PCP7-1

Accurate Determination of Composite Crystal Structure of $Sr_{14-x}Ca_xCu_{24}O_{41}$ Using the Akaike Information Criterion

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The composite crystal structures of the spin-ladder compound, $Sr_{14-x}Ca_xCu_{24}O_{41}$ have been accurately determined using the Akaike Information Criterion (*AIC*) to solve the possible overfitting of atomic parameters. For $Sr_{14}Cu_{24}O_{41}$ as parent material of $Sr_{14-x}Ca_xCu_{24}O_{41}$, the minimizing *AIC* method removes an anomalous behavior of the Cu-O bonds along the 1-D Cu-O chain in the two-legged Cu_2O_3 ladder. Our study reveals the importance of the Cu-O-Cu rung with a strong Cu-O bond in $Sr_{14-x}Ca_xCu_{24}O_{41}$.

In the modulated structure of $Sr_{14}Cu_{24}O_{41}$, non-symmetric hole transfers from the O atom in the CuO_2 chain to the Cu-O-Cu rung in the ladder have been elucidated. The Bond-valence sum analysis of the modulated CuO_2 substructure of $Sr_{14}Cu_{24}O_{41}$ shows the role of large displacive modulation of O atom in the CuO_2 chain and the valence fluctuation of Cu atom with a periodicity almost 200 times that of the average CuO_2 lattice. There exist the $<Cu^{2+}>$-$<Cu^{3+}>$-$<Cu^{2+}>$ arrangements without the discommesuration in the CuO_2 chain. The mutual incommensurability between the average substructures is precisely characterized and the chemical formula of $Sr_{14}Cu_{24}O_{41}$ should be exactly expressed as $(Sr_2Cu_2O_3)_{0.6995}CuO_2$.

The minimizing *AIC* method has enabled us to successfully select the correct superspace group of $Sr_{14-x}Ca_xCu_{24}O_{41}$.

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Keywords: Cuprate spin-ladder compound, Composite crystal, Model selection, AIC

PCP7-2

Synthesis and Superconductivity in Pb-doped $NbSr_2RECu_2O_z$ ($z \approx 8$; RE: rare-earth element)

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Substitution effects of Pb for Nb in $NbSr_2RECu_2O_z$ (Nb-"1-2-1-2"; RE: rare-earth element) are investigated. The first Nb-"1-2-1-2", $NbBa_2LaCu_2O_z$ and $NbBa_2PrCu_2O_z$, were synthesized for the first time in 1991 by Ichinose *et al.* [1] and they did not exhibit superconductivity. Kim *et al.* [2] reported in 2013 that Sn doping into their related compounds, $NbSr_2RECu_2O_z$ *(RE=Sm, Eu)*, made them superconducting with superconducting transition temperature (T_c) of ~30K by generating carriers due to Sn^{4+} partial substitution for Nb^{5+}. In this study, doping effects of Pb^{4+} instead of Sn^{4+} in the Sr-containing Nb-"1-2-1-2" are reported mainly focusing on the occurrence of superconductivity.
Samples were prepared by a solid-state reaction method using Nb_2O_5, PbO, $SrCO_3$, RE_2O_3 (RE=Nd, Sm, Eu, Gd) and CuO. Nominal compositions of $(Nb_{1-x}Pb_x)Sr_2RECu_2O_z$ ($0 \leq x \leq 0.4$) were used. Sintering was carried out in air at temperatures of 1000~1080˚C and post-annealing was performed in a flowing O_2 gas at 800˚C. Characterization of the samples was carried out by means of powder X-ray diffraction (XRD) and the electrical resistivity was measured by a four-probe method.
For the Pb-doped Nb-"1-2-1-2", superconductivity is observed only for the post-annealed samples of RE=Sm, RE=Eu and RE=Gd. This shows that oxygen nonstoichiometry plays an crucial role for the occurrence of superconductivity in these compounds. The maximum value of T_c observed in this study is 43 K (onset) for $(Nb_{0.8}Pb_{0.2})Sr_2EuCu_2O_z$. Some characteristics of the superconductivity in the Nb-"1-2-1-2" will be discussed.

