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TITLE: µSR INVESTIGATION OF MAGNETISM AND SUPERCONDUCTIVITY IN $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$

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μSR INVESTIGATION OF MAGNETISM AND SUPERCONDUCTIVITY IN $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$

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Muon spin rotation and relaxation techniques have been used to study the superconductivity and magnetism in $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ $(0 \leq x \leq 1)$ and $PrBa_2Cu_3O_6$. Clear evidence for magnetic ordering of the Cu moments within the Cu-O planes is seen. Additionally, a lower magnetic transition is observed which, based upon previous work, has been associated with the ordering of Pr moments on the Y sublattice of the $YBa_2Cu_3O_7$ structure. For x = 1, the upper Néel temperature T_{N1} is ~ 270 K and the magnitude of the fully developed local magnetic field is ~ 16 mT. Below the lower Néel temperature T_{N2} = 17 K, the magnitude of the static field is reduced to ~ 12 mT. For $0.4 \leq x \leq 0.54$, there appears to be a coexistence region of long-range magnetism and superconductivity.

Key Words: muon spin rotation; magnetization, phase diagram, substitution effects.

1. INTRODUCTION

The substitution of Pr for Y in $YBa_2Cu_3O_7$ (YBCO) causes a depression of T_c with increased doping [1]. T_c vs. x in $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ follows the classic Abrikosov-Gor'kov pair-breaking curve with $T_c \rightarrow 0$ K for $x \cong 0.6$. The depairing mechanism is presumably due to strong f-spd hybridization between the nearly tetravalent Pr ion and the charge carriers in the adjacent Cu-O planes [1,2]. Complete pseudo-binary alloys of YBCO and PrBCO can be prepared; the structure remains orthorhombic for $0 \leq x \leq 1$ with a slight decrease in the orthorhombic distortion for increasing x [1]. In addition, the oxygen content remains stable for $0<x<1$ [1].

2. EXPERIMENTAL

Zero-field muon spin relaxation (ZF-μSR) measurements on polycrystalline samples of $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ and $PrBa_2Cu_3O_6$ were conducted at the Los Alamos Clinton P. Anderson Meson Physics Facility (LAMPF) using standard techniques [3]. High-resolution x-ray diffraction studies showed that the samples crystallized in an orthorhombic structure for all values of x, and that each contained less than 2% impurity phases.

3. RESULTS

Representative ZF-μSR spectra for $PrBa_2Cu_3O_7$ taken at 300 K and 180 K are shown in Figs. 1(a) and 1(b). At 300 K the internal magnetic field is due to randomly oriented, quasi-static Cu nuclear moments, which depolarize the muon according to $G(t) = \exp[-(1/2)\sigma^2 t^2]$, where σ is a Gaussian depolarization rate related to the second moment of the local field distribution at the muon site. The solid line of Fig. 1(a) is a Gaussian fit to the data with $\sigma = 0.36\ \mu s^{-1}$. In contrast, the spectrum taken at 180 K shows oscillatory behavior with a well-defined muon frequency. This is clear evidence for the existence of an ordered, local magnetic field. The corresponding Fourier transforms of the spectra shown in Figs 1(a) and 1(b) are given in Figs 2(a) and 2(b). The discrete muon precessional frequency at 1.35 MHz (T=180 K) is obvious. Similar data taken on

$(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ as a function of both T and x are summarized in Fig. 3. The ZF-μSR data show that magnetic ordering occurs in this system and that the onset temperature is strongly concentration dependent, similar to the results obtained for oxygen-deficient YBCO [4].

Careful examination of the ZF-μSR data for x = 0.5, taken as a function of temperature, shows that the assignment of a well-defined frequency is tentative. Above T=17 K the full muon asymmetry is measured and the muon depolarization is nearly Gaussian, as shown in Fig. 5. Below this temperature there develops a fast relaxing component of the asymmetry in addition to a long-time tail. Because the asymmetry is low and the relaxation rate is high it is difficult to obtain a good fit to the data. Interestingly, at the lowest temperature measured (3.5 K) we find that the best fit to the data is obtained with a spin-glass function. Similar results were obtained for x=0.54, 0.56, and 0.58.

