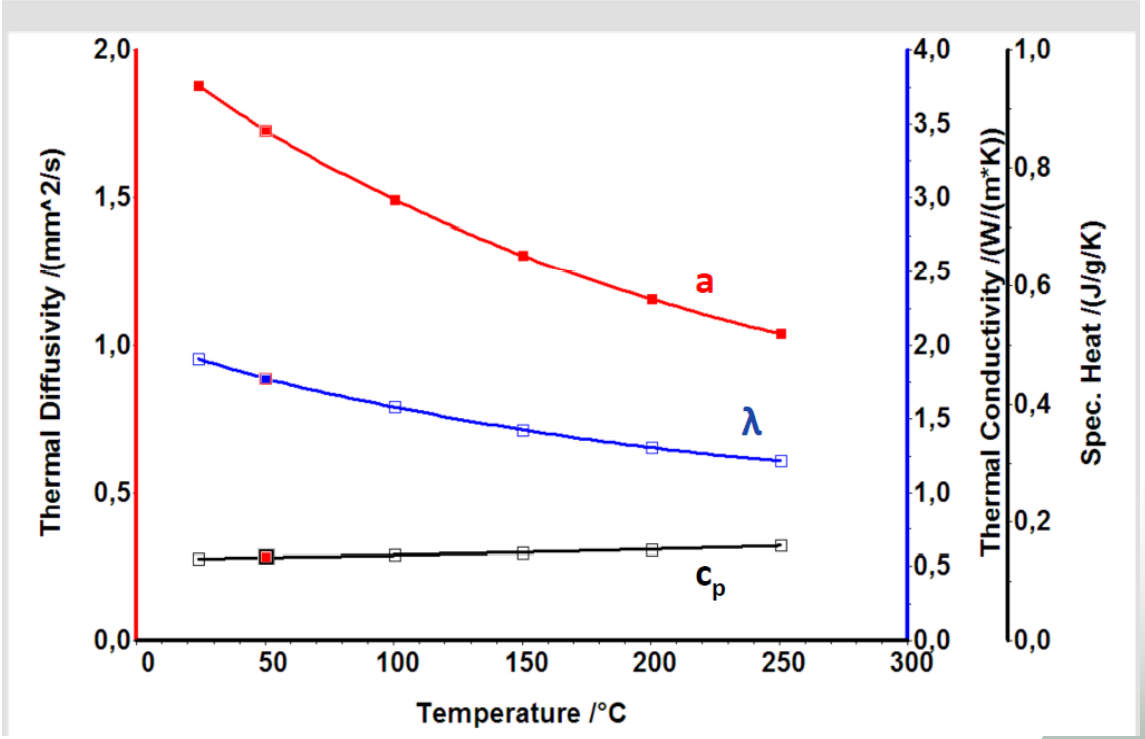


$$ZT = s^2\sigma T/k$$

$$k = \alpha C_p D$$

Thermal Conductivity of PbTe

NETZSCH



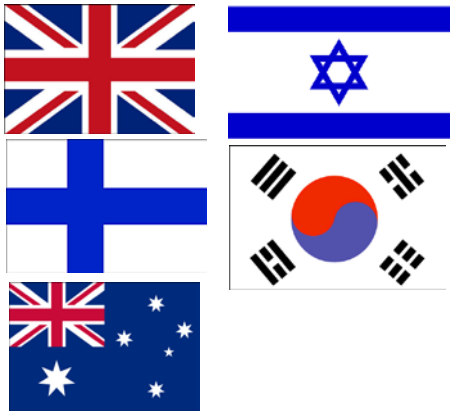
- **Thermal conductivity is not measured**
- **Thermal conductivity is calculated**

Ref. #6

Annex VIII Participants

- **IEA-AMT Thermoelectric Annex**
  - Annex lead: Oak Ridge National Laboratory (H. Wang)
  - USA: Clemson (T. Tritt, S. Zhu); Marlow (J. Sharp); Corning (A. Mayolet, J. Senawiratne) and ZT-Plus (F. Harris)
  - China: SICCAS (S.Q. Bai, L. Chen)
  - Canada: Natural Resource Canada (J. Lo); University of Waterloo (Holger Kleinke); University of Quebec at Chicoutimi (Laszlo Kiss)
  - Germany: Fraunhofer IPM (H. Böttner, J. König)

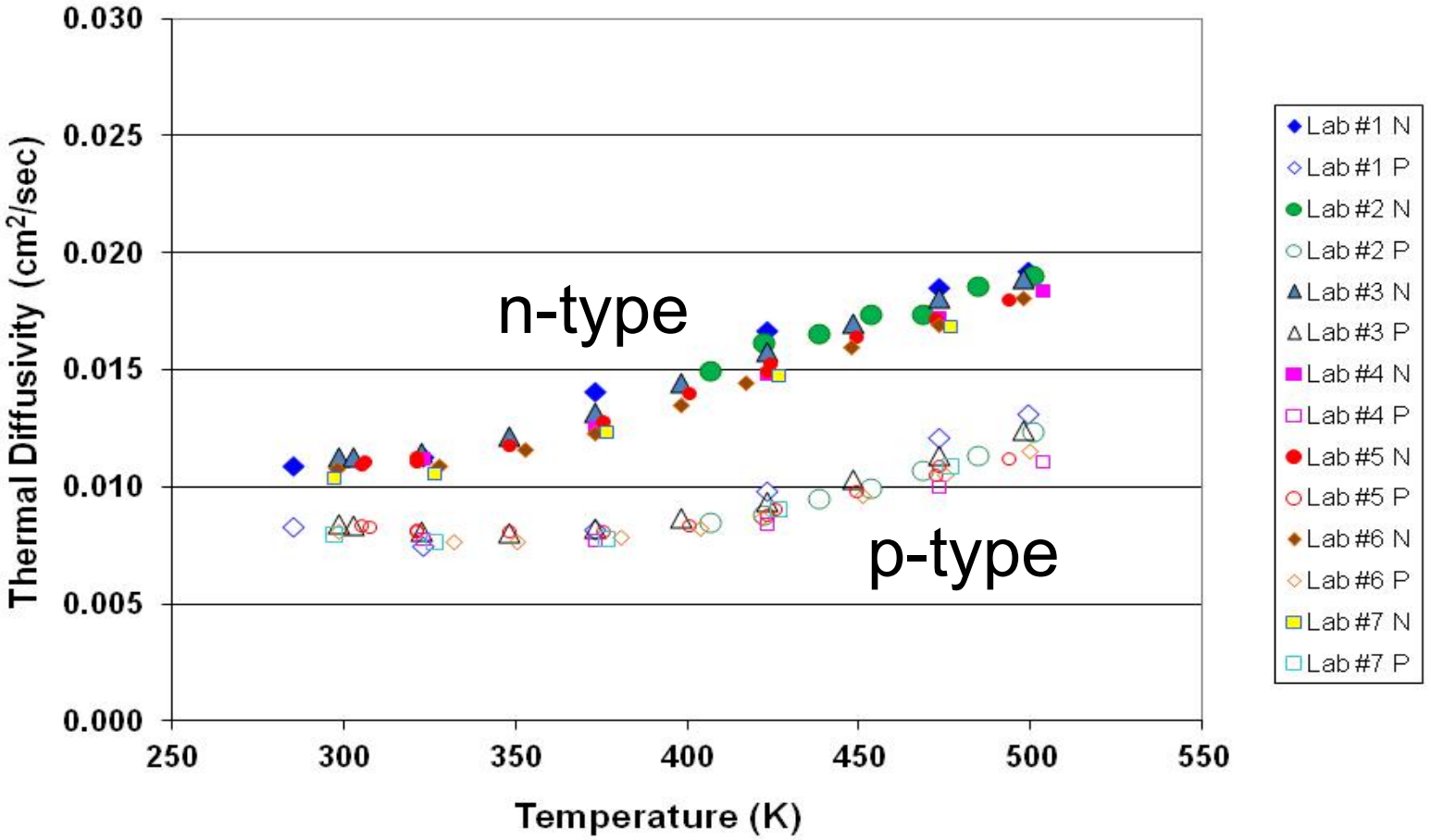
- **IEA-AMT members countries:**
  - UK: NPL
  - Finland: VTT
  - Israel:
  - Australia:
  - Republic of Korea: KERI (H. W. Lee)



