1/13, 2020

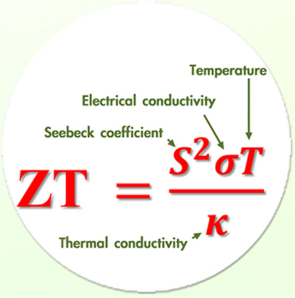
Auditorium (1F), Institute of Physics, Academia Sinica

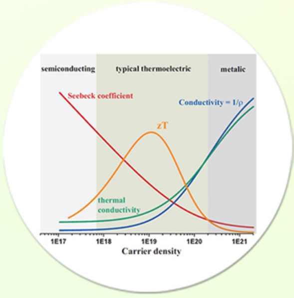
中央研究院物理研究所1F演講廳

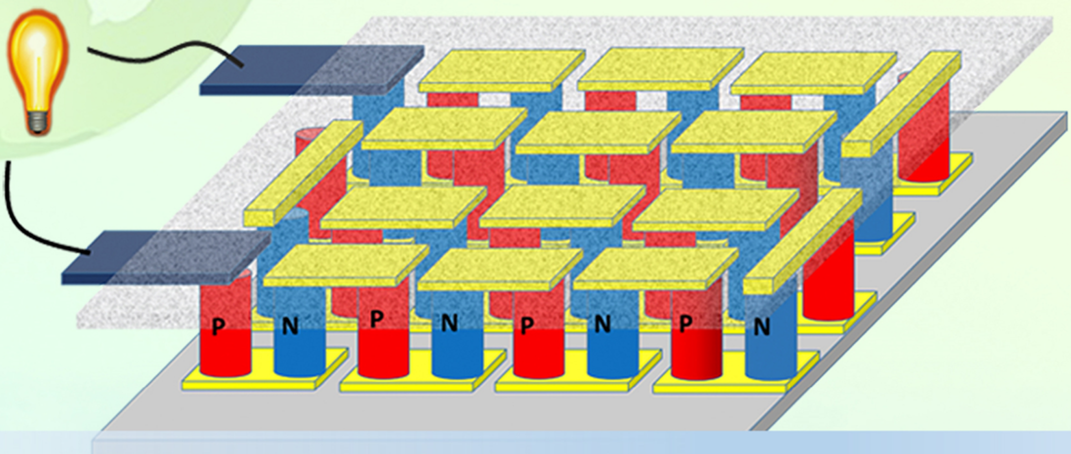
1st Annual Meeting of Taiwan Thermoelectric Society

第1屆台灣熱電學會年會暨第2次會員大會

TTES2020







主辦單位 Organizer

台灣熱電學會 Taiwan Thermoelectric Society

中央研究院物理研究所 Institute of Physics, Academia Sinica

台北市南港區研究院路二段 128 號, 128 Academia Road, Section 2, Nankang, Taipei, Taiwan

Transportation 交通方式

Getting to Academia Sinica from Taipei City:

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Bus route: 205, 212, 212-Straight Line, 270, 276, 306, 620, 645, BL25
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Getting to Banquet from Academia Sinica
By City Bus:
Take bus route 212-Straight Line, 270, BL25, get off at "MRT Nangang Station".

