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Editorial

Layered Superconductors

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Received: 10 January 2018; Accepted: 30 January 2018; Published: 1 February 2018

Keywords: layered superconductors; high-T_c superocnductors; new superconductors

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1. Introduction

Since the discovery of cuprates (Cu-oxide superconductors) in 1986 [1–4], layered superconductors have attracted much attention, due to the emergence of high-transition-temperature (high-T_c) and unconventional superconductivity. The highest record of the cuprates, T_c >130 K, is still the highest among superconductors at ambient pressure. Furthermore, several kinds of new superconductors with exotic mechanisms and properties have been discovered. In 2001, MgB_2 with T_c = 39 K was discovered [5]. In 2008, FeAs-based (Fe-based) superconductor $LaFeAsO_{1-x}F_x$ was discovered [6] and T_c exceeding 50 K has been recorded [7]. Thus, the discovery of new layered superconductors and increased understanding of superconductivity mechanisms are very important for exploring new high-T_c superconductors. Furthermore, application of layered superconductors is an important and developing field of superconductivity. Therefore, this special issue is aimed to publish review and original papers on various layered superconductors and its application.

2. The Present Issue

This special issue consists of 11 papers, which covers the topics on the physics, chemistry, and application of layered superconductors. The target systems are cuprates, Fe-based superconductors, low-dimensional systems, and newly discovered layered superconductors.

The cuprates and the Fe-based superconductors have been a hot issue in the fields of science and application. In this issue, Adachi et al. give an overview on the novel electronic state and superconductivity in the electron-doped high-T_c T′-superconductors [8]. The superconductivity in the T′ structure is one of the hot topics in the field of high-T_c superconductivity. In this review paper, recent advances on this matter and future prospects for elucidating the mechanisms of the superconductivity in this system have been shown. Miller et al. introduces time-correlated vortex tunneling in layered superconductors [9]. Their model can well explain the experimental observation for measured critical current vs. film thickness of HTS-coated conductors, and the concept proposed in this paper can be applicable to other correlated electron systems. Geahel et al. discuss edge contamination, bulk disorder, flux front roughening, and multiscaling in type II superconducting thin films [10]; they particularly investigate the roughening of magnetic flux fronts penetrating into strongly pinning YBCO ($YBa_2Cu_3O_{7-d}$) superconducting films with different degrees of edge and bulk disorder. They also point the similarity to other systems like Fe-based superconductors. Imai, Nabeshima and Maeda give a comparative review on thin film growth of Fe-based superconductors [11]. Since the discovery of the Fe-based superconductors, study on thin films has been actively performed to clarify the mechanisms and to achieve a high performance for superconductivity application. They particularly show the growth of Fe chalcogenide films and their superconducting properties.

According to the experiences of material developments of the cuprates and Fe-based superconductors, several kinds of layered superconductors have been recently discovered. The first example is 122-type pnictides, which have a crystal structure similar to that of FeAs-based

$Ba_{1-x}K_xFe_2As_2$ [12]. Zhang and Zhai review superconductivity in 122-type pnictides without iron [13]. They show the similarity and differences in the structural and physical properties between Fe-based and Fe-free systems. Yajima reviews the properties of titanium pnictide oxide superconductors [14]. The Ti-based system contains Ti_2O_2Pn (Pn:pnictogen) superconducting layers and various kinds of blocking (spacer) layers; the crystal structure is interesting due to the similarity to high-T_c systems. Similarly, BiS_2-based superconductors [15,16], discovered in 2012, also consist of superconducting BiS_2 layers and various kinds of blocking layers. Since new superconductors can be designed by replacing the structure of the blocking layers, such a layered superconductor system is a good playground for novel superconductivity with low dimensionality. In the paper by Mizuguchi, review of the discovery of the BiS_2-based superconductor and material design concept is introduced [17]. In addition, original work on the single crystal growth and superconducting properties of antimony substituted $NdO_{0.7}F_{0.3}BiS_2$ is reported by Demura et al. [18]

Layered materials have been revisited due to the discovery of topological insulators and related superconductors. In this issue, magnetoresistance, gating and proximity effects in ultrathin NbN-Bi_2Se_3 bilayers are reported [19]. Furthermore, in a layered conductor, Fulde–Ferrell–Larkin–Ovchinnikov (FFLO) phase can emerge. Croitoru and Buzdin give a review on the signatures and the underlying theoretical framework for FFLO states in quasi-low dimensional superconductors [20].

