Evaluation of E-J characteristics of YBCO-coated conductor in a wide range of electric field

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Abstract

The E-J characteristics were measured for a YBCO-coated conductor by using the four probe method, third harmonic voltage and the relaxation method of DC magnetization at relatively high electric field($E = 10^{-3} \sim 10^{0}$), middle electric field($E = 10^{-6} \sim 10^{-5}$), extremely low electric field($E = 10^{-8} \sim 10^{6}$), respectively. Inductive measurement of third harmonic voltage induced by an AC magnetic field at various frequencies was used for estimation of the E-J characteristics at middle electric fields. Obtained E-J characteristics at various temperatures and DC magnetic fields are compared with theoretical analysis of the flux creep theory.

Keywords: YBCO-coated conductor, flux creep-flow model, third harmonic voltage

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1 Introduction

YBCO is most promising for a power application because of a superior critical current characteristic at high magnetic fields in various high-T_c superconductors. The critical current characteristic is crucial for applications. This characteristic depends on the electric field and the range of electric field that the superconductor experiences is different depending on the kind of application. For example, AC power cable is used in relatively high electric field region, while NMR device is used in extremely low electric field region. Recently long YBCO coated conductors with high critical current are successfully fabricated. Application of such conductor is really expected. This is why the evaluation of E-J characteristic of YBCO coated conductors in a wide range of electric field is necessary. The E-J characteristic at relatively high electric field and extremely low electric field region are measured by 4 probe method and relaxation method of DC magnetization. However these method cannot measure E-J characteristic at middle electric field region in addition to this 4 probe method is destructive and relaxation method of DC magnetization cannot measure the large sample. In this study, E-J characteristic is measured by inductive method using third harmonic voltage in addition to the 4 probe and relaxation method. This method can measure large sample and measure at middle electric field region.
flux creep-flow model・・・・

2 Experimental

The specimen measured is an YBCO coated wire made by IBAD method. The specification of the specimen is shown in Table 1. The third harmonic voltage was measured in a magnetic field along the c-axis in a vtemperature range of 60 ～ 85 K. The coil(400 turns, inner winding diameter of 2 mm, outer diameter of 6.05 mm, and height of 1.12 mm)are mounted about 0.27 mm above superconducting film. The current density, J, and the electric field, E, are estimated by the following equations

$$J = \frac{2K}{d} I_{\mathrm{c0}} \tag{1}$$

$$E = \frac{3\sqrt{3}}{8} \mu_0 \omega J d^2 \tag{2}$$

In the above K is the coil factor. According to previous study, the E-J characteristic by 4 probe method agree with by relaxation method. So the coil factor determined 合うように。 d is the thickness of superconductor, $I_{\mathrm{c0}}$is the coil current when the third harmonic voltage generated in the coil.

The magnetic relaxation was measured in a magnetic field along the c-axis in a temperature range of 50 ～ 77 K using a SQUID magnetometer. The magnetic field of sufficient strength was first applied to the specimen, and then reduced to an aimed value, and the relaxation of the magnetic moment, m, was measured. The current density, J, and the electric field, E, are estimated by the following equations

$$J = \frac{12m}{w^2 d(3l - w)} \tag{3}$$

$$E = -\frac{\mu_0}{2d(l + w)} \frac{\mathrm{d}m}{\mathrm{d}t} \tag{4}$$

In the above l is the length, w is the width and d is the thickness of specimen.

The four probe method was also used in the magnetic field parallel to the c-axis to measure the E-J characteristics in the range of relatively high electric field in a temperature at 70 K.

3 Results and Discussion

Figure 1 shows the magnetic dependence of I_0-V_3 characteristics at 70 K, 130 Hz. Cleary the I_{c0} decreases with increasing H_0, namely, J_c is decreasing. Figure 2 shows the f dependence at 70 K,3 T. The I_{c0} increase with increasing f. The E-J characteristics at 70 K,77 K,85 K,are shown Figs. 3, Figs. 4 and Figs. 5. The data obtained by the 4 probe method, third harmonic voltage, relaxation method are distributed in the resions of relatively high, middle, and extremely low electric field.

