論文 / 著書情報
Article / Book Information

題目(和文)	走査トンネル顕微鏡/分光法を用いた表面超構造を制御したSrTiO₃上の単層FeSeの超伝導特性の研究
Title(English)	Superconducting properties of monolayer FeSe on various surface superstructures of SrTiO₃ studied by scanning tunneling microscopy/spectroscopy
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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

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

FeSe, one of the iron-based superconductors (FeSCs), has been considered to be useful for understanding the origin of the superconductivity of FeSCs because it has the simplest crystal structure. Furthermore, monolayer (ML) FeSe on $SrTiO_3$ (001) (STO) has attracted great attention because the superconducting transition temperature (T_c) is 40-109 K, much higher than that of bulk (8 K), although the T_c is scattered between different experimental reports. The interaction at the FeSe/STO interface, such as electron doping or optical phonons, has been proposed as the origin of this high T_c. At this interface, the STO surface is present. Different surface superstructures have been reported for STO depending on the amount of oxygen vacancies or the STO surface termination (SrO or TiO_2). The oxygen deficiencies generate excess electrons on the STO surface, and the difference at the surface termination should also affect the amount of excess electrons. From this, it is anticipated that the amount of electron doping to FeSe can depend on the STO surface. In other words, the difference in the superstructure of STO may change the superconducting properties of ML FeSe, which may explain the variation in the reported T_c. However, there has been no systematic study concerning ML FeSe/STO focusing on the surface structure. In addition, there is no report of superconducting dome structure in this FeSe/STO system, although it has been reported in bulk FeSe. Only partial domes have been shown in the literature so far. The presence or absence of the dome can also be discussed based on the change in electron doping. Therefore, the purpose of this thesis is to investigate the superconducting properties of ML FeSe on STO with controlled surface superstructure.

In order to control the STO surface, the substrate was heated in ultra-high vacuum (UHV) or under an oxygen atmosphere. By changing the heating temperature under UHV ($P \sim 1\times10^{-9}$ Torr), $\sqrt{2}\times\sqrt{2}$ (annealed at 710 ◦C) and 2×1 (950 ◦C) structures were successfully prepared. By changing the heating temperature and time under oxygen atmosphere ($P_{O2} = 1\times10^{-5}$ Torr), $\sqrt{13}\times\sqrt{13}$ (1000 ◦C, 1 min) and c(6×2) (1000 ◦C, 3 min) structures were successfully prepared. After confirming the quality of the surface using reflection high energy electron diffraction, I deposited ML FeSe and performed scanning tunneling microscopy/spectroscopy (STM/STS) measurements at liquid Helium temperature (~5 K).

In the STM measurements, different periodicities were observed in the atomic resolution images of ML FeSe depending on the STO surface. This is due to the fact that the electronic structure of the substrate surface is observed through the FeSe and suggests that the bonding between FeSe and STO is strong. First, I found that the difference between $\sqrt{2}\times\sqrt{2}$ and 2×1 structures are likely due to different terminations. Secondly, I found that the atomic structure of $\sqrt{13}\times\sqrt{13}$ has two-fold symmetry. Furthermore, I found that the observed periodicity changes depending on the slightly difference of the actual structure for c(6×2). Finally, by comparing the samples annealed for 5 min with each other, it was found that the excess Se at the interface is released differently depending on the STO surface structure. From these facts, I can say that the atomic resolution image measurements provided detailed information about the atomic structure of the STO surface itself.

In the STS measurements, the peak position of the valence band corresponding to the amount of electron doping changed depending on the surface superstructure. This can be explained by the difference in the amount of oxygen vacancies on the STO surface due to the change in the superstructure. The superconducting gap size also changed accordingly. The relation of the (electron doping level) - (superconducting gap size) shows a superconducting dome structure as seen in copper oxide superconductors. This is the first report that the presence of the superconducting dome has been clarified in this system. I also estimated the amount of electron doping by the STO superstructure based on the proposed structural models and found that this difference of doping level is generally explained by the amount of O vacancies. By estimating the doped electron density, it was found that not all of the excess electrons produced by the oxygen deficiency are used for the doping, but only a portion of them are.

In my research, it was unambiguously revealed that the amount of electron doping and the superconducting gap size of ML FeSe changes depending on the surface superstructure of STO. Not only does this provide insight into variation in T_c in previous studies, but it also provides hints to the unconventional superconducting mechanisms because superconducting domes are also commonly observed in unconventional superconductors.