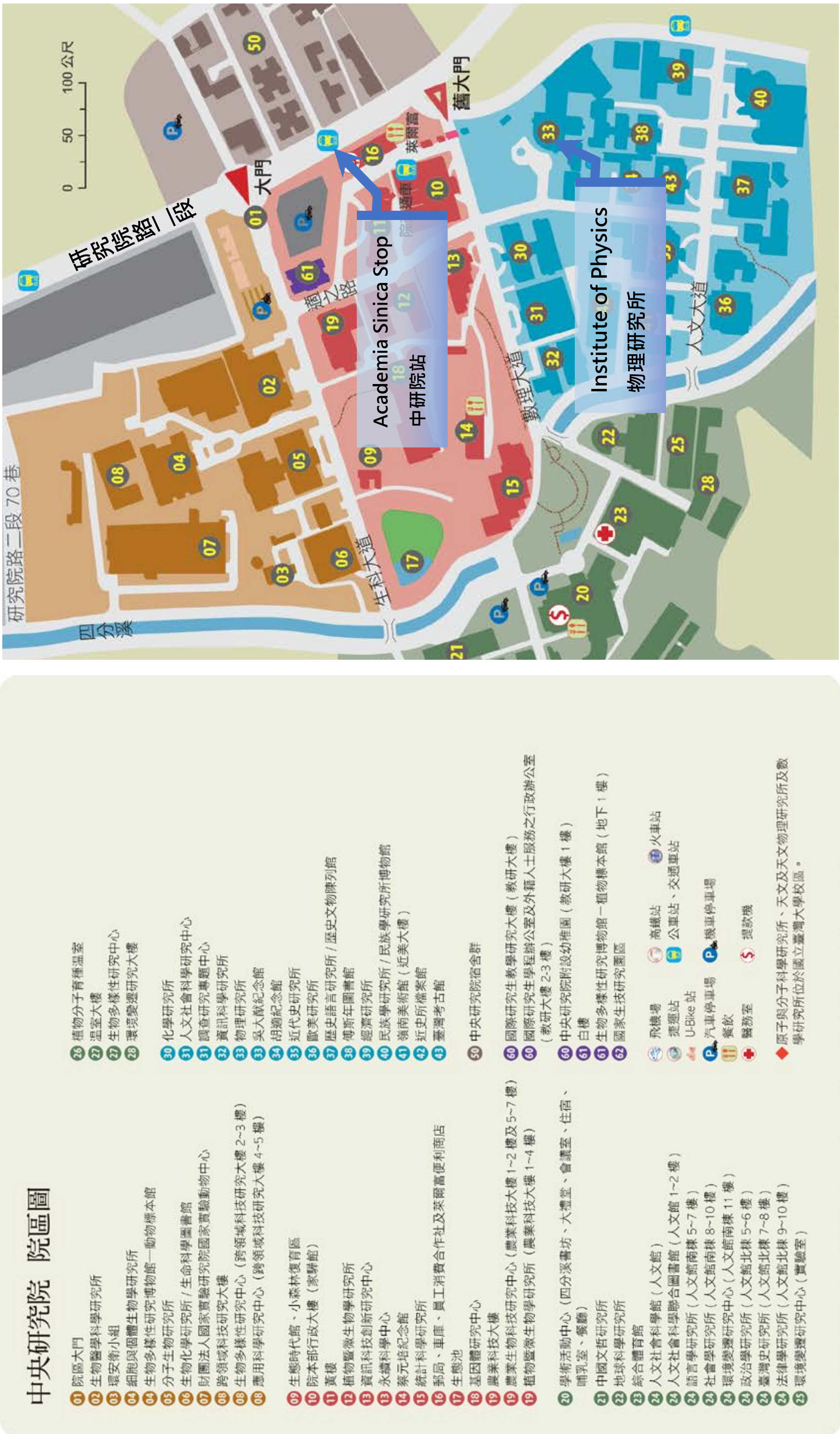
Banquet Place: (Nangang CITYLINK)
9F, Water Crystal (水晶廳)
Courtyard By Marriott Taipei（台北六福萬怡酒店）
No.359, Sec. 7, Zhongxiao E. Rd., Nangang Dist., Taipei, Taiwan
（台北市南港區忠孝東路七段 359 號）

Meeting and Lounge rooms

Meeting room: 1F Auditorium room（一樓演講廳）
Poster Presentation: 1F Hallway（一樓走廊）
Lounge: P101@1F（一樓 P101 室), Lounge Place@3F（三樓休息區）
Committee meeting（理監事會議): P4H @ 4F

- **Taipei-MRT Map**

- **Academia Sinica Campus Map**



TTES annual meeting, pre-school, Jan. 10, 2020,
Chairman: Yang- Yuan Chen

10:00-11:00	**Low Thermal Conductivity in Thermoelectric Materials and High Thermal Conductivity in Boron Arsenide** **Zhifeng Ren**, Director, Texas Center for Superconductivity, University of Houston
11:00-12:00	**Neutron scattering for thermoelectric materials** **Wen-Hsien Li**, Department of Physics, National Central University, Jhongli, Taiwan

TTES annual meeting, Jan. 13, 2020,
Chairman: Yang-Yuan Chen

09:20-09:30	**Opening/Welcome** Chia-Seng Chang, Director, Institute of Physics, Academia Sinica
09:30-10:20	**Plenary: Challenges Facing the Thermoelectrics Community** Zhifeng Ren, Director, Texas Center for Superconductivity, University of Houston
10:20-10:40	**Coffee break**

