実験報告書様式（一般利用課題・成果公開利用）

（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。 ）

| MLF Experimental Report | 提出日 Date of Report |
| --- | --- |
| 課題番号 Project No.<br>2013A0084<br>実験課題名 Title of experiment<br>μSR study of annealing effect on the magnetism in T'-structured cuprate oxides<br>実験責任者名 Name of principal investigator<br>Masaki Fujita<br>所属 Affiliation<br>Institute for Materials Research, Tohoku University | 装置責任者 Name of responsible person<br>Y. Miyake<br>装置名 Name of Instrument/(BL No.)<br>D1<br>実施日 Date of Experiment<br>2013/5/1-5/3 |

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

As-grown $Pr_{1.40}Pr_{0.60}CuO_4$

Annealed $Pr_{1.40}Pr_{0.60}CuO_4$

As-grown $Pr_{1.24}Pr_{0.60}Ce_{0.16}CuO_4$

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

Experimental method: zero field muon spin rotation/relazation
Measured temperature: 5, 50, 75, 100, 125, 150, 175, 200, 300 K.

For the emergence of superconductivity in the electron-doped cuprate oxide, both substitution of cation such as $Ce^{4+}$ at a rear-earth ($R$) site and annealing procedure under oxygen reduction condition are required. Although the magnetism is recognized to play a key role in the mechanism of superconductivity, the effects of oxygen-reduction and Ce-doping on the spin correlation are not fully understood. In order to extract above two effects on the magnetism, we carried out muon spin rotation/relazation measurements on the as-grown and the Ar-annealed $Pr_{1.40}La_{0.60}CuO_{4-d}$, and as-grown $Pr_{1.32}La_{0.60}Ce_{0.08}CuO_4$.

Fig 1 shows muon time spectrum at 5K for each sample. There are two rotation component in the as-grown and annealed x=0 sample, while the as-grown $x$=0.16 sample has a single component.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

Therefore, we analysis the spectra by a following function.

$$AG(t) = Amag\left\{\frac{1}{3}\exp(-\lambda_L t) + \frac{2fraction}{3}\exp(-\lambda_1 t)\cos(2\pi f_1 + \varphi) + \frac{2(1-fraction)}{3}\exp(-\lambda_2 t)\cos(2\pi f_1 + \varphi)\right\} + (1-Amag)(1-(\Delta t)^2)\exp\left(\frac{-(\Delta t)^2}{2}\right) + BG$$

Result of analysis showed that the magnetic volume fraction $A_{mag}$ is almost 100% at 5 K in the all samples. The rotation frequencies are $f_1$=3.438±0.008 MHz, $f_2$=1.137±0.009 MHz for as-grown x=0, $f_1$=2.38±0.13 MHz and $f_2$=0.702±0.005 MHz for annealed x=0 sample, respectively. In the as-grown $x$=0.16, the single rotation component with $f$=1.18±0.08 MHz was determined. These results clearly suggest that the internal magnetic field decreases with both oxygen-reduction and Ce-doping (Fig 2). However, the damping of spectra is more marked in the annealed sample, while the magnetic ordering temperature is weakly suppressed by annealing. Therefore, the effect of Ce-doping is different from that of annealing.

There are a couple of explanations for the degradation of magnetic order by annealing. First, the introduction of carrier in $CuO_2$ planes, which is associated with the reduction of apical oxygen by annealing, could suppress the magnetic order. Second, the removal of in-plane oxygen would degrade the in-plane spin correlation. The distinct effect of annealing and Ce-doping implies the influence of annealing on the local structure, namely, the anneal-induced randomness in the system.

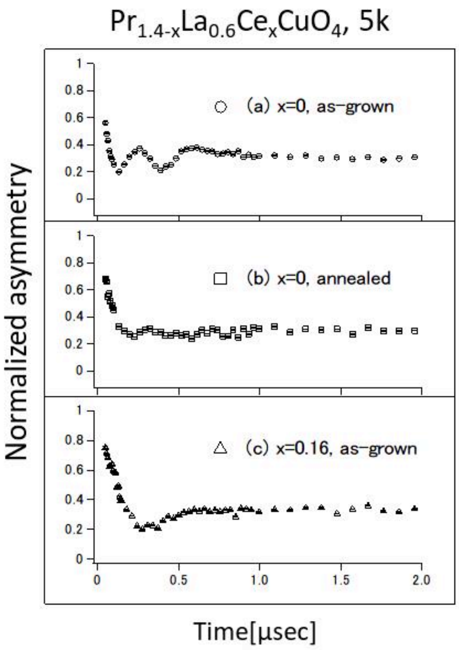


Fig 1: zero field msr spectra at 5K
x=0 (a) as-grown, (b) annealed, and (c) x=0.16, as-grown

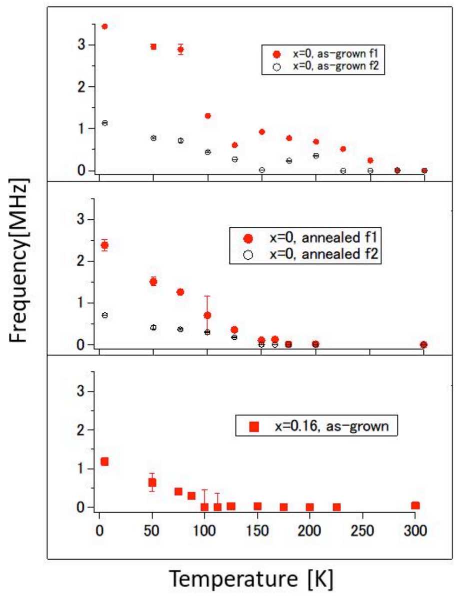


Fig2: Temperature dependence of frequency
x=0 (a) as-grown, (b) annealed, and © x=0.16, as-grown