Marlow Materials Selected for Transport Properties Round-Robin Tests

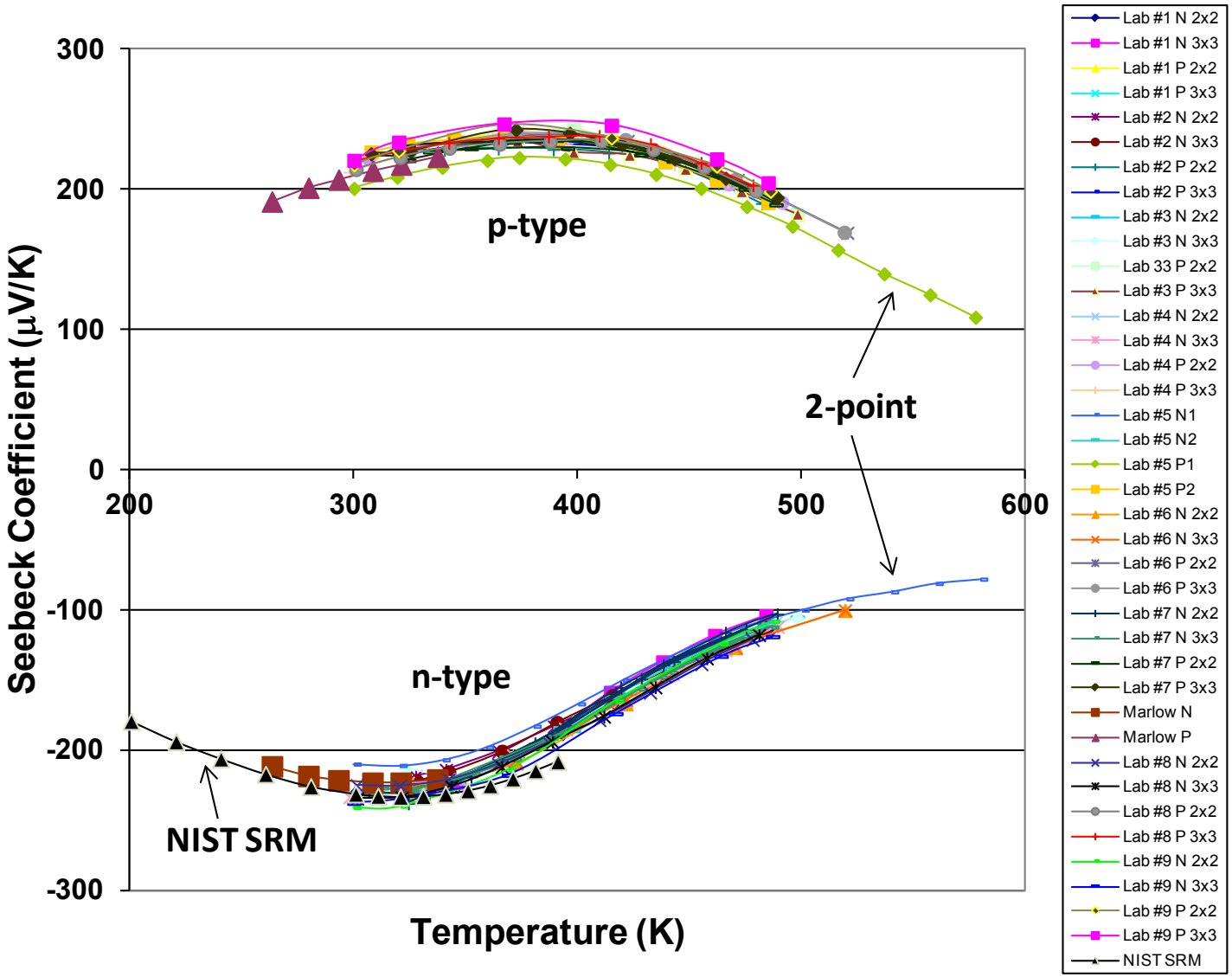
- Materials: $Bi_2Te_{3.005}$ (n-type) $Bi_{0.5}Sb_{1.5}Te_3$ (p-type)
- Four-sample Sets
  - Thermal diffusivity: 12.7 mm diameter disk
  - Specific heat: 4 mm diameter disk
  - Seebeck coefficient and electrical resistivity: 2 x 2 x 15 mm^3 bar, 3 x 3 x 12 m^3 bar
- Temperature range: 300-500K
- No ranking of the labs (lab numbers are assigned randomly in each plot)

