グローバルCOE講演会報告書

大学院理学研究科　吉村 一良

研究集会名:グローバルCOE講演会
講演者: Yang Jin-Hu（楊 金虎）（博士課程大学院生), Zhejiang University（浙江大学), 中国
演 題: “セリウム系化合物の量子臨界点近傍の実験について”
場 所: 京都大学理学研究科6号館第571号室（化学教室セミナー室）
日 時: 2008年3月17日（月） 13:00−16:00
2008年3月18日（火） 10:00−12:00
2008年3月19日（水） 10:00−12:00
参加者: 化学専攻 大学院学生、学部生、博士研究員、教員
参加者総数: 約15-20名

講演内容:量子臨界点近傍の異常物性の研究は、遷移金属化合物における磁性や超伝導の物性科学研究において非常に興味がもたれる重要課題である。この領域で、
最近精力的に研究を行っているZhejiang University（浙江大学）のYang Jin-Hu（楊金虎）氏が、特に氏が最近中心的に研究を行っているNi_3Al型の$CeIn_3$系について、
最新の研究結果に加え、自信の研究以外の研究も紹介しながら講演を行った。講演は英語で行われたが、このテーマは、金相学研究室でも現在、中心的研究課題の一つであり、講演後、活発な質疑応答が想定していた時間を超して行われ、活発な議論が行われ、今後の研究方針・展望につながる充実した講演となった。実際に講演に用いられた資料の主要部分も添付する。

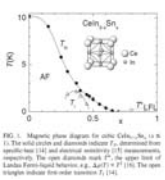
Experiments around Quantum Critical Point in Ce-Compounds

Yang Jinhu (1/1~3/31, 2008)

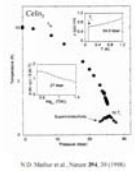
- Quantum phase transition in heavy fermion antiferromagnetic $CeIn_3$
- Layered structure compounds $SnSe_2$ and $MoTe_2$

Quantum phase transition in heavy fermion antiferromagnetic $CeIn_3$

Phy.Rev.Lett. 96 256403 (2006)



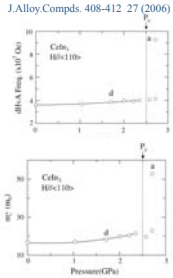
Cu_3Au structure T_N=10K
T_c~0.20K (P~2.5Gpa)



Nature 394 39 (1998)
Magnetism is in favor of superconductivity

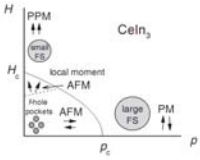
Superconductivity state is related to the antiferromagnetic phase order with the ordering vector Q=(π,π,π) at Ce atom, which strongly suggests that the superconductivity should be connected with 3D AF spin fluctuations
d- wave paring
J.Phys:Condens.Matter 15 S2259 (2003)

J.Alloy.Compds. 408-412 27 (2006)



A change of the Fermi surface from 4f-localized to 4f-itinerant
occurs when pressure crosses the P_c ~2.5Gpa

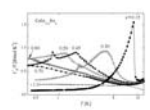
Phy.Rev.Lett. 99 056401(2007)



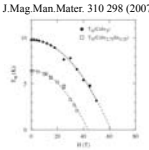
A schematic p versus H phase diagram of $CeIn_3$, including the antiferromagnetic (AFM), paramagnetic (PM), and polarized paramagnetic (PPM) regimes. Solid arrows represent the spin states of the Γ_7 doublet of Ce in each of these regimes, while the gray circles represent the different FS's. The "large FS" includes f-electron charge degrees of freedom whereas the "small FS" does not. Small f-hole pockets have recently been observed inside the antiferromagnetic phase at ambient pressure [12], but are observed to become depopulated in magnetic fields above ≈ 41 T (dotted line) where the staggered moment is canted.

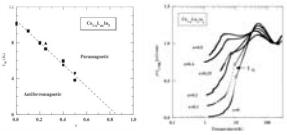
Quantum phase transition in heavy fermion antiferromagnetic $CeIn_3$

Physica B 312-313 406 (2002)



J.Mag.Man.Mater. 310 298 (2007)





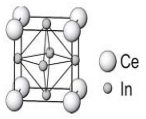
Non-fermi liquid behaviour arises around quantum critical point

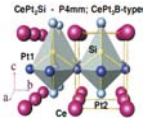
Both substitute Sn for In and external magnetic field or pressure can depress the T_N