Magnetic ordering occurs in $PrBa_2Cu_3O_6$ above 300 K, which is the highest operating temperature of our apparatus. In the temperature interval 12 K ≤ x ≤ 300 K two well-defined frequencies are observed indicative of two magnetically inequivalent muon stopping sites. At 250 K and 15 K the measured frequencies are ν_1 = 1.5 MHz and ν_2 = 3.5 MHz; ν_1 = 2.2 MHz and ν_2 = 4.7 MHz, respectively.

4. CONCLUSIONS

ZF-μSR results show that magnetic ordering occurs in $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ for x≥0.5. It is suggested that the antiferromagnetism is attributed to ordering of the Cu moments within the Cu-O planes, similar to YBCO. Near x=0.5 there appears to be a region of coexistent magnetism and superconductivity; data suggest that the crossover regime is spin-glass-like. $PrBa_2Cu_3O_6$ also exhibits magnetism in the temperature range investigated (12 K≤T≤300 K).

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FIGURE CAPTIONS

Fig. 1. ZF-μSR spectra for $PrBa_2Cu_3O_7$ taken at (a) 300 K and (b) 180 K. The oscillatory pattern in (b) is clear evidence for magnetic ordering. No ordering is evident in (a).

Fig. 2. Fourier transforms of the ZF-μSR spectra shown in Fig. 1(a) and 1(b). No discrete frequency is observed at 300 K. At 180 K a well-defined single frequency is evident, which is due to ordering of the local magnetic field.

Fig. 3. ZF-μSR frequencies for $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ [x=1.0, 0.8, 0.6, and 0.5] as a function of temperature. Néel temperatures are T_{N1} ~ 270 K, 220 K, 20 K, and 10 K, respectively. The precipitous drop in frequency near 20 K (for x = 1.0) and 7 K (for x = 0.6) is due to additional magnetic ordering.

Fig. 4. Phase diagram for $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$. T_{N1} corresponds to antiferromagnetic ordering of Cu moments within the Cu-O planes as determined by ZF-μSR . T_{N2} and T_c were deduced from specific heat, susceptibility, neutron scattering, and μSR measurements.

Fig. 5. ZF-μSR spectra for $(Y_{0.5}Pr_{0.5})Ba_2Cu_3O_7$ taken at T=20 K, 12 K, and 3.5 K. Magnetic ordering occurs near 17 K.