Round-robin 1: Thermal Diffusivity

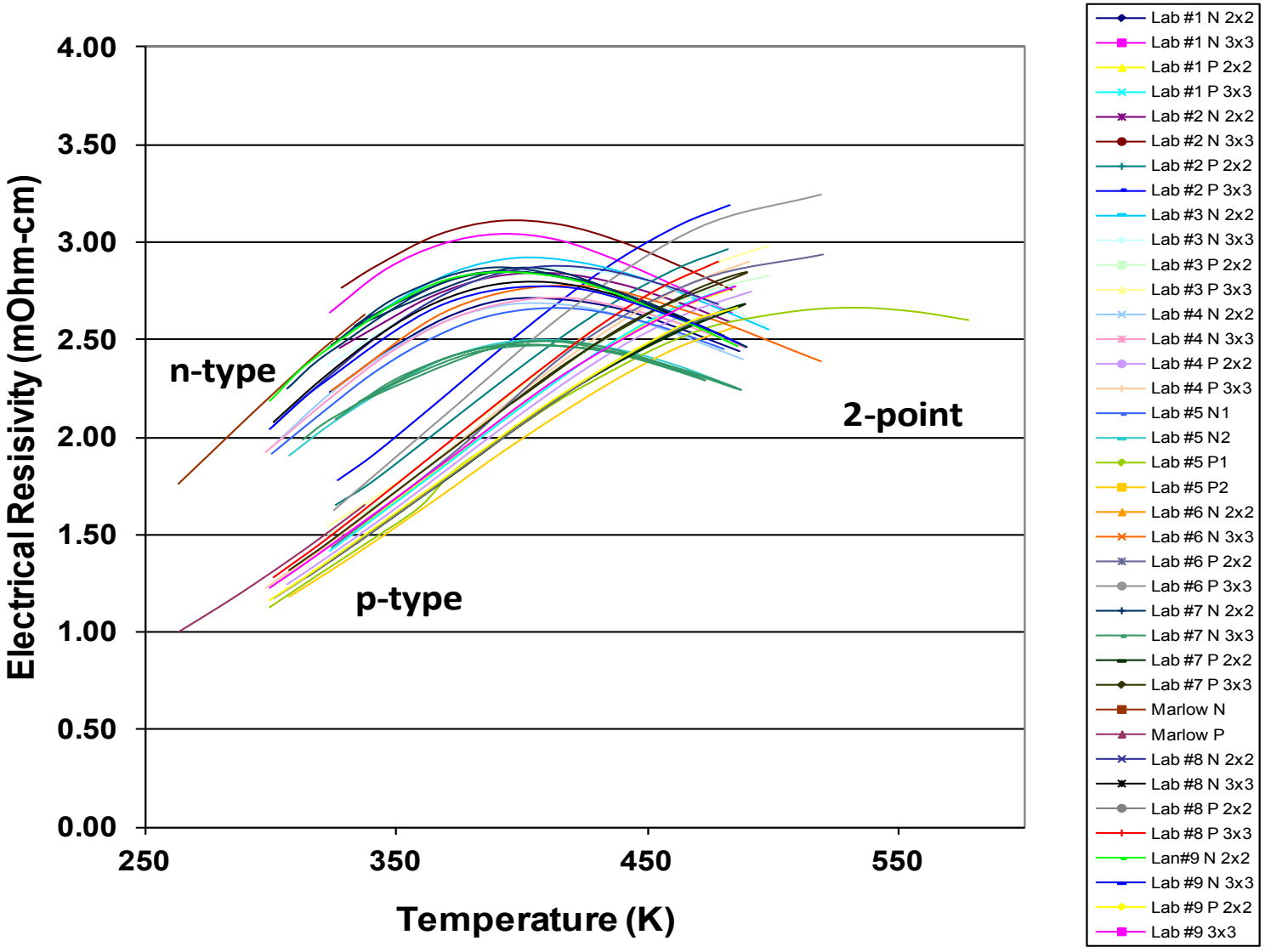


Results from 8 labs

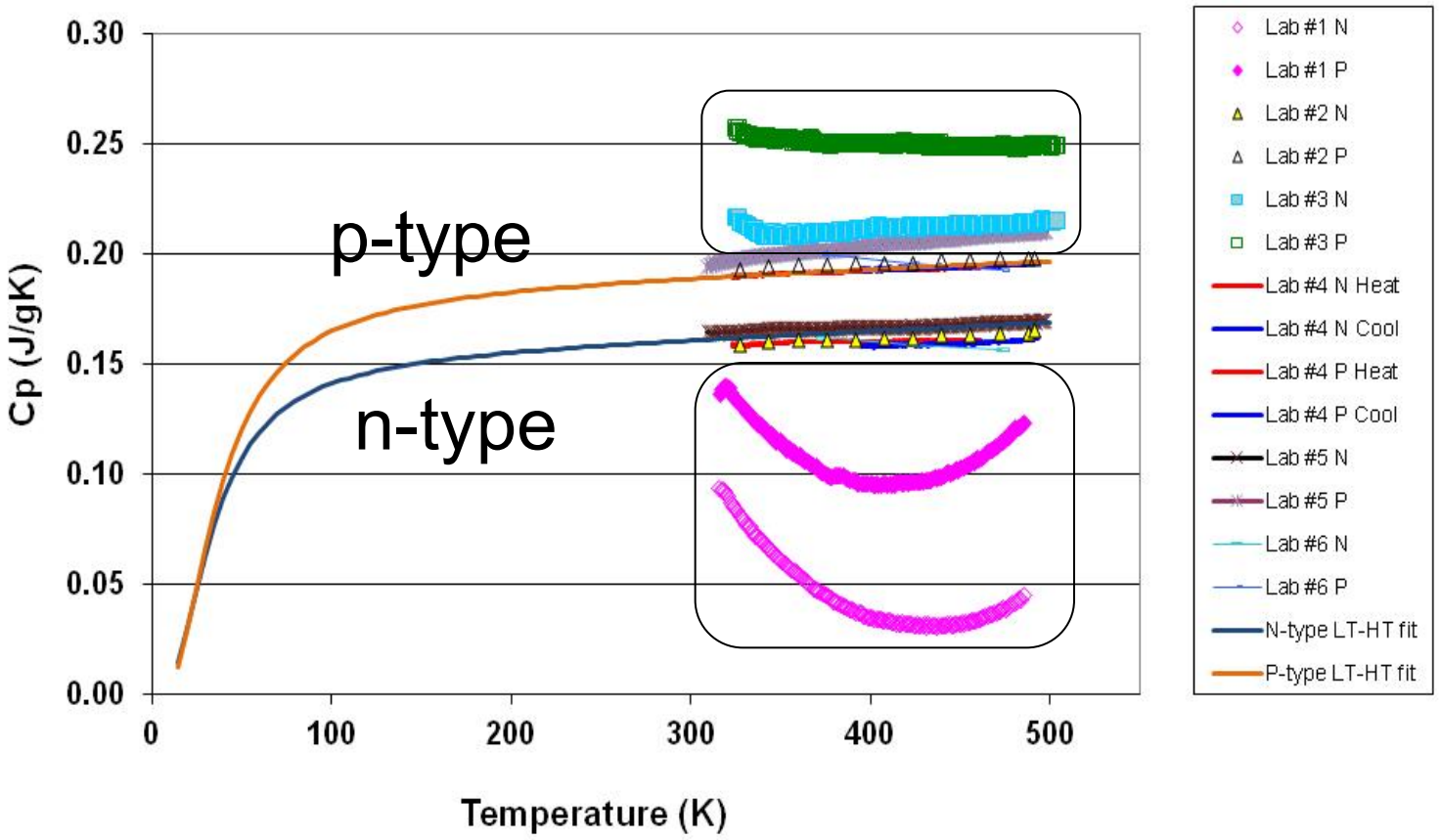
Round-robin 1: Seebeck Coefficient



Round-robin 1: Electrical Resistivity



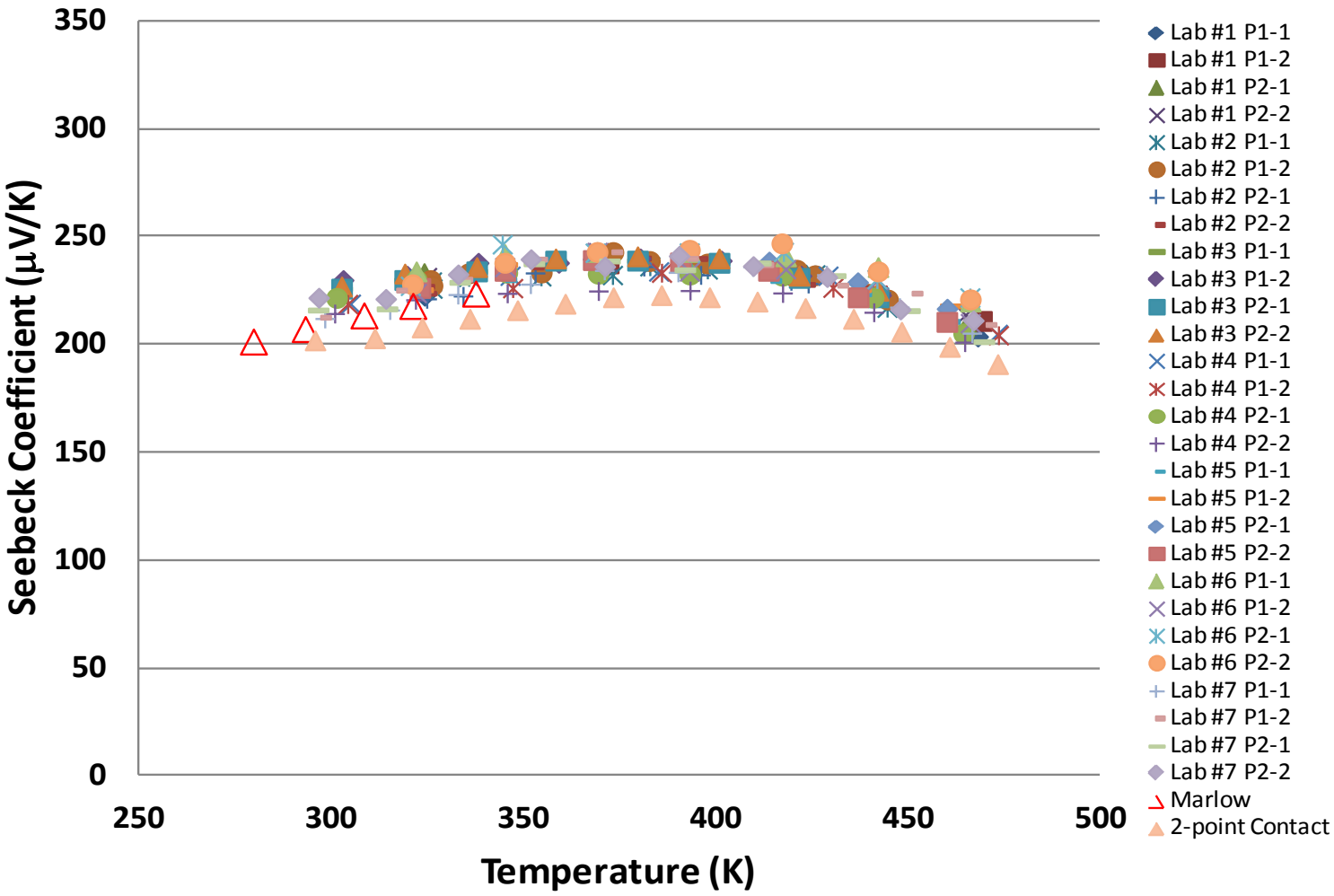
Cp of Round-robin 1 with Debye Fit



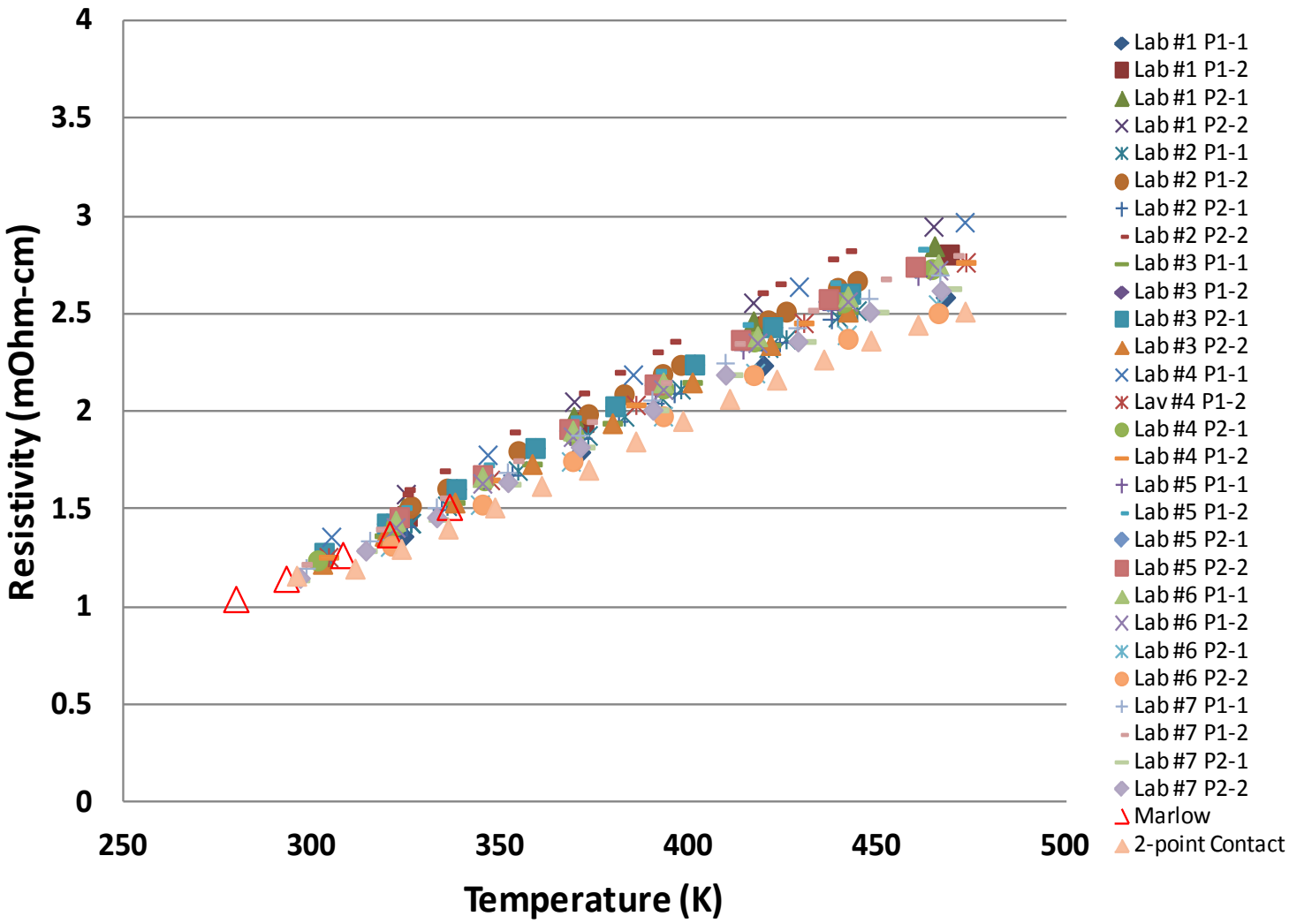
Round-robin #2 Started in October 2010

- Procedures for DSC prepared by ORNL
- Two sets of p-type samples
  - Set #1: ORNL -> Clemson-> Corning -> ZT-Plus -> Germany -> China -> Canada
  - Set #2: China -> (Japan) -> Germany -> ORNL -> Clemson-> Corning -> ZT-Plus -> Canada
- Completed in September 2011
- Report to IEA-AMT: October 2011
- IEA-AMT Topical report November 2011