Substitution induces great disorder

The similarity of structure between $CeIn_3$ and $CePt_3Si$

- Some broken inversion superconductors: $CePt_3Si$, $Cd_2Re_2O_7$, UIr, $CeRhSi_3$ $CeIrSi_3$, $La_3B_2C_6$, and Mo_3P
  $CePt_3Si$: Heavy fermion superconductor: Phys.Rev.Lett. **92** 027003





T_N=2.2K,T_c=0.75K

Quantum phase transition in heavy fermion antiferromagnetic $CeIn_3$

➢ if boron or carbon can be inserted into the body of the Cu_3Au structure , it may change the electron structure as well as the magnetic properties of this system. Compared with Ni_3Al ,when carbon is inserted into the structure, there is a strongly hybridization between C p band and Ni d band which can depress T_C of this sysytem . it is reasonable to expect similiar phenomenon occurs at certain content of carbon or boron in $CeIn_3$.

➢ Due to its large radius of silicon if can be inserted into the structure, it may change the symmetry from Cu_3Au structure into another one for example:$CePt_3Si$. It may give rise to some unexpected phenomenon.

Superconductivity in layered structure compounds

Phy.Rev.B 13 3843 (1976)

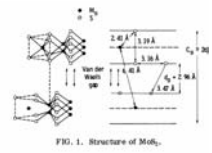
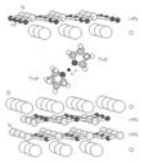


FIG. 1. Structure of MoS_2.

A_xMoS2
A=Na,K,Rb,Cs,Ca and Sr
Tc=3--7K

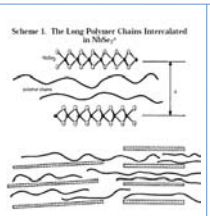
Nature 392 580 (1998)



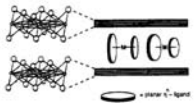
$Li_{0.48}(THF)_yHfNCl$ Tc=25.5K

Superconductivity in layered structure compounds

Scheme 1. The Long Polymer Chains Intercalated in $NbSe_2$

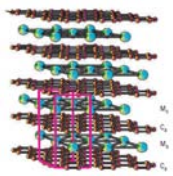


Plastic superconducting polymer
$NbSe_2$+ploymer
T_c=7K
Chem.mater 9 875 (1997)

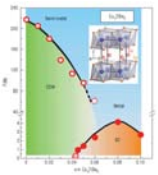


$SnSe_2$ is a semiconductor
$SnSe_2\{Co(\eta\text{-}C_5H_5)_2\}_{0.3}$ Tc=8.3K
Inorg.Chem.34 4287 (1995)

Superconductivity in layered structure compounds



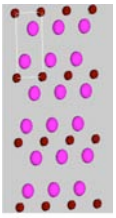
Nature physics 1 39 (2005)
C_6Ca T_c=11.5K
C_6Yb T_c=6.5K



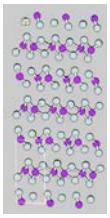
Nature physics 2 548 (2006)
Cu_xTiSe_2

The structure of $SnSe_2$ and $MoTe_2$

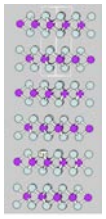
$SnSe_2$ P-3m1



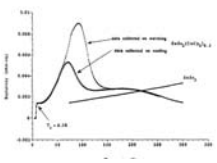
$MoTe_2$P121/m1



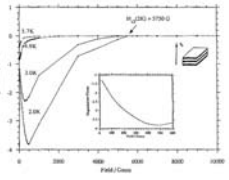
$MoTe_2$P63/mmc



Research on layered structure compouds $SnSe_2$ and $MoTe_2$

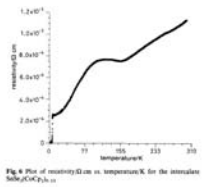


Adv.Mater. 4 658 (1992)

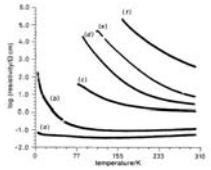


Compound	J [a]	T_c [K]
$TaSe_2(CoCp_2)_{0.3}$	11.5	8.3
TaS_2(cobaltine)$_{0.17}$	9.7	3.2
TaS_2(pyridine)$_{0.5}$	12.0	3.47
TaS_2(aniline)$_{0.33}$	18.1	2.9
$TaS_{1.9}Se_{0.8}$	6.1	4.1
$NbSe_2$	6.3	7.1
$Nb_{0.8}Ta_{0.2}Se_2$		

Research on layered structure compouds $SnSe_2$ and $MoTe_2$

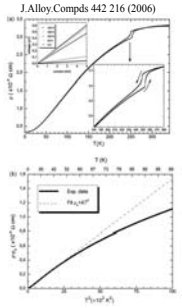


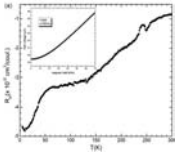
J.Mater.Chem. 1 51 (1991)



