Research Statement

Jing-Han Chen, Ph.D.

Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana

I am a material physicist with extensive experience in material characterization, synthesis and optimization as well as scientific computing. I have a good track record of working independently as well as collaborating with scientists from diverse backgrounds. Currently, I'm a postdoctoral researcher at Louisiana State University. In this research statement, I will describe my past and current research, and discuss my future research plan.

Past and Current Research

My research experience started with investigating optical properties of the liquid crystal as a undergraduate researcher. After completing my master thesis on the magneto-resistance measurement of low-dimensional GaAs and GaN semiconductor systems, I moved my research focus to computational studies of the single molecular devices as a research assistant in Academia Sinica. Therefore, I have been trained in doing the experimental research and computational research since then.

In 2009, I joined Texas A&M University as a Ph.D. student. During my doctoral career, I focused on solid state synthesis and characterization of materials with the thermoelectric and magnetocaloric properties. In my thesis, I studied the magnetic and thermal response of the Ni-Mn-In magnetocaloric materials associated with the first-order magneto-structural transitions. Due to this first-order transitions, I developed an improved method to overcome the experimental difficulties in the conventional calorimeter[1]. The magnetocaloric effect (MCE) describes the thermal exchange of materials caused by applying magnetic fields. They have been employed in low-temperature laboratory research[2] and are potentially applicable near room temperature. My study on off-stoichiometric Ni-Mn-In Heusler alloys[1, 3] shows large MCE due to the first-order magneto-structural transition in the vicinity of the room temperature, and hence they are possibly applicable in magnetic refrigerators near room temperature. By comparing calorimetric and magnetic measurement, the physical mechanisms of MCE are explored in detail and the model based on the mean-field theory explained the cooling power successfully.

After graduating from Texas A&M University, I joined Rice University as a postdoctoral research associate. I conducted research in inorganic chemistry with emphasis on magnetic and thermal properties of phosphides and arsenides compounds. I worked on material synthesis and characterization with emphasis on their magnetic properties, crystal structures and phase transitions. Shortly after joining Rice University, I built up the automatic temperature regulator in the home-built metalorganic vapor phase epitaxy apparatus, which led to improve the synthetic productivity and quality significantly. As a physicist, I enjoyed developing the experimental strategy in the collaborative environment with chemists within the limitation of time and resource. I made heavy use of X-ray diffractometer to identify the crystalline structure, the magnetometer to identify the magnetic properties, and the calorimeter to explore the transition nature of materials.

In additional to the experimental research, I am also an expert in employing density functional theory (DFT) calculations to deepen understanding of materials. DFT calculations take relatively low computational cost among other many-body theories and produces satisfactory results in solid materials. In several of my peer-reviewed articles[4–7], electronic structures of materials from DFT calculations are employed to elaborate the experimental results. In combination with experimental and computational efforts, I am keen on constructing sound manufacturing guidelines for engineering the desired materials.

Currently, I am a postdoctoral researcher at Louisiana State University. I focus on developing, characterizing and optimizing alloys with potential solid-state cooling applications resulting from first-order magneto-structural transitions near room temperature. I synthesized the Ni-Mn based Heusler alloys and MnNiSi based compounds, both exhibiting strong caloric responses due to external stimuli such as strain, pressure, and electric and magnetic fields. After synthesis, I characterized their magnetization response upon applying the magnetic field or hydrostatic pressure. The project aims at the discovery of a practical magnetic refrigeration material which leads to more efficient and environmentally friendly cooling systems. I designed the experiments to identify the root cause of the inconsistent results among different experimental methods. I managed technical and programmatic process on multiple projects, and established and maintained the local and remote collaborative relationship.

Proposed Research and Work Plans

In the near future, I plan to build a solid state functional material lab. My laboratory will focus on solid state research with emphasis on stress, thermal and magnetic response of emerging solid state materials. For the material synthesis, we will utilize arc-melting, induction furnace while x-ray diffractometer, magnetometer and calorimeter will be used for material characterization.

Initially, my lab will focus on the synthesis and characterization of multi-functional caloric materials. The area of research is relatively new, associated with significant challenges and possibilities. Due to the potential refrigeration applications of magnetocaloric materials, there has been a strong push to find new materials with high field-induced entropy, or other features optimized for related applications[8, 9]. As a result, a number of complex alloy systems have been developed, with several promising systems having very recently appeared, such as $Gd_5Si_xGe_{4-x}$[10, 11], MnAs-based compounds[12], Fe_2P-based compounds[13–15], $La(Fe_{1-x}Si_x)_{13}$ and their hydrides[16, 17], Ni-Mn-based Heusler alloys[18–20], and $MnCoGeB_x$[21]. One of the main characteristics in giant magnetocaloric materials is the coexistence of the magnetic and structural transitions, which causes a huge entropy change that can be utilized practically. Although significant inroads have been made in understanding the fundamental behavior driving this first-order magneto-structural transition, the correlation between the magnetic and structural transitions in magnetocaloric materials still remain unsettled. In the short-term, my lab will concentrate on understanding the unique thermal, magnetic and mechanical properties in these materials resulting from these phase transitions, and provide the practical suggestion to design thermodynamic cycles for applications. In the long term, my lab will aim at understanding and developing multi-functional materials, which is expected to positively impact scientific and engineering society.

Summary

To sum up, I am a material physicist with extensive experience of working independently, training students as well as collaborating with scientists from diverse backgrounds. My past career proves my extensive problem-solving skills across materials synthesis, instrumentation and scientific computing. The research topics in contact with engineering applications are always attractive to me and I am open minded to all relevant fields. In the future, I will actively seek external funding to develop a research lab which can educate both undergraduate and graduate students who can navigate physical science, life sciences and engineering in a transdisciplinary manner.