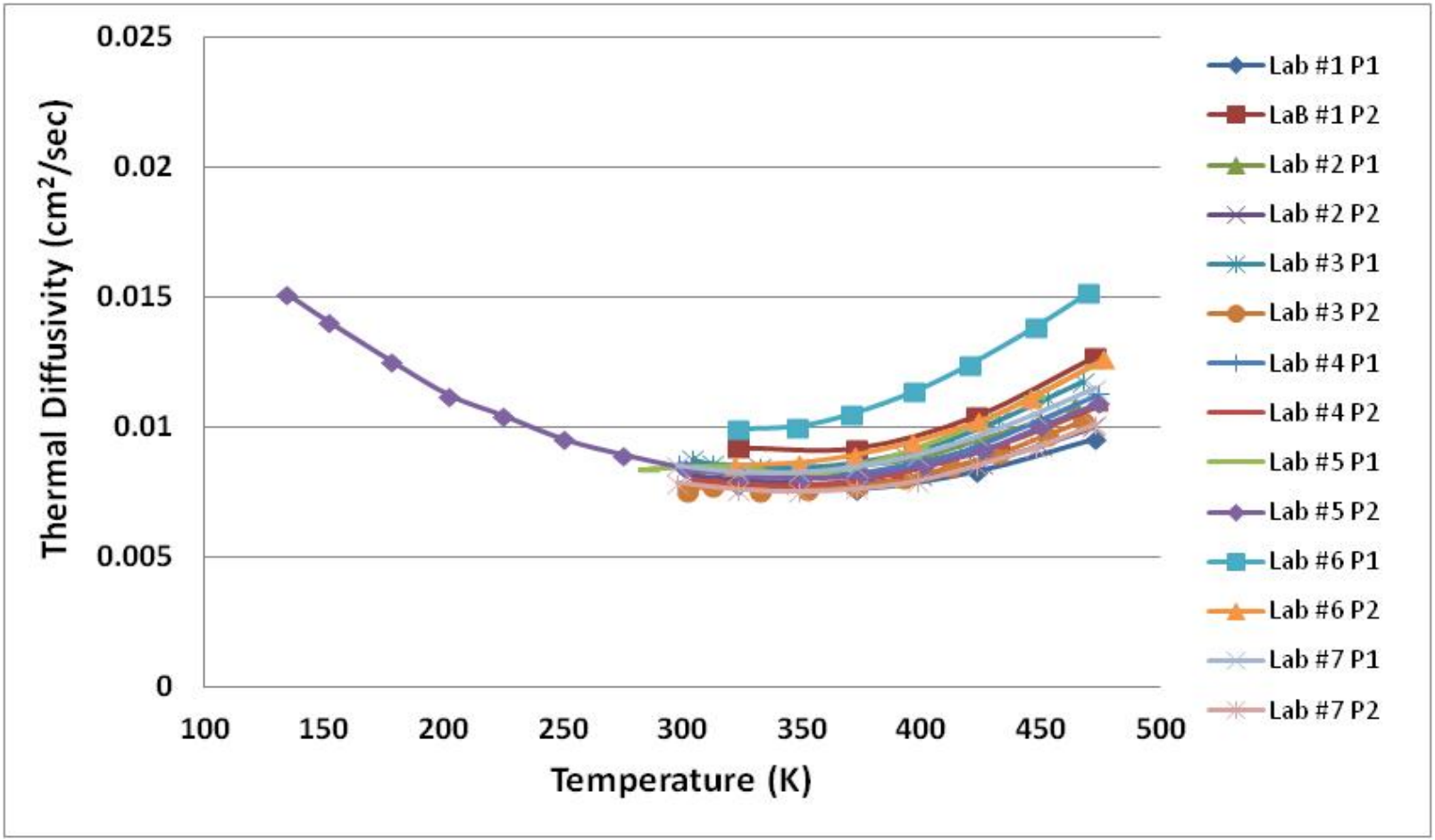
Round-robin 2: Seebeck Coefficient



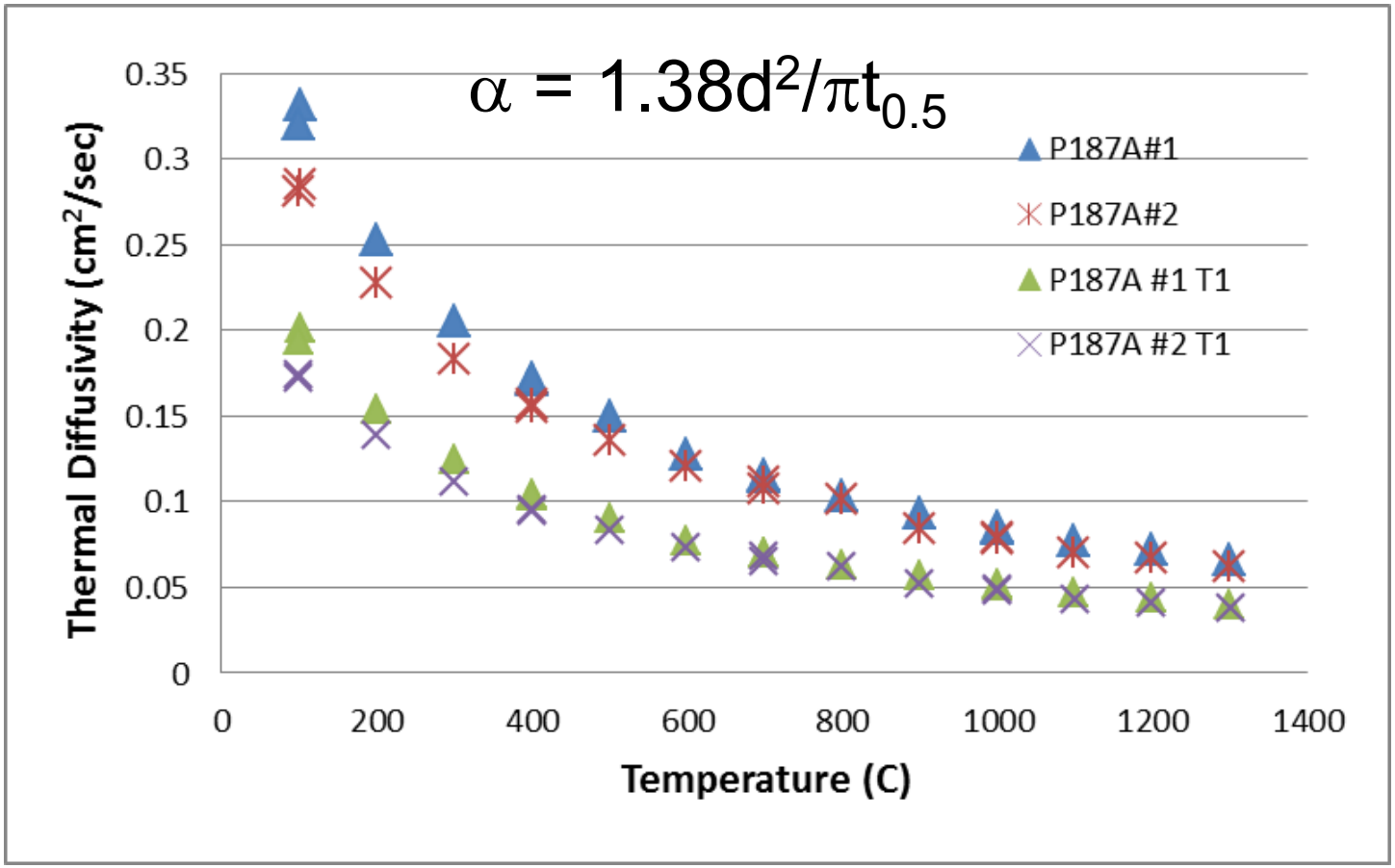
Round-robin 2: Electrical Resistivity



