PHOTO-RESPONSE OF HIGH- T_c SUPERCONDUCTOR FILMS

高 T_c 超伝導膜の光応答

Moriaki WAKAKI, Tadashi SHIRAISHI* and Hiromitsu ASANO*

Department of Electro-Photo-Optics Engineering, Tokai University,
1117 Kitakaname, Hiratuka-shi, Kanagawa, 259-12 JAPAN
TEL:0463-58-1211 FAX:0463-59-2594

*Department of Communications, Tokai University,
1117 Kitakaname, Hiratuka-shi, Kanagawa, 259-12 JAPAN
TEL:0463-58-1211 FAX:0463-58-1812

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ABSTRACT

A photo-response of High- T_c superconducting films(Bi-Sr-Ca-Cu-O) was investigated to know the possibilities of high temperature operating superconducting photodetectors.

Bi-Sr-Ca-Cu-O films were deposited on MgO(100) substrates with AC sputtering. The photo-response was measured for a chopped He-Ne laser irradiation at the temperature from 10 to 300K. The signal was detected using a Lock-in Amp. at the chopping frequency of the laser radiation.

The photo-response of the films were observed at the temperature region of 10-80K. The signal showed a sharp maximum near T_c (about 70K) and linear current dependencies at whole temperatures, which implied the bolometric behaviour.

The detector performance including direct interactions with superconducting electrons in such as Vortex-flow detectors are discussed.

Key words:Photo-response,High- T_c superconductor, Bi-Sr-Ca-Cu-O, Sputtered film

1. INTRODUCTION

A photo-response of superconductor has been investigated using conventional low T_c superconductor materials.^{1,2} These materials interact with a radiation through a bolometric response or direct interaction with superconducting electrons.

Recently, the photo-response of High- T_c superconductors have been observed for bolometric responses³ and nonbolometric response⁴⁻⁷ mainly

in YBCO. But various factors such as defects, domain size, flux pinning and so on which affect the response are not fully studied especially in Bi-Sr-Ca-Cu-O films.

In this study, a photo-response of High- T_c superconductor films(Bi-Sr-Ca-Cu-O films, T_c :80K) was investigated to know the possibilities of high temperature operating superconductor photodetectors.

2. SAMPLE PREPARATION

Bi-Sr-Ca-Cu-O films were deposited on MgO (110) substrates with AC sputtering method.⁸

The substrates were maintained at about 650°C by a IR lamp during a deposition. Ar and O₂ gases were used as sputtering gases at the pressure of about 80x10⁻³ torr.

The sputtering targets were prepared through a calcination and sintering processes to the form of the diameter of 15mm and the thickness of 2mm.

The film samples used for this experiments have thicknesses of about 400nm.

The X-ray diffraction (XRD) peaks for the film are shown in Fig. 1. A Bi₂Sr₂CaCu₂O_x structure (T_c=80K) are suggested from these XRD peaks.

Fig.1. X-ray diffraction pattern of Bi-Sr-Ca-Cu-O film.

3. EXPERIMENTAL PROCEDURES

The temperature dependences of the resistivity were measured using conventional four probes method within the cryostats in the temperature region of 10-300K.

The photo-responses of the films were observed for a chopped (15Hz) He-Ne laser irradiation (about 1mW)

at the temperature of 10-300K as shown in Fig. 2. The signal was detected with a Lock-in amplifier and recorded to the recorder.

Fig.2. Schematic diagram of photo-response experimental setup.

4. RESULTS AND DISCUSSIONS

The current dependences of photo-responses are shown at various temperatures in Fig. 3.

Fig.3. Current dependences of photo-responses at various temperatures.

Non-linear increases followed by linear increases of photo-response are observed up to 80K, which corresponds to the critical temperature T_c . The linear increase of photo-response corresponds to the bolometric behavior of the film. The photo-response of bolometer are written as

$$R_v = (dR/dT)I/\kappa(1+\omega^2\tau^2)^{1/2}, (4.1)$$

where R :resistivity, κ :thermal conductivity, ω :chopping frequency, τ :thermal response time.

As suggested from this relation, the photo-response (R_v) is proportional to the bias current.

The linear parts in Fig. 4 are considered to correspond to the response.

R_v shows the saturated curve after the linear part and the saturation occurs at lower current as the temperature increases, which may be ascribed to the Joule heating of the sample.

The nonlinear parts are well observed at low temperatures. At low temperature Vortex-flow type photo-responses are expected, especially lower than T_{KT} (Koster-Thouless 2D topological phase transition temperature).

Around T_{KT} , R_v is proportional to I^3 . The nonlinear parts are observed strongly below about 30K. Current dependences of R_v at small current are shown in Fig. 4. R_v increases more rapidly than power 3 at 10K. To clarify the assumption, it is required to measure R_v at high frequency chopping or for pulsed light. Bolometric response cannot follow such a rapid change and only the non-bolometric response may be

observed.

Fig. 4. R_v vs. I at small current region.

The temperature dependences of R_v at various currents are shown in Fig. 5. R_v is not shown for large currents because of the upper limit of the output voltage of the voltage supply. To see the feature of the temperature dependence of R_v , the curve for $I=8\text{mA}$ are picked up in Fig. 6. The sharp maximum of R_v are seen around 70K and broad shoulder is followed at lower temperature side.

Resistivity(R) vs. T and its derivative dR/dT are also shown in Fig. 6. The sharp maximum corresponds to the peak of dR/dT , which means the bolometric effect. But low temperature side shoulder is not explained, the origin of which is now under consideration.

Fig. 5. R_V vs. T at various currents.

Fig. 6. Temperature dependences of R_V ($I=8\text{mA}$), R , dR/dT .

5. CONCLUSION

The photoresponse (R_V) of Bi-Sr-Ca-Cu-O thin films deposited with AC sputtering method on MgO(100) were observed at various temperatures and bias currents.

R_V vs. T curves show maximum at about the maximum of the temperature derivative of electrical resistivity, which suggests the bolometric effect near T_C .

At lower temperature, R_V vs. I curve shows non-linear increase at small current, which suggests nonbolometric response.

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