Single crystal growth and characterization of layered compounds $ReTX_2$ (Re=rare earth, T=transition metal, X=Si, Ge, Sb, Bi)

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LA-SiGMA
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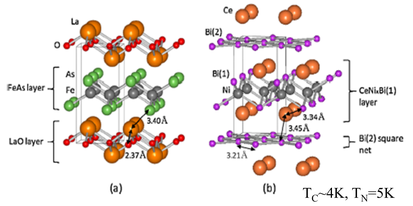
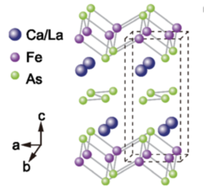
Introduction

With the recent discovery of novel Iron based 112 type superconductors with Tc of 25k and 45k [1], it has brought great excitement to researchers wanting to understand the relationship between magnetism and superconductivity and find novel 112 type superconductors with the possibility of a high Tc. From known $(La,Ca)FeAs_2$ [2], $(Pr,Ca)FeAs_2$ [3] and $CeNi_{0.8}Bi_2$ [4] 112 type superconductors, we wanted to explore other $ReTX_2$ superconductors. Through this research we synthesized and characterized several 112-type systems $ReTX_2$, (Re=rare earth, T=transition metal, X=Si, Ge, Sb, Bi).



Fe-base high Tc-LaFeAsO structure

$CeNi_{0.8}Bi_2$ structure
Mizoguchi, et al, PRL, (2011)



$Ca/LaFeAs_2$
Li, et al. Phys. Rev. B, 91, 045112

We discovered two new phases. One is a superconductor $PrPdBi_2$ with Tc = 3.5K, while the other is a quaternary compound $CuNd_{2.5}Zn_3Ge_7$ with ferromagnetism.

Method

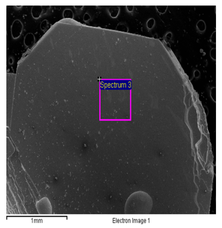
Flux growth of single crystals

We started with the basic formula $ReTX_2$ to figure out what compounds to be synthesized. Once we came up with a list of compounds we wanted to try, we used the Crystal Structure Database and reviewed literature to make sure everything we plan on synthesizing are novel compounds. Metal powders were weighed out based on the stoichiometric molar ratios. Then they were mixed thoroughly and placed into Silica crucibles with a low melting temperature metal used as flux. They were double sealed in quartz tubes and evacuated below $7.0x10^{-4}$ Torr. The metal flux lowers the melting temperature of the high melting temperature elements into an achievable range. The tubes were then placed into a crucible furnace and heated to 600°C and held for 24hr. After 24hr the furnace was slowly raised, at a rate of 40°C/hr, up to 1050°C and held for 48hr. Then they were slowly cooled, at a rate of 3°C/hr, down to 750°C, then followed by quick cooling at the rate of 5°C/hr down 400°C. After that, the furnace was shut down.

The compositions of the sample were analyzed using x-ray energy dispersive spectrometer (EDS). The structure of the synthesized samples were examined by x-ray diffraction. We also measured resistivity and heat capacity of PrPdBi2 in a Physical Property Measurement System (PPMS). The magnetization measurement was performed in a SQUID magnetometer.

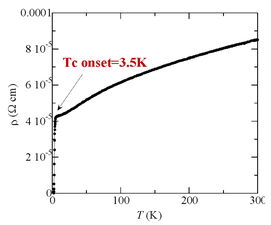
Results and Discussions

$PrPdBi_2$



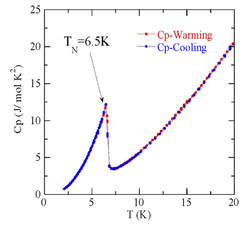
Element	Weight%	Atomic%
Pd L	14.51	23.12
Pr L	19.17	23.06
Bi M	66.33	53.82

Temperature dependence of resistivity



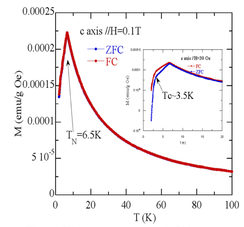
The transition temperature for superconductivity is shown at 3.5K

Low temperature specific heat



Large jump shown in heat capacity at 6.5K suggests a possible antiferromagnetic (AFM) transition caused by f-electron of Pr. The superconductivity doesn't show any anomaly in specific heat data as the peak caused by AFM transition is too strong.

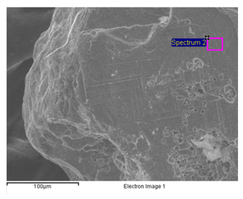
Susceptibility vs.. Temperature

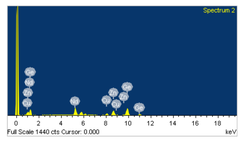


The AFM transition at 6.5K is confirmed by the observation of a anomaly peak in magnetization.

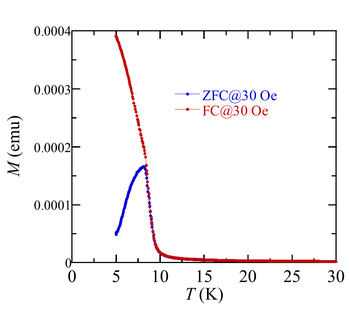
Diamagnetism caused by superconductivity is also observed

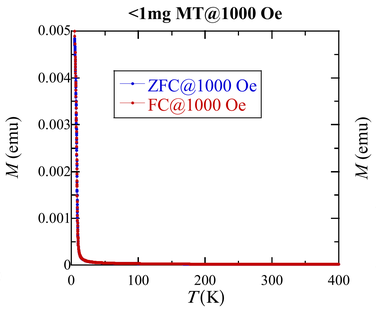
$CuNd_{2.5}Zn_3Ge_7$

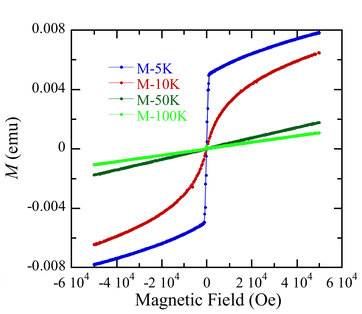




Element	Weight% avg	Atomic% avg
Cu K	5.61	7.33
Nd L	31.44	18.14
Zn K	18.53	23.60
Ge K	46.19	50.94







We also discovered a new quaternary compound with the composition of $CuNd_{2.5}Zn_3Ge_7$. The magnetization measurements on this compound showed it is ferromagnetic with the Curie temperature being around 10K. The magnetic hysteresis loop is small, indicating soft ferromagnetism.

References

1. Wang, et al. Solid State Comm, 200, 61-65 (2014)
2. Katayama, et al. J. Phys. Soc. Jpn., 82, 123702 (2013)
3. Yakita, et al. J. Am. Chem. Soc., 136, 846–849 (2014)
4. Mizoguchi, et al. Phys. Rev Lett., 106(5), 057002 (2011)

Acknowledgements

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