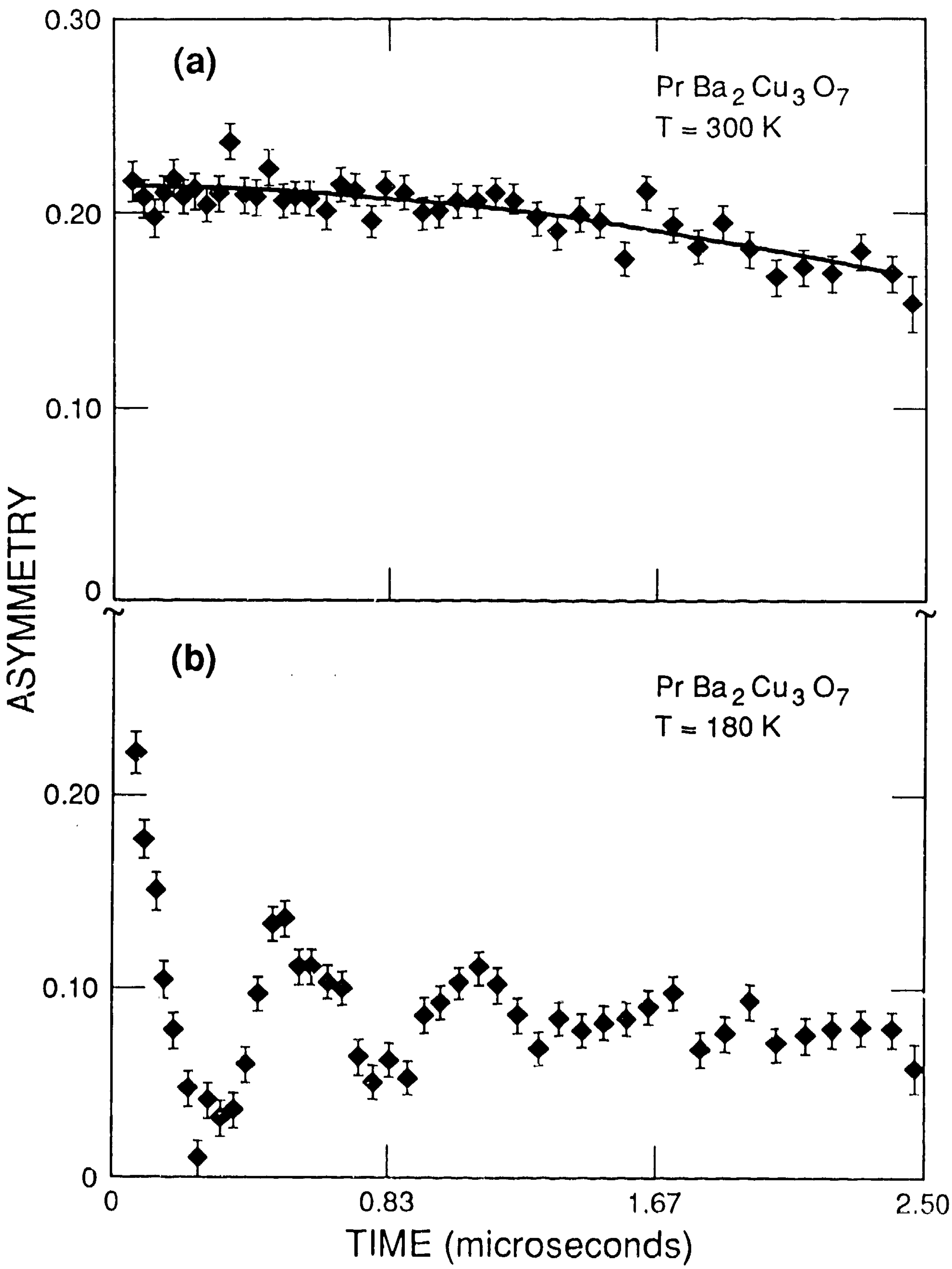

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FIG. 1

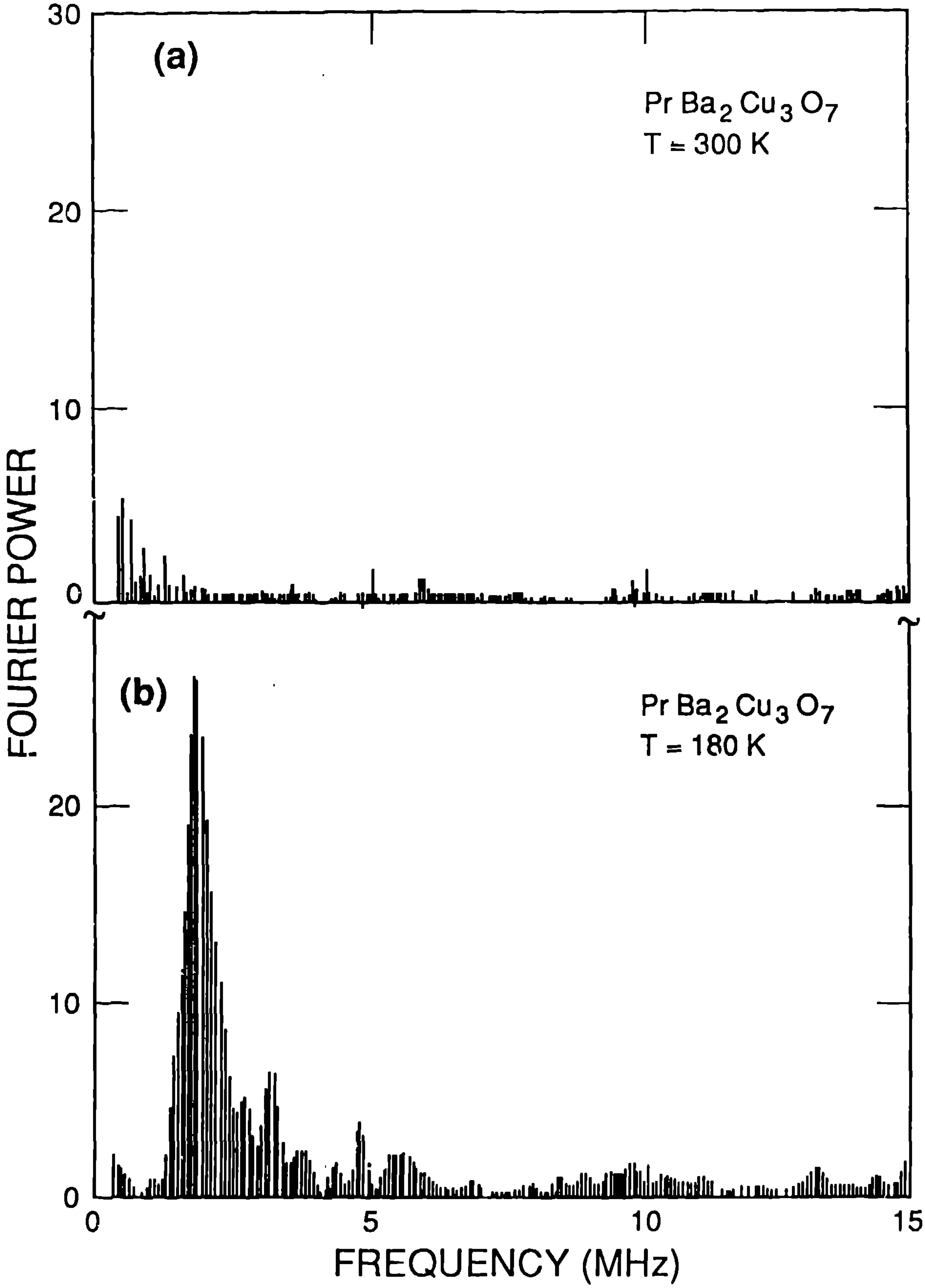

