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THE NATURE OF MAGNETIC FIELD HYSTERETIC MICROWAVE ABSORPTION IN THE HTSC THIN FILMS AND HTSC MODELS EPITAXIAL SUPERLATTICES PbTe-PbS

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For the first time magnetic field nonresonant microwave absorption at 9.4 GHz in the thin film superconductive superlattices (001)PbTe-PbS (T_c=5,5 K) was investigated. These superlattices may be considered as structural HTSC models. It was found that absorption in the superlattices has similar peculiarities to ones in HTSC thin films. The influence of modulating magnetic field, temperature and other factors on the conditions of formation of various hysteretic absorption signals were analysed.

1. INTRODUCTION

EPR spectroscopy technique application to the investigation of the high-T_c superconductors (HTSC) lead to new investigations direction formation - HTSC microwave spectroscopy[1-4]. The aim of these investigations is to clarify the observed microwave response signals (MRS) nature and to determine the connection between MRS peculiarities and investigated samples parameters.

Superlattices PbTe-PbS /(001) KCl close structural analogs of YBaCuO-type system. Introduced on all (001)interfaces PbTe-PbS regular square misfit dislocations grids are responsible for superconductivity of SL and are modelling CuO_2 planes in HTSC structure.

2. EXPERIMENTALS

The epitaxial superlattices (SL) were grown on (001) KCl substrate using sequential deposition of PbTe and PbS in oil-free vacuum of 10^{-5} Pa at temperature of 520-570 K. Period of SL was determined by small-angle X-ray diffraction using Cu-K_α- radiation. Electron microscopy revealed regular square networks of edge misfit dislocations (MD) with period of 5,2 nm along <110> directions of PbTe-PbS interface.

In the present communication the MRS signals in superconducting PbTe-PbS SL were firstly detected and investigated. The superconductivity in this system is caused by the presence of above mentioned regular networks of MD on the interphase boundaries[5-11]. The experiments were carried out at T = 1.8- 10 K using the EPR spectroscopy standard technique at the frequency ν = 9.4 GHz with the aid of both modulational spectrometer ($\omega_m/2\pi$ = 100 KHz) and superheterodine one. The SL samples, consisting of the ≃ 20 interchanged PbTe-PbS layers of 15-18 nm thickness were used.

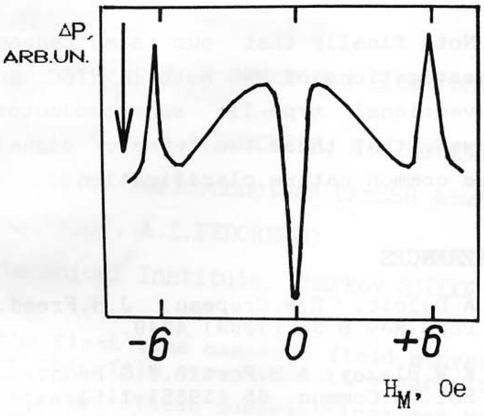

FIGURE 1
The view of direct microwave absorption signal ΔP for superlattice PbTe-PbS at T = 4.2 K. The sinusoidal sweeping of magnetic field H_M is used at frequency $\omega_m/2\pi$ = 50 Hz and amplitude about 6 Oe.

3. RESULTS

Direct microwave absorption signal ΔP at T = 4.2 K, registered oscillographically at the sinusoidal (50 Hz) magnetic field sweep in the interval ± 6Oe is shown at the fig.1. Three peculiar features can be seen: (a) narrow intensive absorption line with maximum at H = 0; (b) broad absorption line with minimum at H = 0 and approximately linear growth with H increase; (c) two symmetrical peaks near the H sweep extrema points, corresponding to ΔP decreasing. It is shown, that signal (b) is stationary one, i.e. can be observed at dH/dT→ 0 as well, instead of signals (a) and (c), which are unstationary and can be observed only if dH/dt ≠ 0. Main attention was paid to clarification of the unstationary MRS signals origin. It was got, that the latter ones has the nature, similar to hysteretic microwave losses signals, registered in the modulative regime (fig.2). The investigations of amplitude and shape of $\Delta P(\omega_m)$ and $\Delta P(2\omega_m)$ dependence on modulation amplitude H_m, slowly alternating external magnetic field H, character of H alternation, sample and H^{mw} (microwave magnetic component) and H mutual orientation and temperature permit to come to the conclusions about the observed unstationary signals origin. There are as follows the hysteretic absorption signal appears because of superconductive state destroying by the flow of screening current, induced by the alternating magnetic field at the sample remagnetization in the critical state.

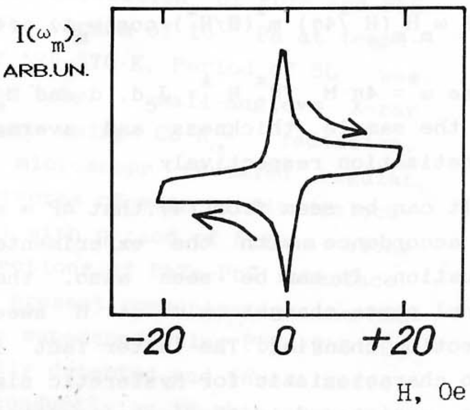

FIGURE 2
The first harmonic of microwave absorption hysteretic signal $I(\omega_m)$ registered at high frequency modulation of magnetic field $\omega_m/2\pi$ = 100 KHz and lock-in detection (T=4,2 K, H_m= 0,032 Oe).

According to the latter

$$\Delta P = A \cdot P(T), \quad (1)$$

where A is the proportional coefficient, P(T) is the absorbed power of alternating field value, which has form

$$P(T) = -V^{-1}\int M(dH/dt)dV, \quad (2)$$

where $M = (B-H)/4\pi$ is the sample magnetization, V is the sample volume. Calculations in the framework of critical state model for the

$$H(T) = H + H_m \sin(\omega t), \quad (3)$$

and in the supposition $J_c(B) \simeq 1/B$ (J_c is the sample critical current density) show, that at $H \gg H_m$ the amplitude of absorption signal first harmonic has the form

$$\Delta P = A \cdot \omega_m H_m (H^* / 4\pi) \cdot m^*(H/H^*) \cdot \cos(\omega_m t), \quad (4)$$

where $m^* = 4\pi \cdot M_{av}/H^*$, $H^* = J_c d$, d and M_{av} are the sample thickness and average magnetization respectively.

It can be seen from (4), that $\Delta P \propto m^*$ in accordance with the experimental situation. It can be seen also, that signal phase changes on π at H sweep direction changing. The latter fact is also characteristic for hysteretic signals, registered in the lock-in detection conditions (fig.2). The narrow line, observed near H= 0 (fig.1) is due to peculiar maximum near B=0 in the dependence $J_c(B)$. This is the reason of the same peculiarities in $m^*(H)$ and $\Delta P(H)$.

4. CONCLUSIONS

Note finally that our simultaneous investigations of MRS both in HTSC and conventional type-II superconductors showed, that these two types of signals have common nature clarification.

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