Oral Section I: Thermoelectrics, Jan. 13, 2020,
Chairman: Kuei-Hsien Chen

10:40-11:10	**OSI 1, Invited: Forging the impossible: the route to efficiency in thermoelectricity** Dario Narducci, Department of Materials Science, University of Milano Bicocca	
11:10-11:30	**OSI 2, Oral: Heat diodes made of quantum-dot superlattice nanowires** Ming Ting Kuo, Electrical engineering, National Central University	
11:30-11:50	**OSI 3, Oral: Boosting thermoelectric performance of ($Ge_{1-x}Bi_x$) Te crystals through Fermi level tuning and thermal conductivity degradation** Cheng-Lung Chen, Institute of Physics, Academia Sinica	
11:50-12:00	**Photo** 全體會員合照	
12:00-13:30	**Lunch, and Poster**	
12:30-13:00	**Lunch, and Poster**	理監事會議**(P4H)**
13:00-13:30	**Lunch, and Poster**	**Membership meeting (1F Auditorium room)**

Oral Section II: GeTe related compounds, Jan. 13, 2020,
Chairman: Chien-Neng Liao

13:30-13:50	**OSII 1, Oral: Enhancing thermoelectric performance in n-type Ga-doped PbTe via phase diagram engineering** Ping Yuan Deng, Department of Materials Science and Engineering, National Chiao Tung University

13:50-14:10	**OSII 2, Oral: Realizing the compositional homogeneity in Cu-GeTe thermoelectric materials and phase transition behavior** Yi Fen Tsai, Department of Materials Science and Engineering, National Chiao Tung University
14:10-14:30	**OSII 3, Oral: Realizing High Thermoelectric efficiency achieved in Sb doped GeTe crystal through minimized thermal conductivity and carrier density control** **V. K. Ranganayakulu**, Institute of Physics, Academia Sinica
14:30-14:50	**OSII 4, Oral: Synergistic optimization of thermoelectric performance of Sb doped GeTe with strained domain and domain boundaries** **Khasim Saheb Bayikadi**, Institute of Physics, Academia Sinica
14:50-15:10	**OSII 5, Invited: Phase diagrams of thermoelectric Ag-Pb-Sn-Te quaternary system** **Sinn-Wen Chen**, Department of Chemical Engineering, National Tsing Hua University
15:10-15:50	**Poster; Coffee break**

Oral Section III: Bi-Te and Zn-Sb related compounds, Jan. 13, 2020, Chairman: Hsin-Jay Wu

15:50-16:10	**OSIII 1, Oral: Phase diagram of Bi-Cu-Te and Thermoelectric Properties of Cu doped Bi_2Te_3** **Wan-Ting Yen**, Department Of Materials Science And Engineering, National Chiao Tung University
16:10-16:30	**OSIII 2, Oral: In-Plane Thermal Conductivity Measurements of a Single-Crystalline Thin-Film by the 3ω Method** **Wei-Han Tsai**, Institute of Physics, Academia Sinica
16:30-16:50	**OSIII 3, Oral: Influence of Co-P Diffusion Barrier on the Reliability of Bi_2Te_3-based Thermoelectric Module** **Chun-Hsien Wang**, Department of Chemical and Materials Engineering, National Central University
16:50-17:10	**OSIII 4, Oral: Phase diagram of ternary Zn-Sb-Ga system and Thermoelectric properties of Ga doped Zn_4Sb_3 alloys** **I-Lun Jen**, Department of Materials Science and Engineering, National Chiao Tung University
17:10	**Close**
17:10-18:00	**To Banquet**
18:00-	**Banquet 萬怡酒店 (Nangang CITYLINK)**

Plenary, 9:30-10:20

Challenges Facing the Thermoelectrics Community

Zhifeng Ren, University of Houston, Texas, USA
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Abstract: Thermoelectric materials can be used for both cooling and power generation that require high figure-of-merit (ZT) for high heat to electricity conversion efficiency. However just high ZT is not good enough, high power factor is also needed for high output power density. Except the challenges on enhancing ZT and power factor, there are many other challenges such as excellent contact layers without electrical nor thermal resistance. For a complete device, we also need both n- and p-type legs that should have the same base composition so that they can have similar coefficient of thermal expansion (CTE). In fact, just high enough peak ZT and power factor are not good enough, we also need very high average ZT and power factor. We also found that average ZT and power factor by traditional method cannot reliably predict the efficiency and power output, respectively, so we developed engineering ZT and power factor to accurately gauge the efficiency and output power density respectively without the need to actually measuring them. In this talk I will discuss all these and other challenges, and show some solutions to some of them.