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FIG. 2

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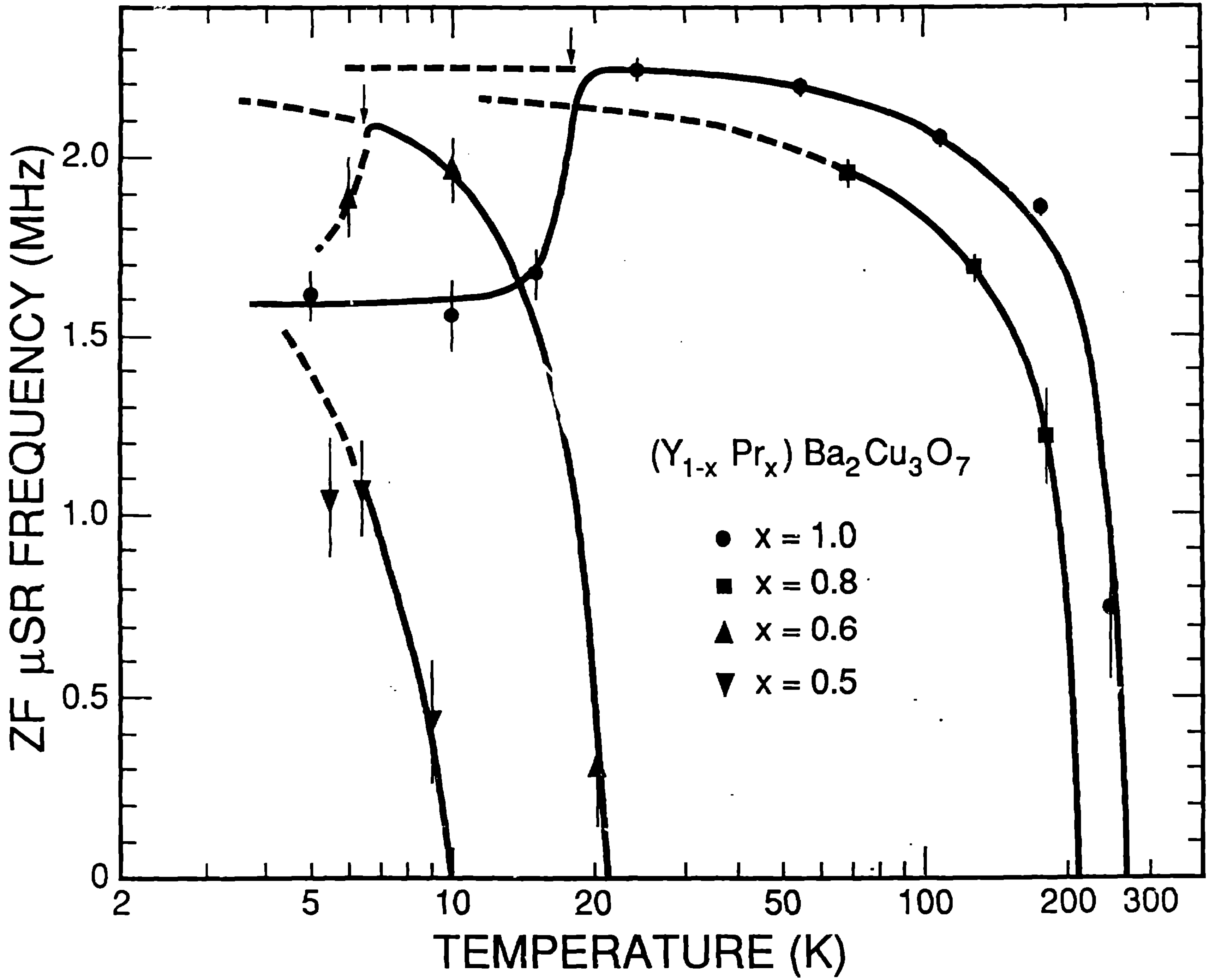