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[2] K. Kim *et al.*, Physica C**492**, 165-167 (2013).

Keywords: Cuporate Superconductor, Nb-"1-2-1-2", Pb-doping, Oxygen nonstoichiometry

PCP7-3

Synthesis and Superconductivity of Pb-based "1-2-0-1" Cuprates

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Three kinds of homologous series are known at present in Pb-based cuprate superconductors. Among them, $(Pb,Cu)Sr_2(Y,Ca)_{n-1}Cu_nO_{2n+3}$ characteristically contains (Pb,Cu)O monolayer in its crystal structure and is known to form in an oxidizing atmosphere. In this series, two compounds of n=1 and n=2 have been synthesized. Chemical formula of the former is represented as $(Pb,Cu)(Sr_{0.5}La_{0.5})_2CuO_5$ (n=1; (Pb,Cu)-"1-2-0-1") in which 50 % of Sr^{2+} site is replaced by La^{3+}. Synthesis and superconductivity with superconducting transition temperature (T_c) of 25 K of this (Pb,Cu)-"1-2-0-1" are reported for the first time by Adachi *et al.* [1,2]. For this compound, however, it has not been made clear how the charge carriers responsible for superconductivity forms. In this study, effects of oxygen non-stoichiometry on superconductivity of the (Pb,Cu)-"1-2-0-1" are investigated. Additionally, we have attempted to substitution effects of Nd and Sm for La on phase formation of (Pb,Cu)-"1-2-0-1".

Samples are prepared by a solid-state reaction method of PbO, CuO, $SrCO_3$ and RE_2O_3 (RE: La, Nd and Sm) using nominal compositions of $(Pb_{0.5}Cu_{0.5})(Sr_{1-x}RE_x)_2CuO_z$ (x=0.0 to 1.0). For the former, calcination and sintering are carried out respectively at 850˚C for 10 h in air and at 950-1050˚C for 2 h in air or flowing O_2 gas. Some samples are subjected to quenching procedure, *i.e.*, after post-annealing at 800˚C for 1.5 h in air, samples are rapidly cooled on a copper plate in air. For the latter, calcination and sintering are carried out respectively at 800˚C for 12 h in air and at 850-920˚C for 10 h in air or flowing O_2 gas. Samples are characterized by means of powder X-ray diffractometry (CuKα; θ-2θ) and temperature dependence of electrical resistivity (ρ) is measured by a four-probe method.

For the case of RE=La, superconductivity is observed for samples of x=0.4, 0.5 and 0.6, and T_c tends to be raised by the quenching. Only these three samples contain (Pb,Cu)-"1-2-0-1" as a dominant phase. Effects of oxygen nonstoichiometry on superconductivity are now being investigated. For the cases of RE=Nd and Sm, formation of the "1-2-0-1" phase are not observed.

Keywords: Pb-"1-2-0-1", Cuprate superconductor

PCP7-4

High-field measurements on bulk $YBa_2Cu_3O_y$ samples prepared by the Infiltration-Growth (IG) technique

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With the objective to concurrence the well-known melt texturing YBCO samples in term of irreversible field and critical current, infiltration growth YBCO bulks (IG-processed) show a recent increase of interest due to their advantage of better controlling the shape of the final product and better mechanical stability. Two types of IG-processed YBCO samples were developed: standard bulk samples and superconducting foams which show the advantage of a huge cooling capacity and a low weight due to his low density, particularly appreciated for space applications.

Intended for use as permanent superconducting magnets (trapped field (TF) magnets), precedents works were done to evaluate the pinning properties of such materials by pinning force scaling (Dew-Hughes and Kramer) but only under relatively low magnetic field (up to 9 T). Considering a very high irreversible field (H_{irr}), even at 77 K, a lot of assumptions and extrapolations were needed.

Small pieces of both designs (standard bulk and foam) were cut and mechanically polished (1 x 1 x 0.1 mm^3) according to the crystallographic orientation (H // c). To experimentally determine the pinning properties for magnetic field above 9 T, we were able to make measurements at high magnetic field (above 30 T) for different temperatures between 85 K and 40 K with the help of EMFL facilities using Cantilever Torque Magnetometry at the High Magnetic Field Laboratory of Nijmegen.