4 Summary

3 通りの手法を用いて, 広範囲電界領域での E-J 特性を評価した。四端子法と SQUID 磁力計による特性はよく一致していたが, 第三高調波による特性でずれが見られた。この原因として, 銀による遮蔽の可能性を考えたが有限要素法でシミュレーションを行ったところ, 本研究で用いた周波数領域では大きな影響は無いことがわかった。また,

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Table 1. Specification of specimen.

	T_c(K)	l(mm)	w(mm)	d(μm)
relaxation	91	4.7	5	1.0
V_3	91	10	10	1.0

Figure 1 説明 1

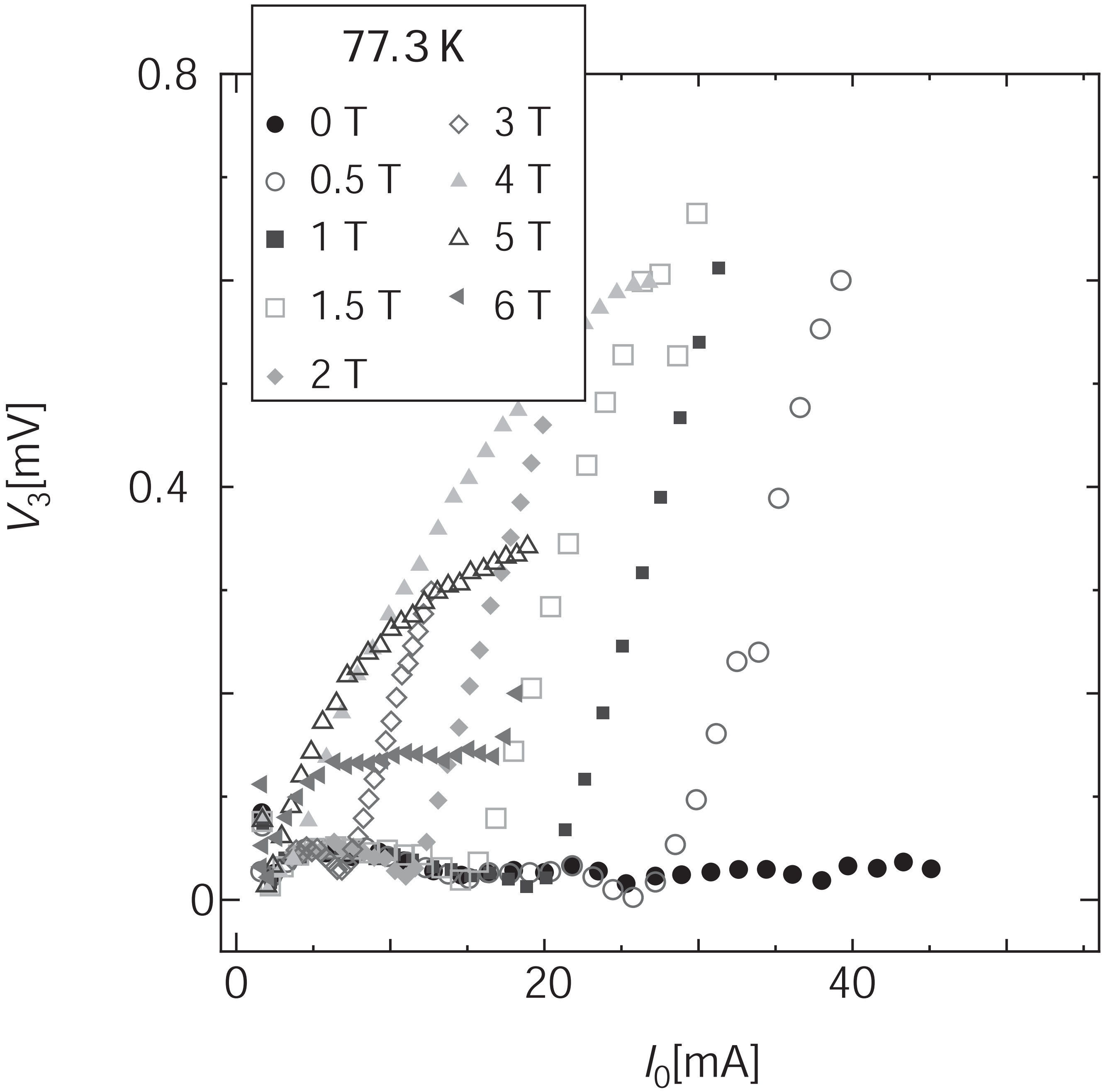

Figure 1: Y. Fukumoto *et al.*/WSP–31/ ISS2003

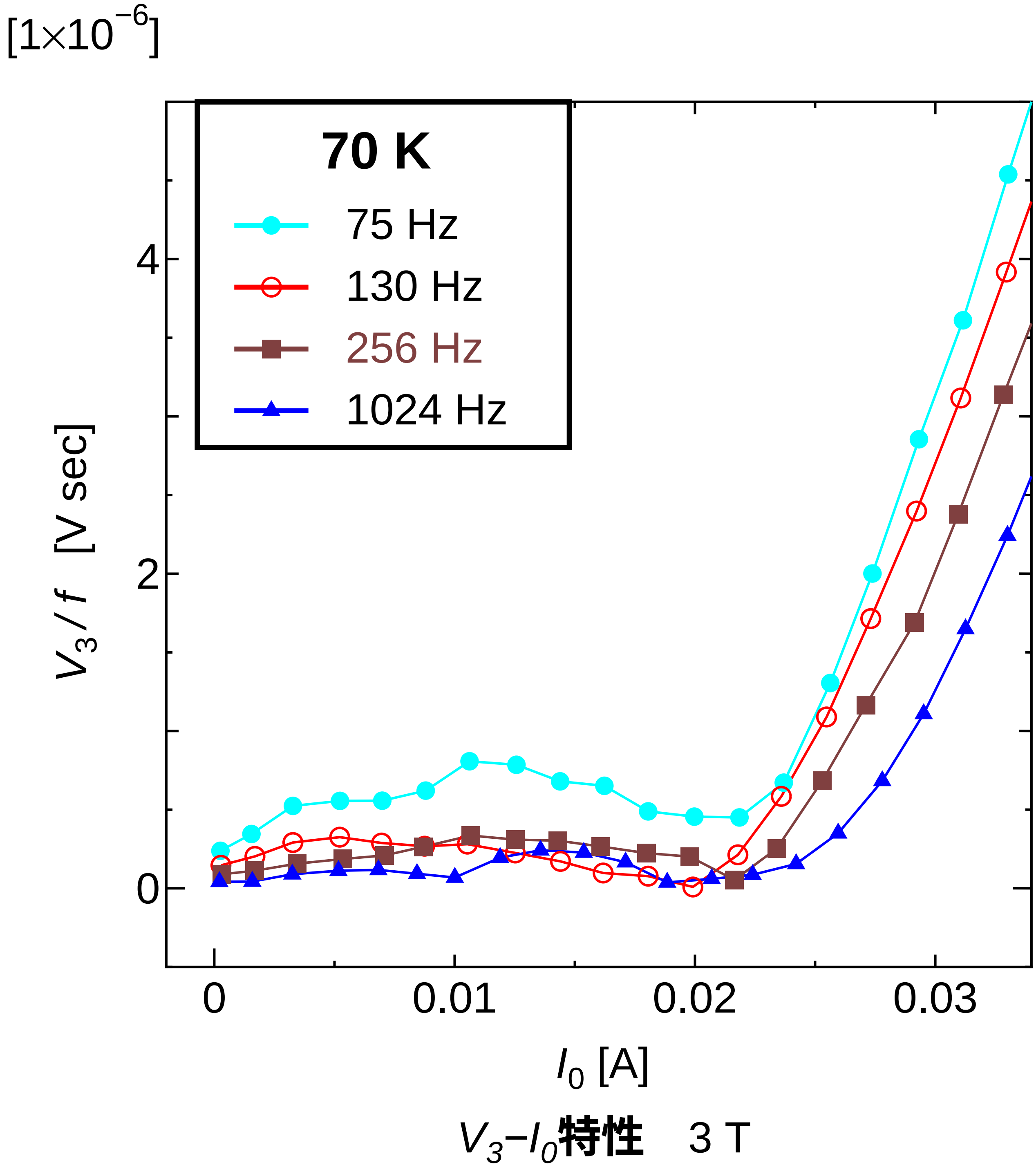