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FIG. 3

89103599-4 RD

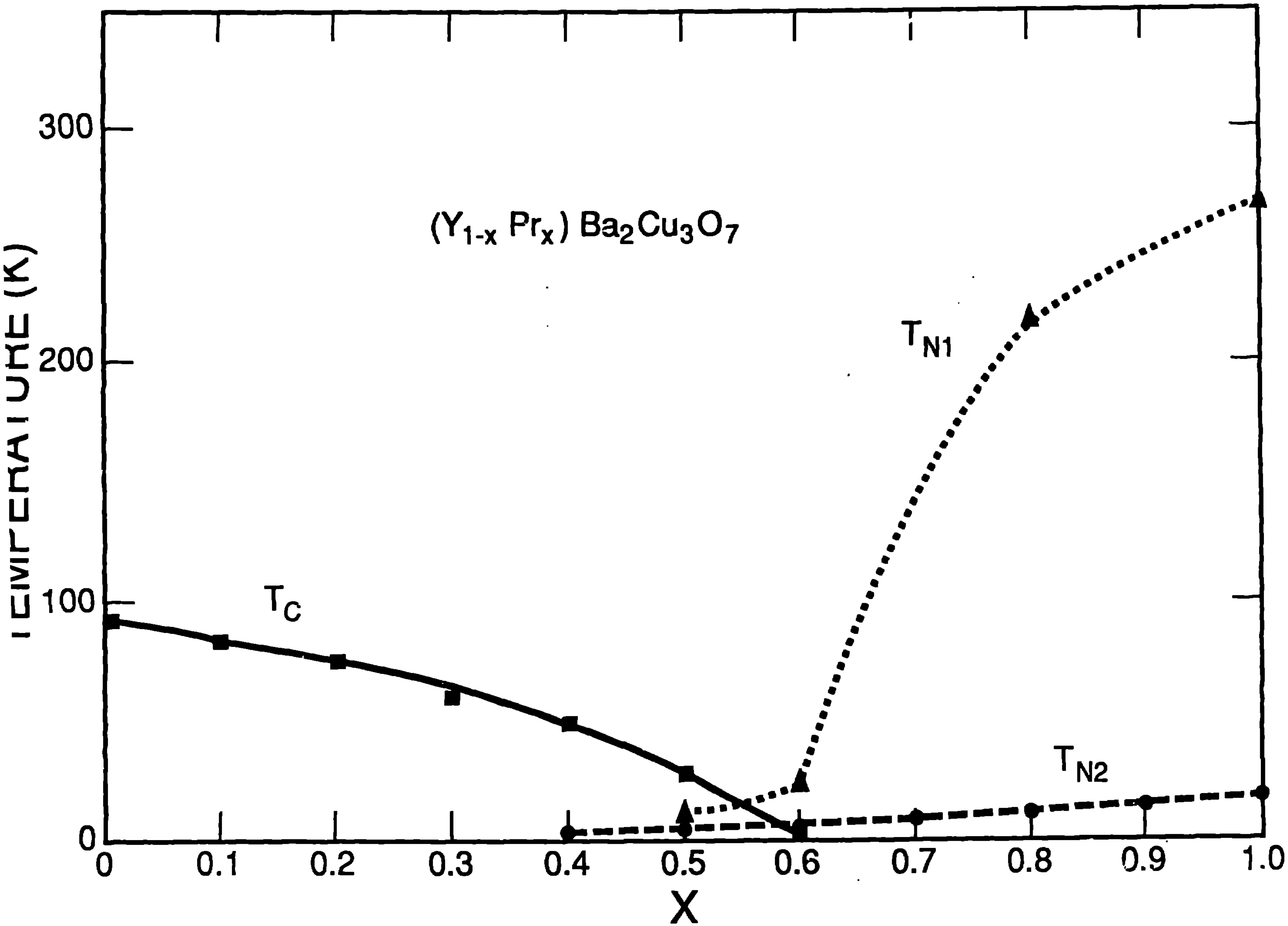

