量子物理学・ナノサイエンス第 218 回セミナー

From ferromagnetism to nonmagnetism to superconductivity in cobalt

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概　要

It has been over a century since the discovery of the phenomenon of superconductivity. A majority of elements in the periodic table have shown superconductivity. Usually metals possessing strong long-range magnetic order, as in antiferromagnetism or ferromagnetism, do not exhibit superconductivity. This includes ferromagnetic transition metals Fe, Co and Ni. Some elements, which do not show superconductivity under ambient pressure, become superconducting under higher pressure. Fe has been found to undergo a superconducting transition at pressures between 15 and 30 GPa with a critical temperature (T_c) of about 2 K [1]. Fe is nonmagnetic at this pressure. However, superconductivity was hitherto not observed in Co and Ni under any condition whatsoever. Recently, a high-density nonmagnetic (HDNM) phase of Co was discovered in Co thin films [2]. As this phase of Co is nonmagnetic, it was logical to explore superconductivity in this HDNM phase of Co. We have indeed discovered superconductivity in these HDNM Co thin films with a superconducting transition temperature (Tc) of ~ 5 K. The transition to the superconducting state has been detected by four-probe measurements. Point-contact spectroscopy has provided a Tc value of ~ 9.5 K. The higher value of Tc obtained in point contact spectroscopy is apparently due to unavoidable pressure at the contact point. First-principles density functional theory calculations for this dense fcc phase of Co show that this phase is nonmagnetic, characterized by zero elementary moment, and the estimated T_C within the BCS theory is 0.30 K. A volume preserving strain in fcc Co is shown to result in anomalous softening of zone boundary phonons which couple strongly with electrons, and stabilize superconductivity at a relatively large temperature (>5 K) [3]. The value of T_C can indeed be higher for other strain conditions.

[1] K. Shimizu et al., Nature **412**, 316 (2001).
[2] Nasrin Banu, S. Singh, B. Satpati, A. Roy, S. Basu, P. Chakraborty, H. C. P. Movva, V. Lauter and B. N. Dev, Sci. Rep. **7**, 41856 (2017).
[3] Nasrin Banu et. al., arXiv:1710.06114

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