Round-robin 2: Thermal Diffusivity



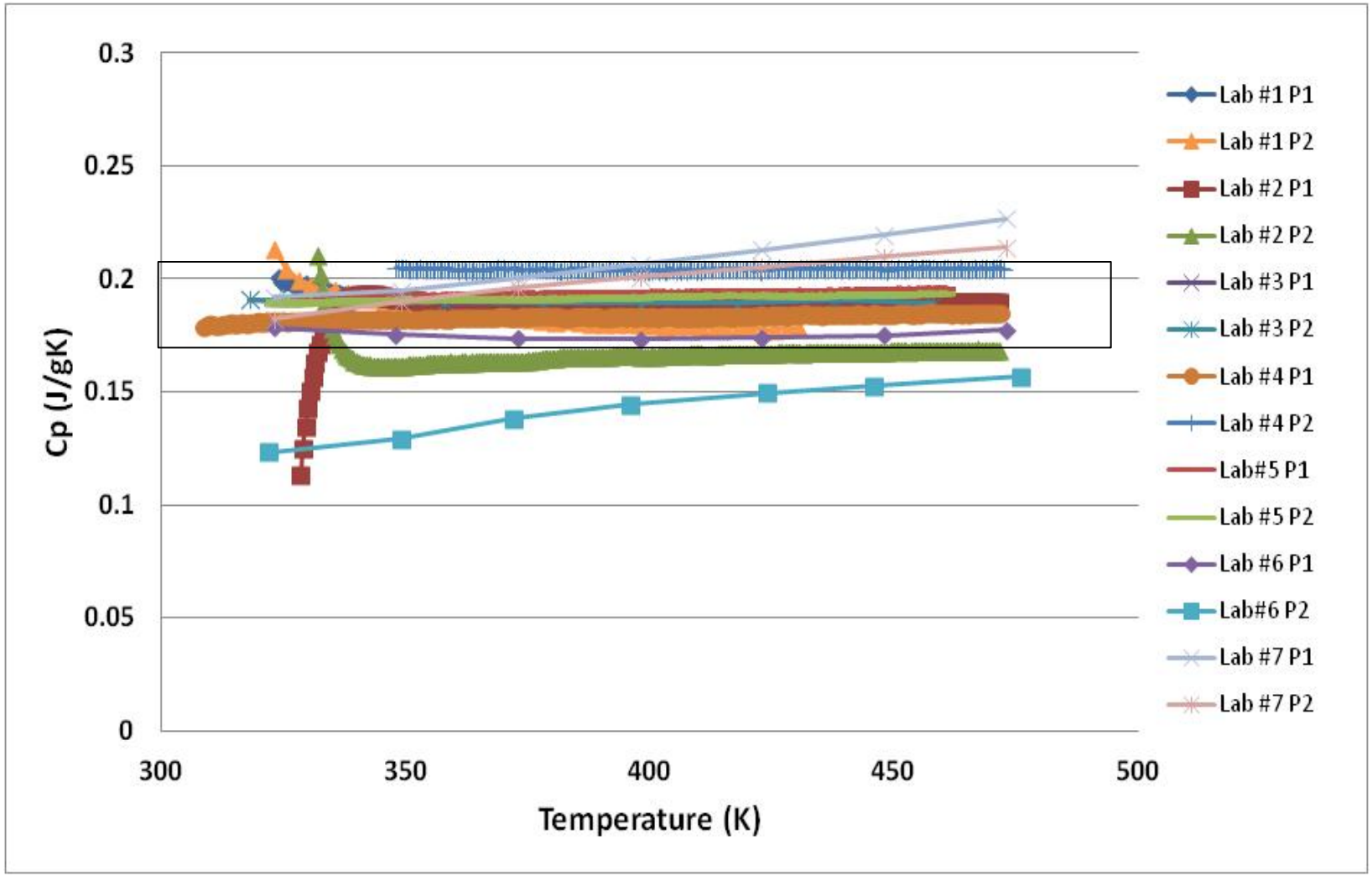
How Difficult is Thickness Measurement?