Oral Section I:1, Invited, 10:40-11:10

Forging the impossible: the route to efficiency in thermoelectricity

Dario Narducci, University of Milano Bicocca, Department of Materials Science, via R. Cozzi 55, 20125 Milano
dario.narducci@unimib.it

Abstract: In principle, thermoelectricity provides a very convenient way to convert heat into electricity with no needs for moving parts. However, its use for electric generation has just begun, and still has a minor visibility among renewable power resources due to its low conversion efficiency, which may be hardly increased as it is ruled by an awkward, inconvenient combination of transport coefficients. As a matter of fact, the perfect thermoelectric material should have the thermal conductivity of a glass, the electrical conductivity of a metal, and the Seebeck coefficient of a dielectric. Search for such an 'impossible material' has not discouraged scientists, however. Quite the opposite, it has motivated a wealth of research, not only impacting thermoelectricity but also leading to major progress in the understanding of the interplay between transport processes and the structural characteristics of materials. The history of this outstanding chapter of materials science will be reviewed, and the role recently played by nanotechnology will be stressed and discussed, especially in view of its complex relationship with applications. Targets and promising lines of research for the next years will be outlined.

The achievements in increasing thermoelectric efficiency are setting additional chemical and mechanical constraints to material scientists and technologists. Thus, research on thermoelectrics should address not only efficient but also geo-abundant, flexible, and ecofriendly materials that may fit the requirements of near-future macro and microharvesting. Implications in modern thermoelectric research will be examined, and contexts of application will be reviewed.

Oral Section I:2, 11:10-11:30

Heat diodes made of quantum-dot superlattice nanowires

David Ming-Ting Kuo[1] and Yia-Chung Chang[2]

[1]Department of Electrical Engineering, National Central University, Chungli, 320 Taiwan

[2]Research Center for Applied Sciences, Academia Sinica, Taipei, Taiwan 11529

Abstract: Solid state heat diodes (HDs) play an important role in the applications of thermoelectric devices in the nonlinear transport regime[1]. The rectification efficiency of HDs is defined as $R=Q_F/|Q_B|$, where Q_F and Q_B are the heat currents under forward and backward temperature bias, respectively. Although high-efficiency HDs have been reported in superconductor junction systems, they must be operated at extremely low temperatures. Here, we report theoretical studies of nonlinear electron heat transport in quantum dot superlattice (QDSL) nanowires connected to metallic electrodes. It is demonstrated that the nonlinear Seebeck effect can lead to significant electron heat rectification for QDSL nanowires with staircase-like energy levels. The asymmetrical alignment of energy levels of QDSL nanowires can be controlled to allow resonant electron transport under forward temperature bias, while in off-resonant regime under reverse bias. The efficiency of electron heat rectification is suppressed in the presence of phonon heat flows. However, the heat rectification efficiency, *R* of QDSL nanowire can still reach around 10 at temperature as high as 30K for Si/Ge QDSL nanowire with width around 3 nm, when the multi-valley degeneracy of Si QDs is taken into account.

Oral Section I:3, 11:30-11:50

Boosting thermoelectric performance of ($Ge_{1-x}Bi_x$)Te crystals through Fermi level tuning and thermal conductivity degradation

Cheng-Lung Chen[1], Pai-Chun Wei[1], Cheng-Xun Cai[2], Cheng-Rong Hsing[3], Ching-Ming Wei[3], Duc-Long Nguyen[3], Hsin-Jay Wu[4], Da-Hua Wei[2], & Yang-Yuan Chen[1]

[1]Institute of Physics, Academia Sinica, Taipei, Taiwan

[2]Graduate Institute of Manufacturing Technology, National Taipei University of Technology, Taipei, Taiwan

[3]Institute of Atomic and Molecular Science, Academia Sinica, Taipei, Taiwan [4]Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu, Taiwan

Abstract: In this work, a high thermoelectric figure of merit, *zT* of 1.9 at 740 K is achieved in $Ge_{1-x}Bi_xTe$ crystals through the concurrent of Seebeck coefficient enhancement and thermal conductivity reduction with Bi dopants. The substitution of Bi for Ge not only compensates the superfluous hole carriers in pristine GeTe but also shifts the Fermi level (E_F) to an eligible region. Experimentally, with moderate 6-10 % Bi dopants, the carrier concentration is drastically decreased from 8.7×10^{20} cm^{-3} to $3\text{-}5 \times 10^{20}$ cm^{-3} and the Seebeck coefficient is boosted three times to 75 μVK^{-1}. In the meantime, based on the density functional theory (DFT) calculation, the Fermi level E_F starts to intersect with the pudding mold band at *L* point, where the band effective mass is enhanced. The enhanced Seebeck coefficient effectively compensates the decrease of electrical conductivity and thus successfully maintain the power factor as large as or even superior than that of the pristine GeTe. In addition, the Bi doping significantly reduces both thermal conductivities of carriers and lattices to an extremely low limit of