References

[1] J.-H. Chen, N. M. Bruno, I. Karaman, Y. Huang, J. Li, J. H. Ross, Jr., Calorimetric and magnetic study for $Ni_{50}Mn_{36}In_{14}$ and relative cooling power in paramagnetic inverse magnetocaloric systems, J. Appl. Phys. 116 (2014) 203901.

[2] C. Zimm, A. Jastrab, A. Sternberg, V. Pecharsky, J. Gschneidner, K., M. Osborne, I. Anderson, Description and performance of a near-room temperature magnetic refrigerator, in: P. Kittel (Ed.), Advances in Cryogenic Engineering, Vol. 43, Springer US, 1998, pp. 1759–1766.

[3] J.-H. Chen, N. M. Bruno, I. Karaman, Y. Huang, J. Li, J. H. Ross, Direct measure of giant magnetocaloric entropy contributions in Ni-Mn-In, Acta Mater. 105 (2016) 176–181.

[4] Y.-H. Tang, V. M. K. Bagci, J.-H. Chen, C.-C. Kaun, Conductance of stretching oligothiophene single-molecule junctions: A first-principles study, J. Phys. Chem. C 115 (2011) 25105–25108.

[5] J.-H. Chen, A. A. Sirusi, X. Zheng, S. Y. Rodriguez, J. H. Ross, Jr., NMR and computational study of $Ba_8Cu_xGe_{46-x}$ clathrate semiconductors, J. Alloys Compd. 593 (2014) 261–266.

[6] A. A. Sirusi, S. Ballikaya, J.-H. Chen, C. Uher, J. H. Ross, Band ordering and dynamics of $Cu_{2-x}Te$ and $Cu_{1.98}Ag_{0.2}Te$, J. Phys. Chem. C 120 (2016) 14549–14555.

[7] D. E. Schipper, J.-H. Chen, K. H. Whitmire, Iron carbonyl clusters with ECl_2 units (E=P,As), J. Organomet. Chem. 849-850 (2017) 279–285.

[8] L. Mañosa, A. Planes, M. Acet, Advanced materials for solid-state refrigeration, J. Mater. Chem. A 1 (2013) 4925–4936.

[9] A. Tishin, Y. Spichkin, The Magnetocaloric Effect and its Applications, Condensed Matter Physics, CRC Press, 2016.

[10] V. K. Pecharsky, K. A. Gschneidner, Jr., Giant magnetocaloric effect in $Gd_5Si_2Ge_2$, Phys. Rev. Lett. 78 (1997) 4494–4497.

[11] G. J. Liu, J. R. Sun, J. Lin, Y. W. Xie, T. Y. Zhao, H. W. Zhang, B. G. Shen, Entropy changes due to the first-order phase transition in the $Gd_5Si_xGe_{4-x}$ system, Appl. Phys. Lett. 88 (2006) 212505.

[12] H. Wada, Y. Tanabe, Giant magnetocaloric effect of $MnAs_{1-x}Sb_x$, Appl. Phys. Lett. 79 (2001) 3302–3304.

[13] O. Tegus, E. Brück, K. H. J. Buschow, F. R. De Boer, Transition-metal-based magnetic refrigerants for room-temperature applications, Nature 415 (2002) 150–152.

[14] N. T. Trung, Z. Q. Ou, T. J. Gortenmulder, O. Tegus, K. H. J. Buschow, E. Brück, Tunable thermal hysteresis in MnFe(P,Ge) compounds, Appl. Phys. Lett. 94 (2009) 102513.

[15] N. H. Dung, Z. Q. Ou, L. Caron, L. Zhang, D. T. C. Thanh, G. A. de Wijs, R. A. de Groot, K. H. J. Buschow, E. Brück, Mixed Magnetism for Refrigeration and Energy Conversion, Adv. Energy Mater. 1 (2011) 1215–1219.

[16] F.-x. Hu, B.-g. Shen, J.-r. Sun, Z.-h. Cheng, G.-h. Rao, X.-x. Zhang, Influence of negative lattice expansion and metamagnetic transition on magnetic entropy change in the compound $LaFe_{11.4}Si_{1.6}$, Appl. Phys. Lett. 78 (2001) 3675–3677.

[17] A. Fujita, S. Fujieda, Y. Hasegawa, K. Fukamichi, Itinerant-electron metamagnetic transition and large magnetocaloric effects in $La(Fe_xSi_{1-x})_{13}$ compounds and their hydrides, Phys. Rev. B 67 (2003) 104416.

[18] T. Krenke, E. Duman, M. Acet, E. F. Wassermann, X. Moya, L. Mañosa, A. Planes, Inverse magnetocaloric effect in ferromagnetic Ni-Mn-Sn alloys, Nat. Mater. 4 (2005) 450–454.

[19] E. Liu, W. Wang, L. Feng, W. Zhu, G. Li, J. Chen, H. Zhang, G. Wu, C. Jiang, H. Xu, F. de Boer, Stable magnetostructural coupling with tunable magnetoresponsive effects in hexagonal ferromagnets, Nat. Commun. 3 (2012) 873.

[20] J. Liu, T. Gottschall, K. P. Skokov, J. D. Moore, O. Gutfleisch, Giant magnetocaloric effect driven by structural transitions, Nat. Mater. 11 (2012) 620–626.

[21] N. T. Trung, L. Zhang, L. Caron, K. H. J. Buschow, E. Brück, Giant magnetocaloric effects by tailoring the phase transitions, Appl. Phys. Lett. 96 (2010) 172504.