To study physics, chemistry, and application of layered superconductors, one of the most important contributions is growth of high quality single crystals. Therefore, we invited Nagao to review crystal growth technique for layered superconductors [21]. For various layered superconductors, the suitable method to grow high quality crystal is introduced.

3. Conclusions

As introduced here, we have published 11 papers related to *Layered Superconductors*. Although about 30 years have passed since the discovery of the cuprate system, the field of layered superconductors is still developing. One of the ultimate goals of this field may be the discovery of a room-temperature superconductor and its application. Recently, superconductivity with T_c = 203 K under extremely high pressure has been achieved in H_3S [22,23]. This fact encourages our field because of the realization of very high T_c exceeding the cuprate record. If we could reproduce the superconducting states of H_3S in a layered structure, we will be able to approach room-temperature superconductivity. I hope that this special issue is useful for further development of this field toward the ultimate goal.

Acknowledgments: I express thanks to the authors of the above contributions, and to the journal Condensed Matter and MDPI for their support during this work.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Bednorz, J.B.; Müller, K. Possible high T_c superconductivity in the Ba−La−Cu−O system. *Z. Phys. B Condens. Matter* **1986**, *64*, 189–193. [CrossRef]
2. Wu, M.K.; Ashburn, J.R.; Torng, C.J.; Hor, P.H.; Meng, R.L.; Gao, L.; Huang, Z.J.; Wang, Y.Q.; Chu, C.W. Superconductivity at 93 K in a new mixed-phase Y-Ba-Cu-O compound system at ambient pressure. *Phys. Rev. Lett.* **1987**, *58*, 908. [CrossRef] [PubMed]
3. Maeda, H.; Tanaka, Y.; Fukutomi, M.; Asano, T. A New High-T_c Oxide Superconductor without a Rare Earth Element. *Jpn. J. Appl. Phys.* **1988**, *27*, L209. [CrossRef]
4. Schilling, A.; Cantoni, M.; Guo, J.D.; Ott, H.R. Superconductivity above 130 K in the Hg–Ba–Ca–Cu–O system. *Nature* **1993**, *363*, 56–58. [CrossRef]
5. Nagamatsu, J.; Nakagawa, N.; Muranaka, T.; Zenitani, Y.; Akimitsu, J. Superconductivity at 39 K in magnesium diboride. *Nature* **2001**, *410*, 63–64. [CrossRef] [PubMed]
6. Kamihara, Y.; Watanabe, T.; Hirano, M.; Hosono, H. Iron-Based Layered Superconductor $La[O_{1-x}F_x]FeAs$ (x = 0.05–0.12) with T_c = 26 K. *J. Am. Chem. Soc.* **2008**, *130*, 3296–3297. [CrossRef] [PubMed]