1.57 W $m^{-1}K^{-1}$ at 740 K with 10 % Bi dopants, which is an about 63 % reduction as compared with that of pristine GeTe. The elevated figure of merit observed in $Ge_{1-x}Bi_xTe$ specimens is therefore realized by synergistically optimizing the power factor and downgrading the thermal conductivity of alloying effect and lattice anharmonicity caused by Bi doping.

Oral Section II:1, 13:30-13:50

Enhancing thermoelectric performance in n-type Ga-doped PbTe via phase diagram engineering

Ping-Yuan Deng[1], Yi-hui Du[2], Kuang-kuo Wang[3] and Hsin-jay Wu[1*]

[1]Department of Materials Science and Engineering, National Chiao Tung University.

[2]Department of Chemical Engineering, National Tsing Hua University.

[3]Department of Materials and Optoelectronic Science, Nation Sun Yat-Sen University.

Abstract: The moderate zT of n-type PbTe limits the development of mid-temperature TE generator. Gallium (Ga) has been a successful n-type dopant for PbTe through contributing extrinsic carriers and optimizing the carrier concentration. The isothermal section of ternary Ga-Pb-Te is determined by various post-annealed alloys. In particular, the single-phase PbTe could only tolerate a very small amount of Ga solubility, and that single-phase region shows an asymmetrical homogeneity in the ternary Ga-Pb-Te Gibbs triangle. The combination between TE properties and phase diagram provided a better understanding in the dopant capability, which makes it serves as a crucial guideline for searching the high-efficient alloys where the compositional regions are seldom being explored before. Isothermal section as a compositional guideline, selective Gallium intercalated PbTe alloys are grown through the Bridgman method. High zT of 1.34 at 766 K and a record high average zT above 1 in the temperature range of 373-673 K are attained in n-type PbTe by phase-diagram engineering, which is attributed to the Gallium intercalated filtering effect and nano-scale secondary phase inclusion.

Keywords: Thermoelectric (TE) materials; Ga-doped PbTe; Phase diagram; Bridgman method

Oral Section II:2, 13:50-14:10

Realizing the compositional homogeneity in Cu-GeTe thermoelectric materials and phase transition behavior

Yi-Fen Tsai[1], Meng-yuan Ho[1] and Hsin-jay Wu[1]*

[1]Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan

Abstract: Lately, the thermoelectric (TE) community has been fascinated by the Germanium-tellurides (GeTe-based alloys) which feature high electrical conductivity and high thermal conductivity. Additionally, the GeTe undergoes a phase transition from the low-temperature rhombohedral α-GeTe to high-temperature cubic β-GeTe at 673 K, which induces the discontinuities in temperature-dependent TE property curves. In this work, the GeTe is doped with Cu via long-term heat treatment. According to the information from thermal analysis, we further realized that the α-to-β phase transition could be greatly affected by the dopants. The compositional homogeneity and microstructural texture vary dramatically in Cu-doped GeTe as well, which eventually leading to a wide distribution in their zT peak values, ranging from 0.8 to above 2.1 (723 K).

Keywords: GeTe; phase transition; thermoelectric material; Cu dopant

Oral Section II:3, 14:10-14:30

Realizing High Thermoelectric efficiency achieved in Sb doped GeTe crystal through minimized thermal conductivity and carrier density control

V.K.Ranganayakulu[1, 2, 3], Tian Wey Lan[1], Shih Hsun Yu[1], Min Nan Ou[1], Chen-Lung Chen[1], Chih-Hao Lee, Yang -Yuan Chen[1]

[1]Institute of Physics, Academia Sinica, Taipei 115, Taiwan.

[2]Department of Engineering and System Science, National Tsing Hua University, Taiwan.

[3]Taiwan international Graduate Program, Taipei 115, Taiwan.