Figure 2: Y. Fukumoto *et al.*/WSP–31/ ISS2003

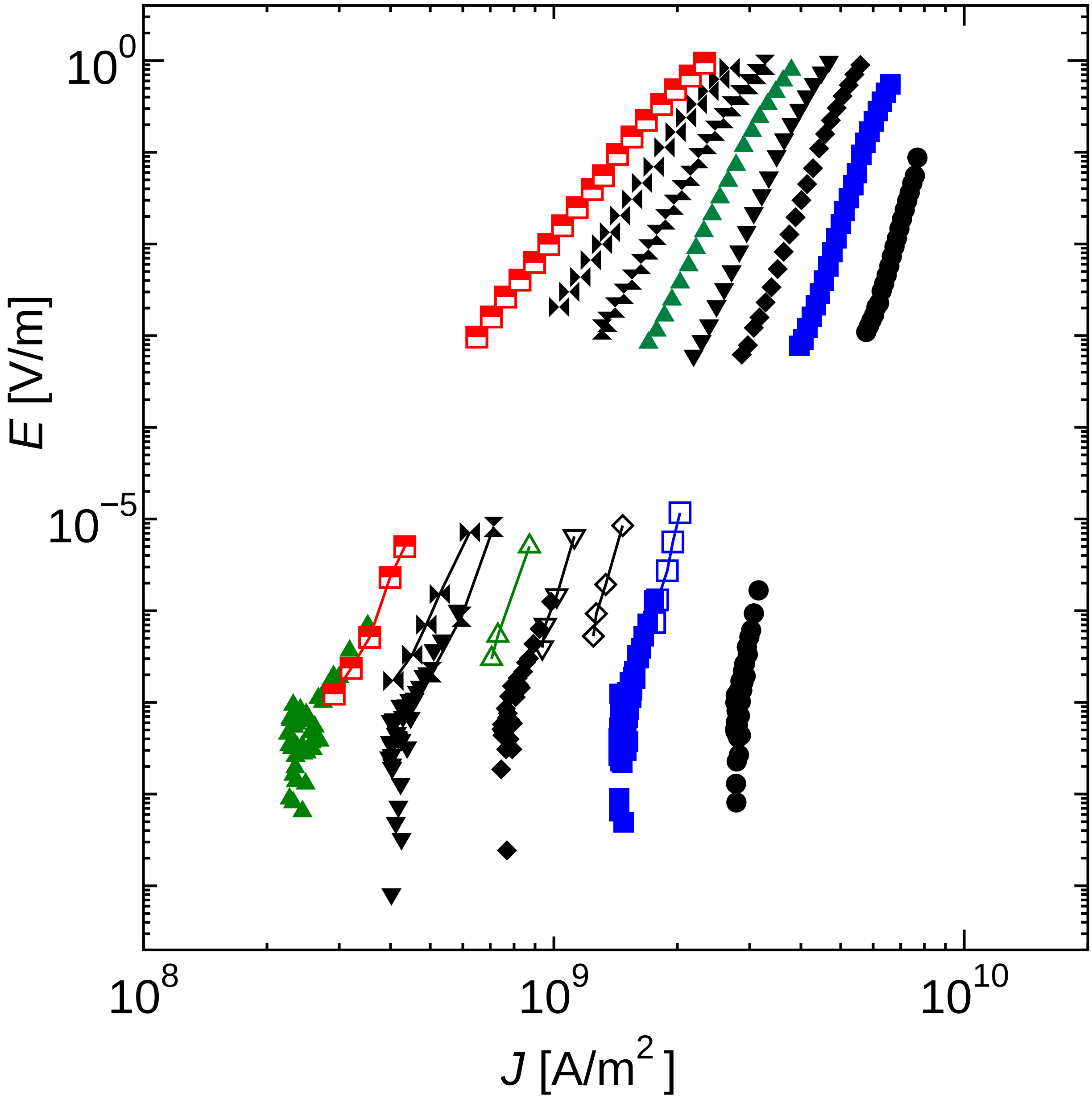

Figure 3: Y. Fukumoto *et al.*/WSP–31/ ISS2003

