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Double-dimensional crossover in layered superconductor

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Abstract. The critical magnetic fields H_{c2} of superconducting layered structures V/Cu were investigated. The double-dimensional crossover 3D-2D-3D was observed on the temperature ($H'_{c2}(\theta)$) dependences of critical magnetic fields. The field crossover 3D-2D is caused by strong temperature dependence of superconducting coherence length ξ_s near T_c. The second crossover 2D-3D is provided by temperature dependence of normal metal coherence length ξ_N and reflects the 3D isotropization of layered structure V/Cu at low temperature.

1. Introduction

Dimensional crossover from three-dimensional (3D) to two-dimensional (2D) behaviour in S/N layered structures has been the subject of great interest during the last few years (Beasley 1980). The superconductivity in such structures is localized in S-layers (2D) at low temperatures, but the sharp increase of superconducting coherence length at $T \rightarrow T_c$ leads to appearance of large superconducting domain, which overlaps many layers (3D). Dimensional crossover should be observable in the temperature dependence of parallel critical magnetic field $H''_{c2}(T)$ and angular dependences $H_{c2}(\theta)$ at different temperatures. $H_{c2}(T)$ changes from square-root law ($H_{c2} \sim (T_c - T)^{1/2}$) to linear law ($H_{c2} \sim (T_c - T)$) as $T \rightarrow T_c$, while angular dependence $H_{c2}(\theta)$ changes from "cusp"-like (2D) to "soft" like (3D) behaviour, when temperature rises. However the low-temperature properties ($T \ll T_c$) of such structures have not been investigated properly.

2. Experiment

The temperature and angular dependences of upper critical field were investigated for magnetron-sputtered multilayers V/Cu with different thicknesses of vanadium and copper layers: $d_V = 25\,\text{nm}$, $d_{Cu} = 10$–$20\,\text{nm}$, and the number of layers $N_V = 10$, $N_{Cu} = 11$. The sample rotation inside the superconducting magnet was operated with accuracy of 0.1°, and the temperature was measured by a calibrated Ge-thermometer.

3. Results and discussion

Figure 1 shows the angular dependences $H_{c2}(\theta)$ for V/Cu (25 nm/10 nm) at different temperatures, where $\theta = 0°$ corresponds to parallel field. The transition of behaviour from "soft"-like (figure 1A) to "cusp"-like (figure 1B) near the $\theta = 0°$ orientation corresponds to 3D $\rightarrow$ 2D-dimensional transition mentioned above. At lower temperatures the "cusp"-like form of the dependence is maintained (figure 1C).