Abstract: Over the past decades, global warming and energy crisis are increasing due to burning the combustion of fuels. In the searching of alternative renewable energy sources such as solar cells, wind power energy, thermoelectric materials have a great ability to convert the industrial waste heat into consumable energy or vice versa, which is cost-effective as well as very friendly environmental devices without moving parts, and longtime durability has a wide range of applications in thermoelectric fields. Pristine GeTe is a p-type degenerate semiconductor that shows very low thermoelectric performance compared to doped GeTe due to its large carrier concentration induced by the presence of high Ge Vacancy. In this work, we report a promising enhanced thermoelectric figure of merit (zT) of ~2.1 at 700~740 K was obtained for 0.08 % of Sb-doped GeTe high-quality crystalline material grown by the Bridgman method which is higher efficiency value in this doping reported till now. This *ZT* enhancement can be attributed to the reduction of carrier density due to Sb doping, as well as optimization of electrical conductivity which subsequently enhances the Seebeck coefficient in $Ge_{1-x}Sb_xTe$ compared to the pristine GeTe. Meantime, spontaneous reduce the thermal conductivity arisen from enhancing phonon scattering by doping effect. In summary, the combination of optimal power factor, reduction in thermal conductivity and highly crystalline lead to higher *ZT* values.

Oral Section II:4, 14:30-14:50

Synergistic optimization of thermoelectric performance of Sb doped GeTe with strained domain and domain boundaries

Khasim Saheb Bayikadi[a], Chien Ting Wu[b], Li-Chyong Chen[c,d], Kuei-Hsien Chen[c,e*], Fang-Cheng Chou[c,d*], Raman Sankar[a,c*]

[a] Institute of Physics, Academia Sinica, Nankang, Taipei, Taiwan 11529.

[b] Taiwan Semiconductor Research Institute, Hsinchu Science Park, Hsinchu 300, Taiwan.

[c] Centre for Condensed Matter Sciences, National Taiwan University, Taipei 10617, Taiwan.

[d] Center of Atomic Initiative for New Materials, National Taiwan University, Taipei 10617, Taiwan.

[e] Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan.

Abstract: In addition to the Ge-vacancy control of GeTe, the Antimony (Sb) substitution of GeTe for the improvement of thermoelectric performance is explored for $Ge_{1-x}Sb_xTe$ between x=0.08-0.12. The concomitant carrier concentration (n) and the ion size change via single ion Sb substitution led to an optimal doping level of x=0.10 to show ZT ~2.35 near ~800 K, which is significantly higher than those single- and multi-elements substitution studies of GeTe system reported in the literature. In addition, $Ge_{0.9}Sb_{0.1}Te$ demonstrates an impressively high power factor of ~ 36 $\mu Wcm^{-1}K^{-2}$ and low thermal conductivity of ~1.1 $Wm^{-1}K^{-1}$ at 800 K. The enhanced ZT level for $Ge_{0.9}Sb_{0.1}Te$ is explained through a systematic investigation of micro-structural change and strain analysis from room temperature to 800 K. Significant reduction of lattice thermal conductivity (κ_{lat}) is identified and explained by the Sb substitution-introduced strained and widened domain boundaries for the herringbone domain structure of $Ge_{0.9}Sb_{0.1}Te$. The Sb substitution created multiple forms of strain near the defect centre, the herringbone domain structure, and the widened tensile/compressive domain boundaries to support phonon scattering that covers wide frequency (ω) range of phonon spectrum to reduce lattice thermal conductivity effectively.

Keywords: vacancy control, Sb doping, melt quenching, lattice strain, ZT.

Oral Section II:5, Invited 14:50-15:10

Phase diagrams of Ag-Pb-Sn-Te quaternary system

Sinn-Wen Chen[1,2]*, Yohanes Hutabalian[1], Yi-Huei Du[1] and Dr. Aleš Kroupa[3]

[1.] Department of Chemical Engineering, National Tsing Hua University, Hsinchu, Taiwan

[2.] High Entropy Materials Center, National Tsing Hua University, Hsinchu, Taiwan