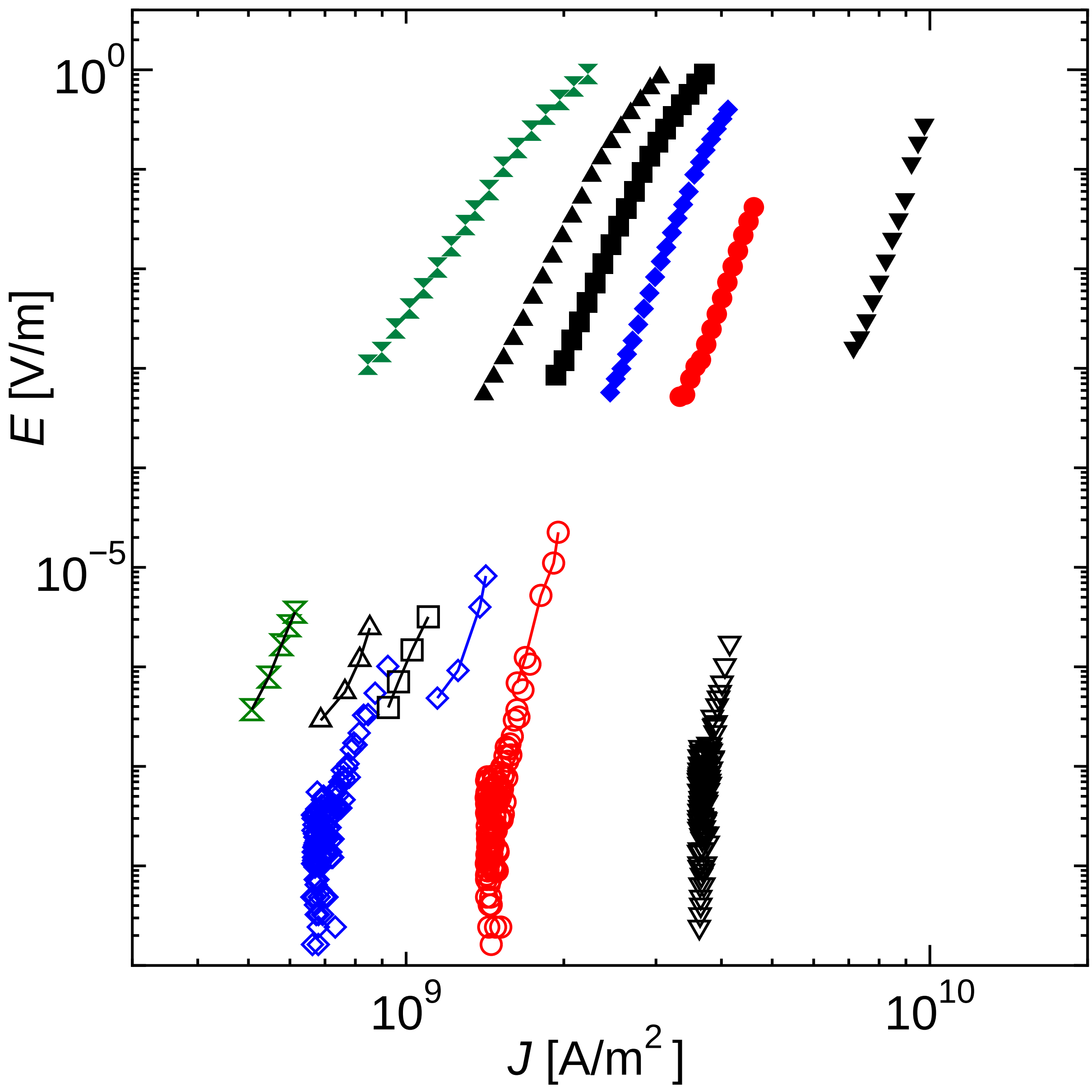

Figure 4: Y. Fukumoto *et al.*/WSP–31/ ISS2003

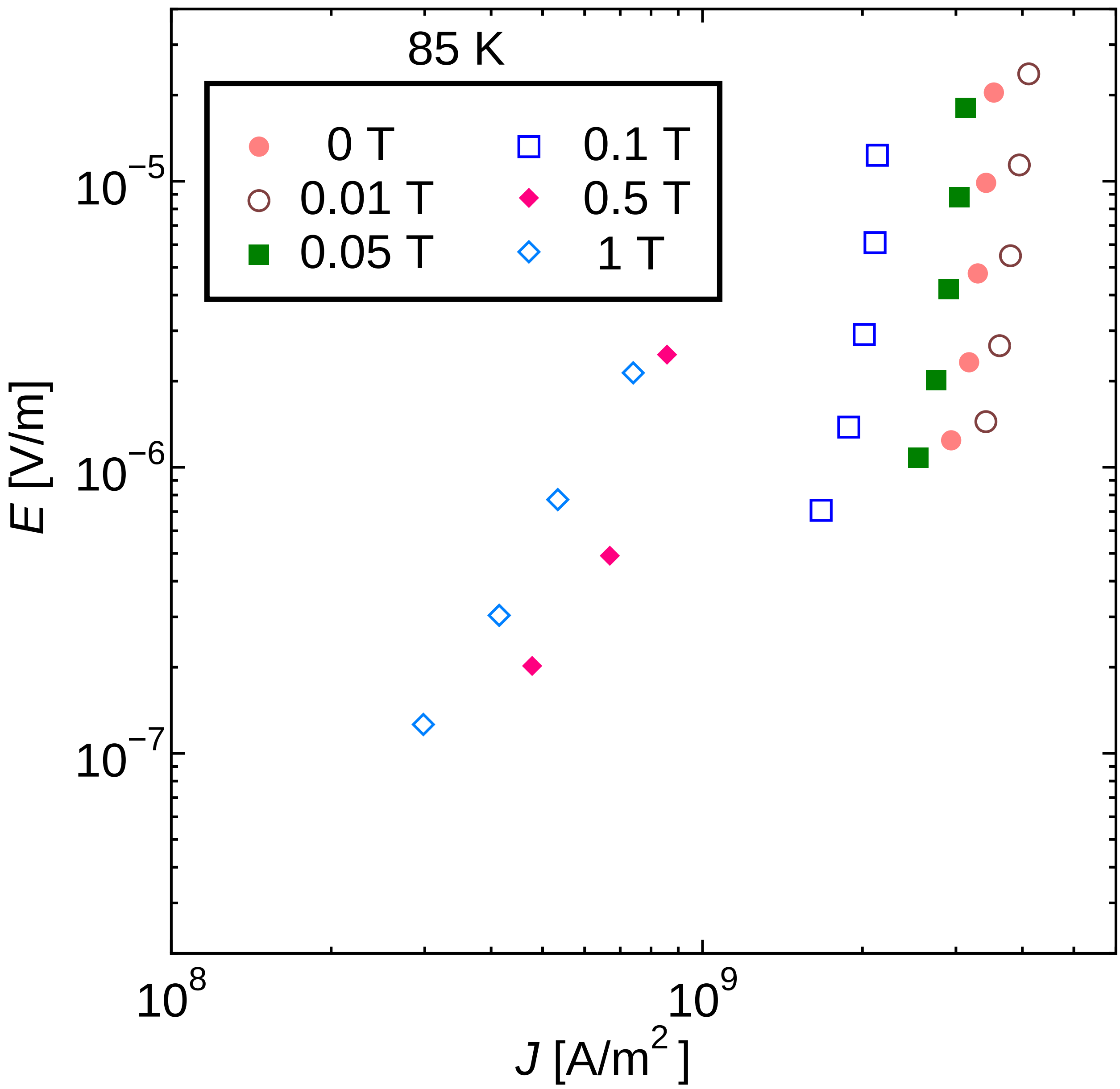

Figure 5: Y. Fukumoto *et al.*/WSP–31/ ISS2003