Analyses of Upper Critical Fields of H-Substituted SmFeAsO Epitaxial Films Based on Single- and Multi-Band Models

Kota Hanzawa[1], Masashi Miura[2,3,4], Jumpei Matsumoto[1], Hidenori Hiramatsu[1,5], Hideo Hosono[5,6]

[1] *Materials and Structures Laboratory, Institute of Integrated Research, Institute of Science Tokyo, 4259 Nagatsuta-cho, Midori-ku, Yokohama 226-8501, Japan*

[2] *Graduate School of Science and Technology, Seikei University, 3-3-1 Kichijoji-kitamachi, Musashino-shi, Tokyo 180-8633, Japan,*

[3] *Materials Physics and Applications Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA,*

[4] *JST-FOREST, 7 Gobancho, Chiyoda-ku, Tokyo 102-0076 Japan,*

[5] *MDX Research Center for Element Strategy, Institute of Integrated Research, Institute of Science Tokyo, 4259 Nagatsuta-cho, Midori-ku, Yokohama 226-8501, Japan*

[6] *National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-004, Japan*

SmFeAsO possesses the highest critical temperature among the iron-based superconductors via H/F substitution. Although fabrication of $SmFeAsO_{1-x}H_x$ epitaxial films had been technologically difficult, we developed a H substitution process using topochemical reaction, and successfully obtained the films [1]. Then, high field measurements directly unveiled that the film exhibited the highest upper critical field ($H_{c2}(0)$) among them at low temperature limit [2]. For practical superconductor applications, critical current density (J_c) is another important property. Even though it is possible that the J_c is tuned and enhanced with pinning centers, the upper limit of J_c is restricted by depairing current (J_d). Thus, to achieve maximally high J_c, it is essential to understand J_d. In Ginzburg-Landau theory, the J_d is inversely proportional to coherence length (ξ), which is generally calculated from orbital-limiting field at 0 K. Therefore, estimation of $H_{c2}(0)$ is a key issue to investigating J_c. In this study, we analyzed H_{c2} of the $SmFeAsO_{1-x}H_x$ epitaxial films based on single- and multi-band models.

For single-band fittings, we employed Werthamer-Helfand-Hohenberg (WHH) theoretical model [3]. Figure 1a summaries the fitting results for H_{c2} under external fields applied along the *ab* plane (||*ab*). By changing the dominant fitting parameter α (Maki parameter), the $H_{c2}(0)$ varies between ~120 ($\alpha = 1.2$) and ~185 T ($\alpha = 0$). In ||*c* case, H_{c2} was fitted by using the clean limit two-band model [4]. The fitting curve is displayed in Figure 1b, where the $H_{c2}(0)$ was estimated to be 154 T. From the $H_{c2}(0)$, ξ was calculated to be as short as 1.46 nm. This short ξ results in an extremely high J_d value of ~415 MA/cm^2, which contributes to high J_c (~10 MA/cm^2) of $SmFeAsO_{1-x}H_x$ [5].

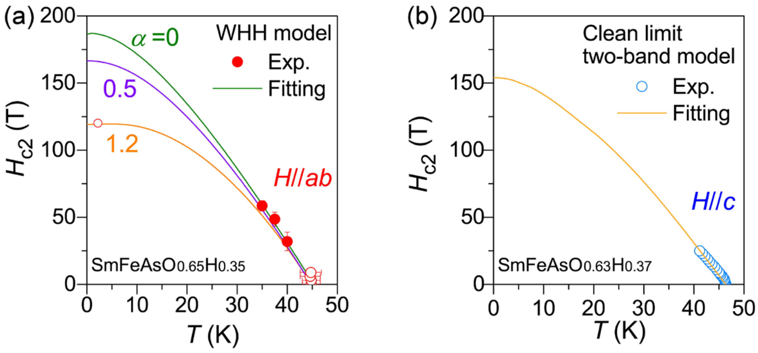

Figure 1: Fitting results for H_{c2} of $SmFeAsO_{1-x}H_x$ based on (s) single-band WHH and (b) two-band clean limit models.

References [1] J. Matsumoto, *et al. Phys. Rev. Mater.* 3, 103401 (2019). [2] K. Hanzawa, *et al. Phys. Rev. Mater.* 6, L111801 (2022). [3] E. Helfand, *et al. Phys. Rev.* 147, 288 (1966). [4] A. Gurevich, *Rep. Prog. Phys.* 74, 124501 (2011). [5] M. Miura, *et al. Nat. Mater.* 23, 1370–1378 (2024).