[3.] Institute of Physics of Materials, ASCR, Brno, Czech

Abstract: Ag-Pb-Sn-Te is a quaternary system of high thermoelectric application interests. SnTe, PbTe, Ag_2Te are all promising thermoelectric compounds. Phase diagrams provide fundamental materials information and are important for materials design, processing route determination and illustration of formation of materials microstructures. This study determines phase diagrams of the Ag-Pb-Sn-Te quaternary system. Phase diagrams of its constituent binary systems, Ag-Pb, Ag-Sn, Ag-Te, Pb-Sn, Pb-Te and Sn-Te, are available in the literatures. Phase diagrams of two constituent ternary systems, Ag-Pb-Te and Pb-Sn-Te, are available; but phase diagrams of the other two systems, Ag-Pb-Sn and Ag-Sn-Te, are lacking. Phase diagrams at 350ºC and 500ºC of Ag-Pb-Sn and Ag-Sn-Te ternary systems are experimentally determined. Ag-Pb-Sn-Te quaternary alloys of selected compositions are prepared and their equilibrated phases are determined. No ternary or quaternary compounds are observed. The stable binary compounds at 350ºC and 500ºC are ζ-Ag_4Sn, ε-Ag_3Sn (not stable at 500°C), Ag_2Te, Ag_5Te_3 (not stable at 500°C), PbTe and SnTe. Pb(Se,Te) and (Pb,Sn)Te are continuous solid solutions.

Oral Section III:1, 15:50-16:10

Phase diagram of Bi-Cu-Te and Thermoelectric Properties of Cu doped Bi_2Te_3

Wan-ting Yen[1], Kuang-Kuo Wang[2] and Hsin-jay Wu[1]*

[1] Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan

[2] Department of Materials and Optoelectronic Science, National Sun Yat-Sen University, Kaohsiung, 804, Taiwan

Abstract: The bismuth tellurides are the best thermoelectric materials at room-temperature region, and has been widely commercialized in recent years. Herein, we prepared two series of Cu-doped Bi_2Te_3, which are $(Bi_2Te_3)_{1-x}(Cu_2Te)_x$ and CuyBi2-yTe3 series, using the Bridgman method, and their thermoelectric properties are discussed. Among them, the *p*-type $(Bi_2Te_3)_{0.99}(Cu_2Te)_{0.01}$ / $Cu_{0.01}Bi_{1.99}Te_3$ achieve a high zT ~ 1.2 in at 300 K while the n-type $(Cu_2Te)_{0.09}(Bi_2Te_3)_{0.91}$ attains a high zT ~ 1.07 in at 360 K, respectively. An isothermal section of the ternary Bi-Cu-Te is constructed based on the microstructural and compositional analysis. We further notice that there is a strong correlation between the p / n-type transition and the grain boundary precipitates.

Oral Section III:2, 16:10-16:30

In-Plane Thermal Conductivity Measurements of a Single-Crystalline Thin-Film by the 3ω Method

Wei-Han Tsai[1,2*], Ying-Hsiang Lou[2], Cheng-Lung Chen[2], Yang-Yuan Chen[2]

[1]Department of Physics, National Taiwan University, Taipei, Taiwan

[2]Institute of Physics, Academia Sinica, Taipei, Taiwan

Abstract: $Bi_{0.5}Sb_{1.5}Te_3$ is a widely known room-temperature thermoelectric material and has been extensively studied the thermal conductivity properties along the specified orientation plane. Especially, the previous research presented the prominent thermal conductivity along with the out of plane direction. Herein, we report the result of the in-plane thermal conductivity of $Bi_{0.5}Sb_{1.5}Te_3$ thin films via the 3ω method. Furthermore, a piece of a specimen is obtained from the artificial scratched thin film that further processed as a wire sample by following the focused ion beam (FIB) treatment. The wire is suspended above a hole on our measurement chip and heated by itself when a current through. Then, we use the lock-in amplifier to gain the 3ω signal and estimate the thermal conductivity along the in-plane direction of our sample. Lastly, an optimal thermal conductivity is around 0.28 ±0.02 W/m-K in 1um thin film with a unique preparation procedure.

Keywords: Thin film, 3ω method, Thermoelectric

Oral Section III:3, 16:30-16:50

Influence of Co-P Diffusion Barrier on the Reliability of Bi_2Te_3-based Thermoelectric Module

Chun-Hsien Wang, Zhen-Wei Sun, and Albert T. Wu*

Department of Chemical and Materials Engineering, National Central University, Taoyuan city 32001, Taiwan.

