T2R2 東京科学大学 リサーチリポジトリ
Science Tokyo Research Repository

論文 / 著書情報
Article / Book Information

題目(和文)	ペロブスカイト型の厚いブロック層をもつ鉄系超伝導体の単結晶作製と異方的物性評価
Title(English)	Crystal Growth and Anisotropic Properties of Iron-based Superconductors Having Thick Perovskite-type Blocking Layers
著者(和文)	片桐隆雄
Author(English)	Takao Katagiri
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第9492号, 授与年月日:2014年3月26日, 学位の種別:課程博士, 審査員:笹川　崇男,東　正樹,吉本　護,舟窪　浩,中村　一隆
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第9492号, Conferred date:2014/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

Powered by T2R2 (Science Tokyo Research Repository)

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	物質科学創造	専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（工学）
学生氏名： Student's Name	片桐 隆雄		指導教員（主）： Academic Advisor(main)	笹川 崇男	准教授
			指導教員（副）： Academic Advisor(sub)	東 正樹	教授

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The recently discovered Fe-based superconductors have been actively studied. It is well known that all Fe-based superconductors have layered crystal structures which are correlated with superconducting properties. Since it has been reported that the 1111 compounds have more anisotropic physical properties than the 122 systems, it seems that the blocking layer plays fundamental roles for the material-dependent anisotropy in the Fe-based superconductors as similar in the Cu-based high-T_c superconductors. The present study aimed to systematically verify the relationship between the crystal structure and the anisotropy, and the influence of anisotropy on the critical field H_c and the critical current density J_c in the Fe-based superconductors. To this end, we focused on the Fe-based superconductors having thick perovskite-type blocking layers and evaluated the anisotropic superconducting properties through the resistivity and magnetization measurements under magnetic fields in grown single crystals of $Ca_5(Mg,Ti)_4Fe_2As_2O_{11}$ and $Sr_2VFeAsO_{3-\delta}$.

We succeeded in growing single crystals of $Ca_5(Mg,Ti)_4Fe_2As_2O_{11}$, which were large enough to perform magnetic, transport, and other measurements with respect to anisotropy. The anisotropy parameter was quantitatively determined from the angle dependence of resistivity under the magnetic field. The anisotropy parameter Γ was determined to be 80 ~ 180. This value was the highest among the other observed Fe-based superconductors (e.g. $BaFe_2As_2$ $\Gamma \sim 2$, NdFeAsO $\Gamma \sim 5$). These values were comparable to the typical high-T_c superconductor $Bi_2Sr_2CaCu_2O_y$. It was found that J_c was rapidly suppressed with increasing temperature and magnetic field. From this result, it was suggested that vortex pinning was very weak and this compounds might have 2D pancake-like vortices.

Crystal growth of $Sr_2VFeAsO_{3-\delta}$ was achieved. The control of oxygen content was carried out through changing nominal compositions of the starting materials. With increasing the oxygen deficiency, the superconducting transition temperature shifted to lower temperature. On the other hand, ferromagnetism emerged with oxygen deficiency, which seems to suppress the superconductivity in the oxygen deficient compositions. It became clear that superconductivity and ferromagnetism coexisted in $\delta = 0.25$ and 0.5 and ferromagnetism without superconductivity was observed in $\delta = 0.75$.

The quantitatively estimated anisotropy parameter Γ of each composition was about 20. This value was several times larger than other typical Fe-based superconductors.

We discussed the origin of ferromagnetism within the Sr_2VO_3 blocking layers in oxygen deficient $Sr_2VFeAsO_{3-\delta}$. The observation of the magnetic moment in our crystal was lower than what was predicted by first principles calculations for the case of the Sr_2VO_3 blocking layers being a ferromagnetic metallic state. Furthermore, the anisotropy parameter did not change dramatically by oxygen deficiency as mentioned above. Therefore, it is highly likely that the Sr_2VO_3 blocking layers are a ferromagnetic insulating state.

Using the quantitatively estimated anisotropy parameters for $Ca_5(Mg,Ti)_4Fe_2As_2O_{11}$ and $Sr_2VFeAsO_{3-\delta}$, we found a universal correlation between the anisotropy parameter and the thickness of blocking layers in Fe-based superconductors.

In cuprate high-T_c superconductors, it has been well known that the resistivity anisotropy (ρ_c/ρ_{ab}) in the normal state just above T_c has a good correlation with the blocking layer thickness. For the Fe-based superconductors, the anisotropy parameter (in $\log\Gamma^{-2}$) as a function of the blocking layer thickness was found to result in scaling into a straight line. It was found that the influence of the blocking layer thickness on anisotropy in the Fe-based superconductors was lower than that in the cuprate high-T_c superconductors. For easily estimation of the anisotropy parameter in Fe-based superconductors, we proposed that there were a new general and simple rule between the anisotropy parameter and the crystal structure; the number of atomic layers in blocking layers can be used instead of the blocking layer thickness. The obtained simplified relationship can be expressed as $\Gamma^{-2} = 3.32\exp(0.9N)$. The exponential change of Γ^{-2} on N is indicative of a tunneling of the Cooper pairs across the blocking layers, suggesting a realization of the stacks of superconductor-normal-superconductor layers (intrinsic Josephson junctions) along the *c*-axis.

We also found that J_c was rapidly suppressed with increasing the anisotropy parameter or the number of atomic layers in the blocking layers. These results indicated that the vortex state changes from the 3D rod-like vortices in samples with small anisotropy to the 2D pancake-like vortices in those with large anisotropy.

Since $Sr_2VFeAsO_3$ superconductor has thick blocking layers, it is possible that this compound forms the intrinsic Josephson junction. Moreover, the blocking layers were the ferromagnetic state with oxygen deficiency. In superconductor-ferromagnet-superconductor (S/F/S) junction, the Josephson current has π-shifted phase compared to that in a superconductor-normal-superconductor junction. This is why S/F/S junction is called π-junction. It is considered that this π-junction will act as a quantum bit, thus can be used for superconductor-based quantum computing.

In conclusion, our findings in $Ca_5(Mg,Ti)_4Fe_2As_2O_{11}$ and $Sr_2VFeAsO_{3-\delta}$ may open up a versatile novel research avenues (such as individual vortex states, their collective phases, intrinsic Josephson Junctions, *etc*.) in Fe-based superconductors.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note：Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).