Effect of Chemical Pressure on Superconductivity of $Nd(Sr_{2-x}Ba_x)(Cu_{2.7}Mo_{0.3})O_z$ system

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Abstract

$Nd(Sr_{2-x}Ba_x)(Cu_{2.7}Mo_{0.3})O_z$($x$=0-1.0) samples were synthesized and examined with respect to the chemical pressure effect. It is found that the non-superconducting phase $NdSr_2(Cu_{2.7}Mo_{0.3})O_z$ can be made superconducting by substitution Ba at the Sr site. Raman measurements indicate that the movement of the apical oxygen toward the CuO_2 planes induced by the chemical pressure is similar to that observed in $Y(Ba_{2-x}Sr_x)Cu_3O_z$ system. Thermoelectric power measurements show that all the samples are underdoped and hole density on the CuO_2 planes decreases as the Sr:Ba ratio raised.These results are discussed in relation to the local structural changes induced by the chemical pressure

Key words: superconductivity;chemical pressure;cuprate;Raman

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Unlike $RBa_2Cu_3O_7$, the Sr analog $RSr_2Cu_3O_7$ cannot be made at ambient pressure without partial substitution of Cu with some higher-oxidation state ions, for examples, Pb, Al, Fe, Co, Ga, Ti, V, Ge, Mo, W or Re[1,2]. The complete series of single-phase $RSr_2(Cu_{3-x}Mo_x)O_7$ (Sr-123) with x=0.3 was successfully synthesized[3] for R representing all rare-earth elements except Ce and Lu. These compounds have a T_c centering around 30 K except for R=La,Pr and Nd which are not superconducting. This behavior is very different to $RBa_2Cu_3O_7$[4] where both $LaBa_2Cu_3O_7$ and $NdBa_2Cu_3O_7$ are superconductors with T_c as high as others(about 90 K). In an attempt to understand the non-superconductivity of Sr-123 with R=Nd and its possible correlation to the chemical pressure effect, we study the effect of Ba substitution for Sr-site on the changes in structural and superconducting properties of the $NdBa_2(Cu_{2.7}Mo_{0.3})O_z$ compounds.

The samples with nominal composition of $Nd(Sr_{2-x}Ba_x)(Cu_{2.7}Mo_{0.3})O_z$ (x=0,0.25,0.5,0.75,1.0) were prepared by solid state reaction technique. The powder x-ray diffraction patterns of $Nd(Sr_{2-x}Ba_x)$-$(Cu_{2.7}Mo_{0.3})O_z$ samples with $x \leq 1.0$ showed a single-phase nature and the peaks could be indexed on the base of a tetragonal unit cell. The lattice constants a and c increased near linearly with increasing Ba content.

Figure 1 shows the variation of the resistance (R) normalized to the value of R at T=150 K as a function of temperature for $Nd(Sr_{2-x}Ba_x)(Cu_{2.7}Mo_{0.3})O_z$ (x=0∼1.0). From the Fig.1, one can notice that the samples with x=0(Ba-free) and 0.25 are not superconducting. But, with the increase of Ba content x, superconducting properties appear and the samples reveal a transition from semiconducting behavior to metallic behavior. The samples with x=0.75 and 1.0 exhibit zero resistance of 15 K and 18 K, respectively. Thermoelectric power measurements show that all samples are underdoped and room temperature thermoelectric power was 99.5 μV/K, 61.2 μV/K, 41.7 μV/K, 35.5 μV/K and 31.1 μV/K for x=0,0.25,0.5,0.75 and 1.0,

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respectively. This result indicates that the hole concentration on CuO$_2$ planes decreases with increasing Sr content[5].

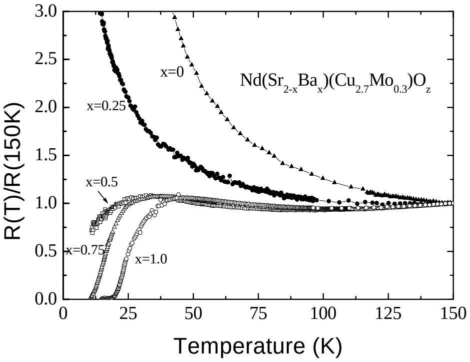

Fig. 1. Temperature dependence of the normalized resistance for Nd(Sr$_{2-x}$Ba$_x$)(Cu$_{2.7}$Mo$_{0.3}$)O$_z$

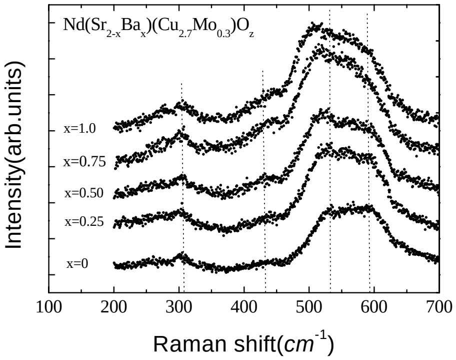

Fig. 2. The Raman spectra of Nd(Sr$_{2-x}$Ba$_x$)(Cu$_{2.7}$Mo$_{0.3}$)O$_z$

The Raman spectra for the samples of Nd(Sr$_{2-x}$Ba$_x$)-(Cu$_{2.7}$Mo$_{0.3}$)O$_z$(x=0∼1.0)are shown in Fig.2. In the range of Raman scattering shifts from 200 to 700 cm^{-1}, four distinct Raman peaks observed at around 310, 430, 530 and 590 cm^{-1}. These peaks are corresponding to those of typical vibration modes in YBa$_2$Cu$_3$O$_z$[6], except the disorder-induced vibration mode at around 590 cm^{-1}[7]. In Y(Ba$_{2-x}$Sr$_x$)Cu$_3$O$_z$(x=0∼1.0) system[6], it was found that the Raman peak associated with apical oxygen stretching mode(500 cm^{-1}) along the c-axis increase in frequency with increasing Sr content, as the case of present Nd(Sr$_{2-x}$Ba$_x$)(Cu$_{2.7}$Mo$_{0.3}$)O$_z$ system.The shift of apical oxygen vibration mode due to the substitution of Sr for Ba-site in YBa$_2$Cu$_3$O$_z$ system was explained from the change of inter-atomic distance[6,8,9] which show a higher contraction of Cu(2)-apical oxygen bond distance than the whole unit cell along the c-axis. This highly inhomogeneous character of the chemical pressure was also confirmed in a recent study[10] on structural refinements for YBaSr(Cu$_{2.8}$Mo$_{0.2}$)O$_z$ and YSr$_2$(Cu$_{2.8}$Mo$_{0.2}$)O$_z$. Consequently, the same trend of frequency shift of apical oxygen mode for both systems can be understood based on the local structural changes induced by chemical pressure. The thermoelectric power measurements suggest that the local structural changes induced by chemical pressure in Sr-site result in the reduction of changes transfer from the charge reservoir to the CuO$_2$ planes.

In summary, It is found that the phase NdSr$_2$(Cu$_{2.7}$Mo$_{0.3}$)O$_z$ can be made superconducting by substitution Ba at the Sr site and the disappearence of superconductivity for the NdSr$_2$(Cu$_{2.7}$Mo$_{0.3}$)O$_z$ compound is related to the reduction of charge transfer from the charge reservoir to the CuO$_2$ planes caused by the local structural changes induced by the chemical pressure.

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