7. Ren, Z.A.; Lu, W.; Yang, J.; Yi, W.; Shen, X.-L.; Zheng, C.; Che, G.-C.; Dong, X.-L.; Sun, L.-L.; Zhou, F.; et al. Superconductivity at 55 K in Iron-Based F-Doped Layered Quaternary Compound Sm[$O_{1-x}F_x$] FeAs. *Chin. Phys. Lett.* **2008**, *25*, 2215.
8. Adachi, T.; Kawamata, T.; Koike, Y. Novel Electronic State and Superconductivity in the Electron-Doped High-T_c T′-Superconductors. *Condens. Matter* **2017**, *2*, 23. [CrossRef]
9. Miller, J.H., Jr.; Villagrán, M.Y.S. Time-Correlated Vortex Tunneling in Layered Superconductors. *Condens. Matter* **2017**, *2*, 21. [CrossRef]
10. Geahel, M.; Jouanny, I.; Gorse-Pomonti, D.; Poirier-Quinot, M.; Briatico, J.; van der Beek, C.J. Edge Contamination, Bulk Disorder, Flux Front Roughening, and Multiscaling in Type II Superconducting Thin Films. *Condens. Matter* **2017**, *2*, 27. [CrossRef]
11. Imai, Y.; Nabeshima, F.; Maeda, A. Comparative Review on Thin Film Growth of Iron-Based Superconductors. *Condens. Matter* **2017**, *2*, 25. [CrossRef]
12. Rotter, M.; Tegel, M.; Johrendt, D. Superconductivity at 38 K in the Iron Arsenide ($Ba_{1-x}K_x$)Fe_2As_2. *Phys. Rev. Lett.* **2008**, *101*, 107006. [CrossRef] [PubMed]
13. Zhang, P.; Zhai, H.-F. Superconductivity in 122-Type Pnictides without Iron. *Condens. Matter* **2017**, *2*, 28. [CrossRef]
14. Yajima, T. Titanium Pnictide Oxide Superconductors. *Condens. Matter* **2017**, *2*, 4. [CrossRef]
15. Mizuguchi, Y.; Suzuki, K.; Kuroki, K. Minimal electronic models for superconducting BiS_2 layers. *Phys. Rev. B* **2012**, *86*, 220510. [CrossRef]
16. Mizuguchi, Y.; Demura, S.; Deguchi, K.; Takano, Y.; Fujihisa, H.; Gotoh, Y.; Izawa, H.; Miura, O. Superconductivity in Novel BiS_2-Based Layered Superconductor $LaO_{1-x}F_xBiS_2$. *J. Phys. Soc. Jpn.* **2012**, *81*, 114725. [CrossRef]
17. Mizuguchi, Y. Discovery of BiS_2-Based Superconductor and Material Design Concept. *Condens. Matter* **2017**, *2*, 6. [CrossRef]
18. Demura, S.; Otsuki, S.; Fujisawa, Y.; Takano, Y.; Sakata, H. Single crystal growth and superconducting properties of Antimony Substituted $NdO_{0.7}F_{0.3}BiS_2$. *Condens. Matter* **2017**, *3*, 1. [CrossRef]
19. Koren, G. Magnetoresistance, Gating and Proximity Effects in Ultrathin NbN-Bi_2Se_3 Bilayers. *Condens. Matter* **2017**, *2*, 14. [CrossRef]
20. Croitoru, M.D.; Buzdin, A.I. In Search of Unambiguous Evidence of the Fulde–Ferrell–Larkin–Ovchinnikov State in Quasi-Low Dimensional Superconductors. *Condens. Matter* **2017**, *2*, 30. [CrossRef]
21. Nagao, M. Crystal Growth Techniques for Layered Superconductors. *Condens. Matter* **2017**, *2*, 32. [CrossRef]
22. Drozdov, A.P.; Eremets, M.I.; Troyan, I.A.; Ksenofontov, V.; Shylin, S.I. Conventional superconductivity at 203 kelvin at high pressures in the sulfur hydride system. *Nature* **2015**, *525*, 73–76. [CrossRef] [PubMed]
23. Einaga, M.; Sakata, M.; Ishikawa, T.; Shimizu, K.; Eremets, M.I.; Drozdov, A.P.; Troyan, I.A.; Hirao, N.; Ohishi, Y. Crystal structure of the superconducting phase of sulfur hydride. *Nat. Phys.* **2016**, *12*, 835–838. [CrossRef] [PubMed]