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FIG. 4

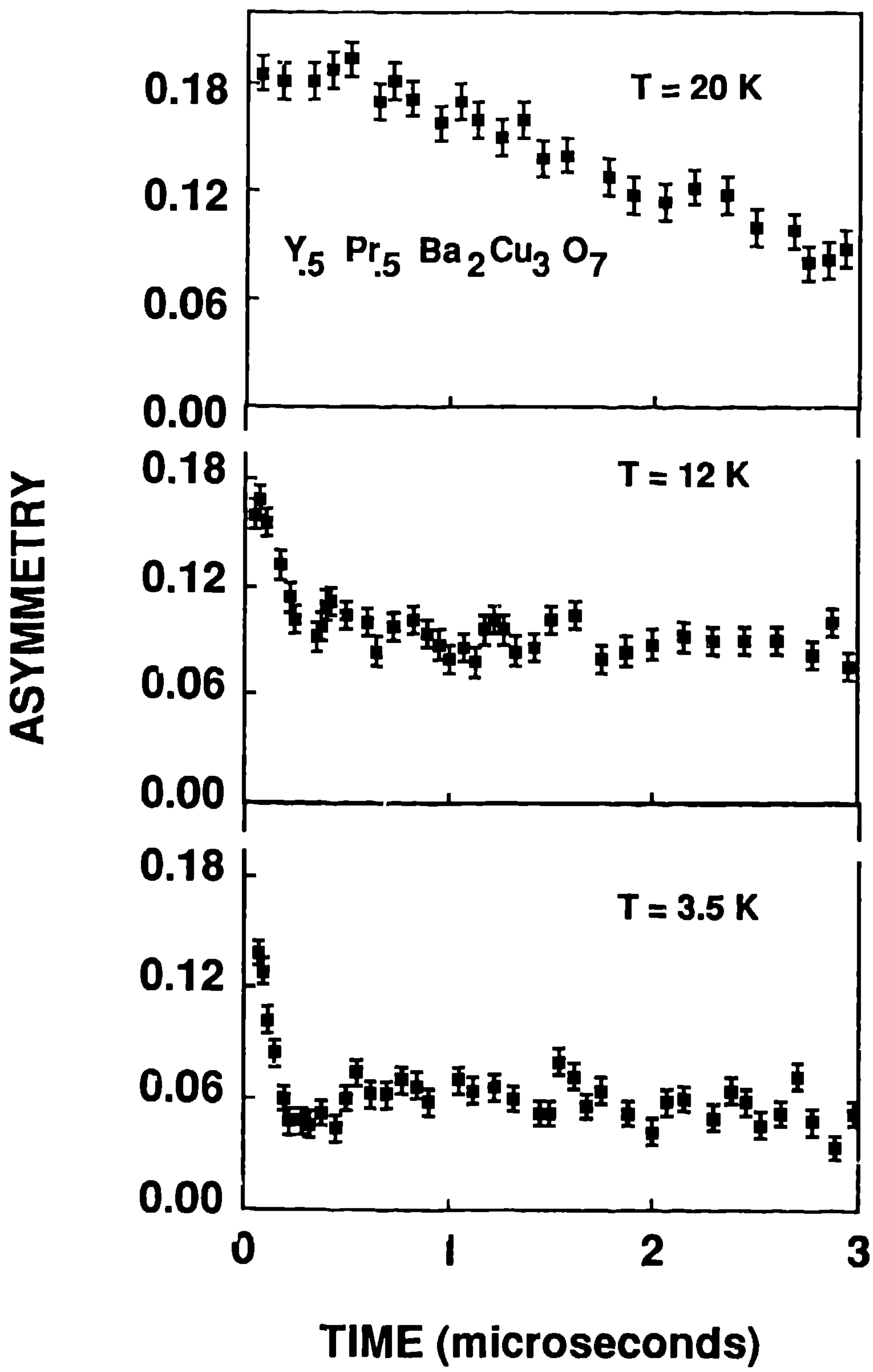

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FIG. 5