Keywords: IG-processed YBCO, Material characterization, superconducting Bulks, High field measurements

PCP7-5

Advances in Novel $YBa_2Cu_3O_{x-\delta}$ Superconducting Materials

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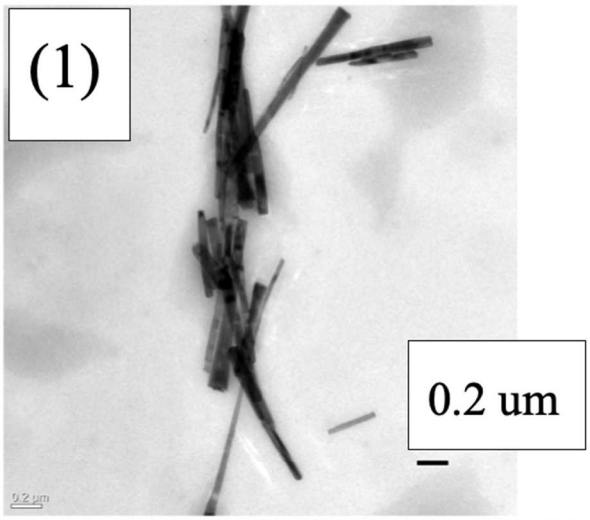
We report the fabrication of high-temperature superconductor $YBa_2Cu_3Ox_{-\delta}$ (YBCO) in the various new forms of wafers, bi-wafers, and spiral morphologies made by solution chemistry [1]. Reagent grade oxides of Yttrium Oxide (Y_2O_3), Barium Oxide (BaO) and Copper Oxide (CuO) in stoichiometric proportions prepared in solution, and upon precipitation, an intimate mixture of fine-grained materials was obtained [2]. The precipitate calcined at 773 K for two h, then subsequently converted to YBCO morphologies by heating to 1223 K in oxygen for 12 h. X-ray diffraction in one case showed that the powder consisted of nanorods and nanotubes predominantly of the $YBa_2Cu_3Ox_{-\delta}$ phase. A critical superconducting transition temperature T_c of 92 K achieved in a critical magnetic field of 10 Oe, along with observing the Meissner effect using MMPS.
Herein, this presentation presents additional material of this novel discovery not presented in our previous work [3] of these. Transmission electron microscope (TEM) and scanning electron microscope (SEM) images (Fig. 1—2) reveal the tubular morphology of the structures. A significant finding is that these morphologies are superconducting without the need for further sintering or oxygenation, providing an avenue for the application of $YBa_2Cu_3O_{x-\delta}$ to substrates at room temperatures or direct use in the form of a superconducting powder.



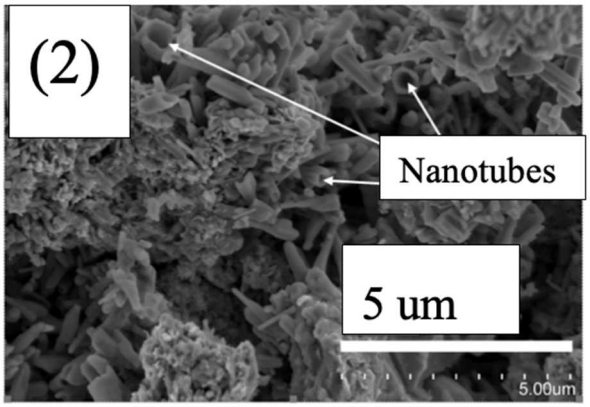


Figure (1): TEM image of superconducting nanorods and nanotubes showing thickness as little as 50 nm and lengths of several micrometers. Figure (2): SEM image of slice of material clearly showing nanotubes.