Research on layered structure compouds $SnSe_2$ and $MoTe_2$

J.Alloy.Compds 442 216 (2006)





$MoTe_2$ is a semi-metal

Layered structure compounds $SnSe_2$ and $MoTe_2$

- **It is easy to intercalate guest into the compound with layered structure which has only Weak Van der waals intercaction between two layers.**
- **Superconductivity in layered structure compound may have sth in common.**
- **$SnSe_2$ has the similar structure as $TiSe_2$ which shows superconductivity when Cu intercalated into the two Selenium sheets. The superconductivity occurs at the side of disappearance of CDW .**
- **$SnSe_2\{Co(\eta\text{-}C_5H_5)_2\}_{0.3}$ T_c=8.3K, using $Fe(\eta\text{-}C_5H_5)_2$ or other guest may also introduce superconductivity in this system.**
- **$MoTe_2$ has a layered structure and shows metallic conductivity .**
- **At present, there are few study on the intercalation of $SnSe_2$ or $MoTe_2$.**

Preparation of samples

- Using Arc-melting method to prepare polycrystal $CeIn_3X$ compound, X=Si,C and B.

if time permits, using flux method to grow single crystal of $CeIn_3X$.

- Using solid state reaction to prepare poly crystal $SnSe_2$ and $MoTe_2$

Trying to grow single crystal of $SnSe_2$and $MoTe_2$ by chemical vapor transport.

- Intercalating guest into $SnSe_2$ and $MoTe_2$.

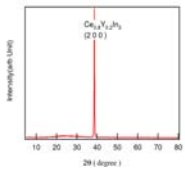
measurements

- Using XRD to check the structure of the compounds
- Using SQUID to measure the magnetic properties of $CeIn_3X$
- Using PPMS to measure the resistivity of the compounds

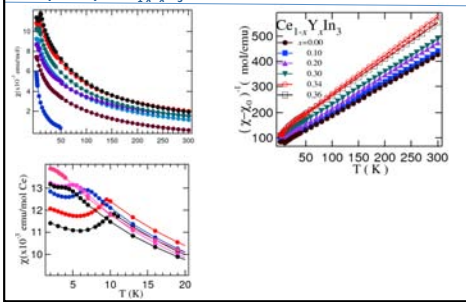
$Ce_{1-x}Y_xIn_3$ experiment analysis

- **XRD**
- **Susceptibility**
- **High magnetic filed *M-H***

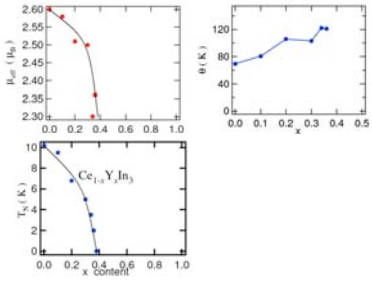
XRD pattern of single crystalline $Ce_{0.8}Y_{0.2}In_3$



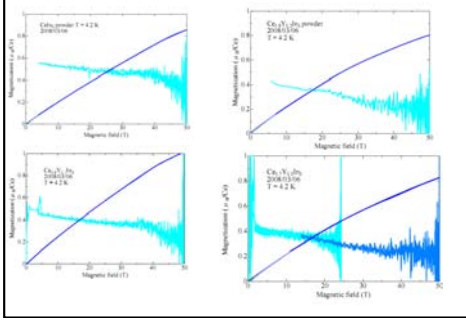
Susceptibility of $Ce_{1-x}Y_xIn_3$



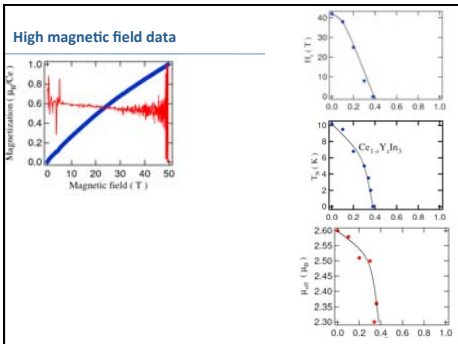
Results of susceptibiliy measurement



High magnetic field data



High magnetic field data



Conclusion

- XRD and EDX pattern shows the sample is single crystalline,
- Susceptibility of $Ce_{1-x}Y_xIn_3$ indicates T_N will vanish at about x =0.38 which is the antiferromagnetic quantum critical point.
- High magnetic field M-H curve also shows something interesting when Y substitute for Ce. The changed slope may have relation with 4f electron and RKKY interaction of the system.