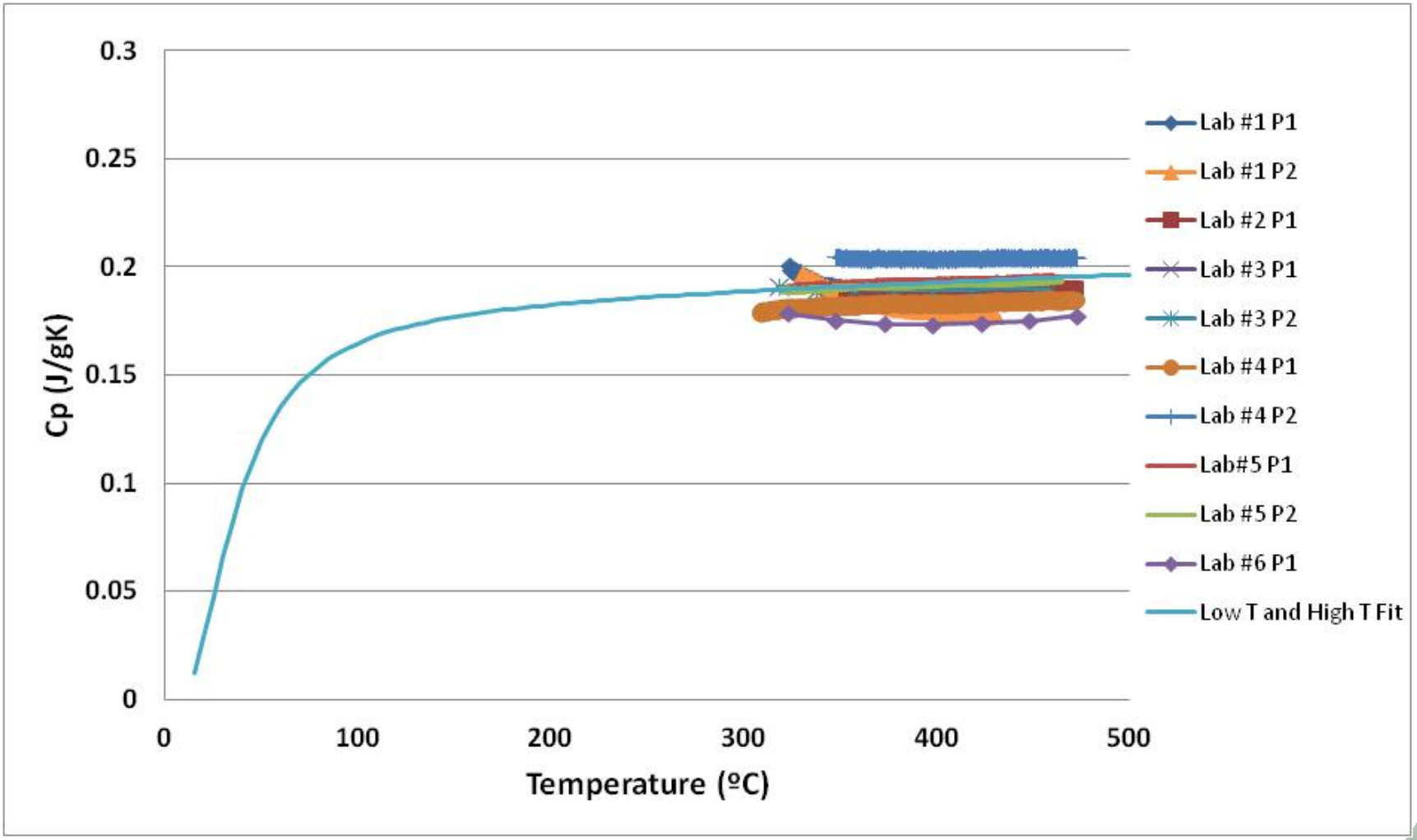
Thickness = 1.568 mm

Thickness = 2.011 mm

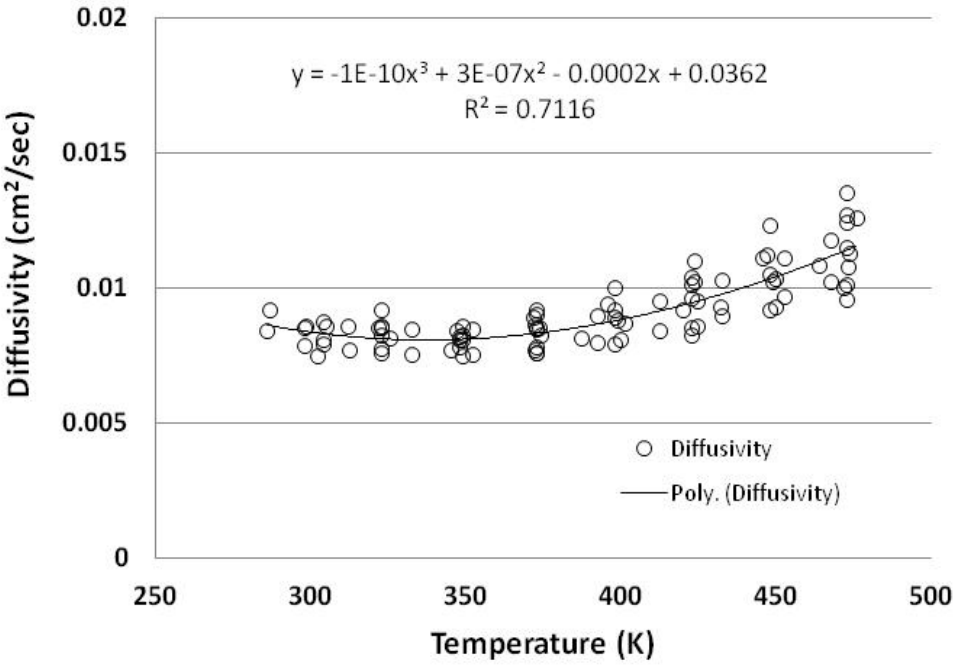
Round-robin 2: Specific Heat

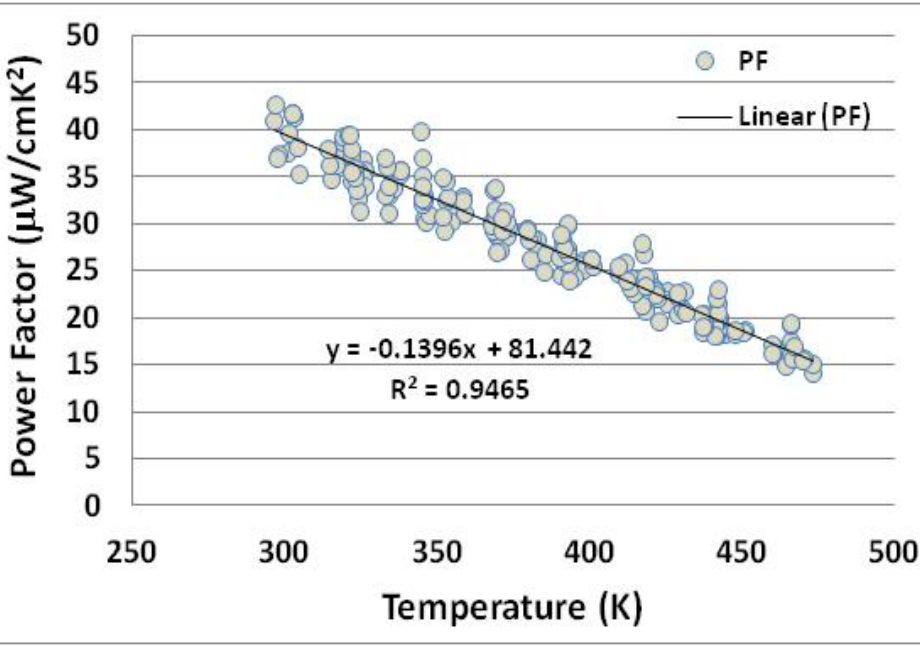


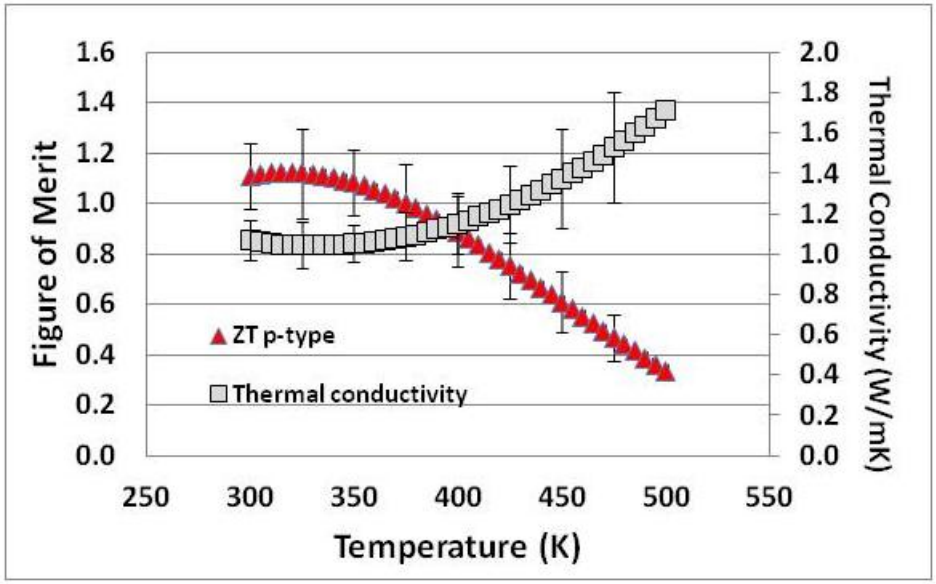
Cp of Round-robin 2 with Debye Fit



Calculation of ZT: P-type







Calculated from Full Scatter

- PF: ± 7.1 to 11.7%
- K: ±8.5 to 17.9%
- ZT: ± 11.7 to 20.9%

Summary

- Reliability of transport property is critical for vehicle applications
- IEA-AMT is addressing this issue timely
- Round-robin #3: 300K-800K
  - GMZ half-heusler materials for the round-robin effort (March 2012)
  - Materials processed and machined at GMZ Energy and first set measurements completed in May 2012