Abstract: Bi_2Te_3-based thermoelectric material is well-known for its excellent ability to transform waste heat into electricity. Besides from pursuing high *zT* value thermoelectric materials, it is critical to evaluate the reliability of the module. This study focuses on the interface of the joints in the modules and assesses the improvement of a stable interface. A severe reaction between thermoelectric materials and solder would occur after assembling the module. Thick reaction layer degrades the thermoelectric performance. In this study, electroless Co-P diffusion barrier was used to improve the joint stability by preventing the reaction between Bi_2Te_3-based thermoelectric materials and commercial Sn-based solders. The results of interfacial reaction showed that rapid formation of SnTe IMC could be effectively suppressed by the Co-P layer. Moreover, shear test validated the enhancement of mechanical strength for the thermoelectric joints. The analyses of fracture surface showed that high shear strength could be attributed to the transformation of failure mode from brittle to ductile fracture with the addition of Co-P layer. Measurement of thermoelectric properties was conducted to confirm that adding a Co-P layer did not deteriorate the zT values. The results in our study proved that Co-P could be an effective diffusion barrier to improve the reliability of Bi_2Te_3 thermoelectric module.

Oral Section III:4, 16:50-17:10

Phase diagram of ternary Zn-Sb-Ga system and Thermoelectric properties of Ga doped Zn_4Sb_3 alloys

I-Lun Jena and Hsin-Jay Wu*

Department of Materials Science and Engineering, National Chiao Tung University Hsinchu 30010, Taiwan

Abstract: In order to cope with the global warming and energy sustainability, the development of thermoelectric (TE) materials has grown extremely in recent years. The p-type β-Zn_4Sb_3 attracts great attention in the application of middle temperature thermoelectric generators. The addition of Gallium (Ga) in the Zn_4Sb_3 leads to the power factor (PF) increasing with two times in selective Ga-doped Zn_4Sb_3 which is grown crystal by the Bridgman method. At 623 K, the maximum solubility of Gallium in Zn_4Sb_3 under the thermally equilibrium state is less than 4 at.%Ga, as suggested by the isothermal section of ternary Zn-Sb-Ga system. As a result, the Ga-substituted $(Zn_{1-x}Ga_x)_4Sb_3$ achieves high figure of merit zT of 1.36 at 673 K as a result of the reduced κ~0.70 (W/mK) and enhanced PF~1.3 (mW/mK^2) compared with the undoped Zn_4Sb_3 (zT~0.8), showing an ideal demonstration of phonon-glass-electron-crystal (PGEC).

Poster Presentation, 10:20 - 15:50

P01	**Phase diagrams of the thermoelectric system Cu-PbTe-GeTe** Meng-Yuan Ho and Hsin-Jay Wu
P02	**Fabrication of $BiCu_{0.7}Ni_{0.3}O$ Thermoelectric Thin Films by Sol-Gel Method** Cheng-Hsing Hsu, Ching-Fang Tseng and Chun-Hua Teng
P03	**Microstructure engineering and thermoelectric characterization of electrically sintered Ge-Pb-Te compounds** Yu-Che Lee and Chien-Neng Liao
P04	**Design and Fabrications of sputtered p and n-type Bi_2Te_3-based thermoelectric microdevices** Wei-Ting Liou, Cheng-Lung Chen, Tzu-An Lin and Yang-Yuan Chen
P05	**Microstructures and thermoelectric properties of Bi-Te films deposited by e-beam evaporation** Sheng-Chi Chen, Ya-Cheng Lin, Yen-Ju Wu, Shih-Chieh Hsu, Yibin Xu and Tung-Han Chuang
P06	**The Study of Zn-Sb Alloy Thin Films Deposited by Ion Beam Assisted Deposition: Micro-structureandMix-phase** Sheng-Chi Chen, Jhen-Yong Hong, Ya-Cheng Lin, Jia-Han Zhen, Yu-Wei Lin, Shih-Chieh Hsu and Tung-Han Chuang
P07	**Topological Insulator Nanoribbons – A Possible Way to ZT>10** Te-Hsien Wanga and Horng-Tay Jeng
P08	**Effect of high mixing entropy on Ge(S,Te)-based thermoelectric materials** Pei-Fang Lee and Chien-Neng Liao
P09	**Observation of solubility anomalies in liquid phase epitaxy of SiGe thermoelectric crystals** Hung-Wei Li, Kuan-Ling Huang and Chih-Wei Chang
P10	**The self-tuning of carrier type in Skutterudite $CoSn_{1.5}Te_{1.5}$** Suneesh Meledath Valiyaveettil, Ta-Lei Chou, Li-Chyong Chen and Kuei-Hsien Chen
P11	**Study of interface for $Cu/Sb_2Te_3/Cu$ thin film thermoelectric modules** Zhen-Wei Sun and Albert T. Wu
P12	**Effect of diffusion barrier on interface stability between PbTe and electrodes** Yu-Chien Wang and Albert T. Wu
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