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Keywords: Superconductor, Morphology, YBCO, Solution Chemistry

PCP7-6

Properties of electron-doped high temperature superconductor $Nd_{2-x}Ce_xCuO_4$ Films deposited by TFA-MOD

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Superconducting materials with a high in-field critical current density (J_c) and a low-cost process are required for superconducting applications such as nuclear magnetic resonance equipment, generators, and energy storage devices. The in-field J_c is strongly related to not only the vortex pinning but also crystallinity and critical temperature (T_c). The trifluoroacetates metal organic deposition (TFA-MOD) process is effective process to crystalize the high crystallinity film and introduce the artificial pinning centers. We reported that the TFA-MOD derived hole-doped high temperature superconductor (HTS) $(Y_{0.77}Gd_{0.23})Ba_2Cu_3O_y$ ((Y,Gd)BCO) film shows high in-field J_c due to high crystallinity and T_c even with the introduction of high density of adding artificial pinning centers [1]. Although electron-doped $RE_{2-x}Ce_xCuO_4$ (RECCO, RE = Nd, Pr, Eu…) is also high temperature superconductor, J_c in RECCO film has not yet been clarified.

In this work, we report that the structural and electrical properties of TFA-MOD derived $Nd_{2-x}Ce_xCuO_4$ (NCCO, x = 0, 0.15) films grown on the substrates with various lattice mismatch. The X-ray diffraction result shows that c-axis oriented NCCO films were grown on $LaAlO_3$ and $DyScO_3$ substrate. The c-axis oriented NCCO films show high crystallinity ($\Delta\omega \approx 0.14°$). The ρ-T curve of the NCCO (x = 0.15) film on $LaAlO_3$ shows superconducting transition ($T_c \approx 9$ K). This T_c value is lower than that of the bulk value (~24 K). The low T_c could be attributed to the lattice mismatch between the NCCO and the $LaAlO_3$ substrate (-4.0%, compressive strain). The structural and electrical properties of NCCO films grown on substrates with various lattice mismatch will be reported.

[1] M. Miura et al., NPG Asia Materials 9, (2017) e447

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Keywords: Electron-doped HTS, TFA-MOD

PCP7-7

Enhanced critical current density in TFA-MOD $(Y_{0.77}Gd_{0.23})Ba_2Cu_3O_y$+$BaHfO_3$ films on CeO_2 buffered *R*-Al_2O_3 substrates

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$REBa_2Cu_3O_y$ (REBCO) coated conductors produced by the trifluoroacetate metal organic deposition (TFA-MOD) process are promising candidates for applications, because of the low cost and high superconducting performance. The *R*-Al_2O_3 substrate is a good candidate for a high sensitivity REBCO resonator filter because of the low dielectric constant. For the resonator filter application, a $(Y_{0.77},Gd_{0.23})Ba_2Cu_3O_y$ ((Y,Gd)BCO) film with high critical current density (J_c) is required because the surface resistance (R_s) is strongly correlated with J_c ($R_s\mu(1/J_c)$)[1]. Recently, the TFA-MOD (Y,Gd)BCO films on CeO_2 buffered *R*-Al_2O_3 substrates indicate that the high self-field J_c ($J_c^{s.f.}$) of (Y,Gd)BCO films increases with increasing density of incoherent $BaMO_3$ (M=Zr, Hf, Sn) nanoparticles (NPs) [2,3]. For further improvement of the J_c, introducing a high density of BMO NPs as flux pinning centers without degradation of crystallinity and critical temperature (T_c) is key.

In this work, in order to investigate the effect of $BaHfO_3$ (BHO) NPs on the superconducting properties, we fabricated the (Y,Gd)BCO and (Y,Gd)BCO+BHO films on CeO_2 buffered *R*-Al_2O_3 substrates using the TFA-MOD process. The (Y,Gd)BCO+BHO film shows higher $J_c^{s.f.}$ without T_c degradation compared with that of standard (Y,Gd)BCO film. We will discuss the mechanism of improvement of the $J_c^{s.f.}$ by the introduction of BHO NPs based on crystallinity, T_c and microstructure.

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[3] M. Miura *et al.*, *NPG Asia Materials* **9** (2017) e447.

Keywords: R-Al2O3, TFA-MOD, REBa2Cu3Oy, resonator filter