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SUPERCONDUCTIVITY AND METAL-INSULATOR TRANSITION IN ZINC-SUBSTITUTED $La_{1.85}Sr_{0.15}Cu\ O_4$.[†]

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When Zn is substituted for Cu in $La_{1.85}Sr_{0.15}Cu\ O_4$, T_c goes to zero near 3 at %. The metal-insulator transition occurs at a higher concentration, so that there is a non-superconducting but metallic range of impurity concentration.

In two recent papers it has been shown that the transition temperature of $La_{1.85}Sr_{.15}Cu\ O_4$ decreases linearly when Zn or Ga is substituted for the Cu, with T_c going to zero near 3 at %, as shown on Fig. 1 (1,2). The lowest temperature of the measurements was 3K, too high to allow an unequivocal determination of the metallic or non-metalllic character of the specimens.

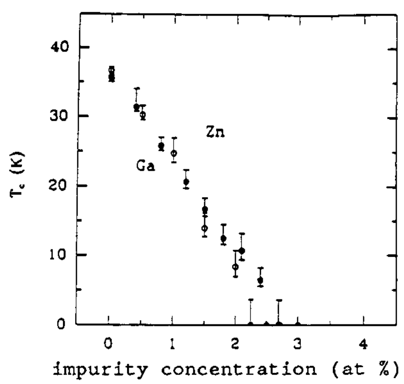

FIGURE 1
The dependence of T_c on Zn or Ga concentration.

We have carried the measurements down to 50 mK with and without magnetic fields up to 8T, in specimens with 3.3% Zn, 3.7% Zn, and 8% Zn. The specimens were ceramic, polycrystalline, made by the same procedures as those in Refs. 1 and 2.

The results show that all three specimens are metallic. This is illustrated in Fig. 2, which shows the conductance 1/R of the 8% specimen as a function of temperature in a

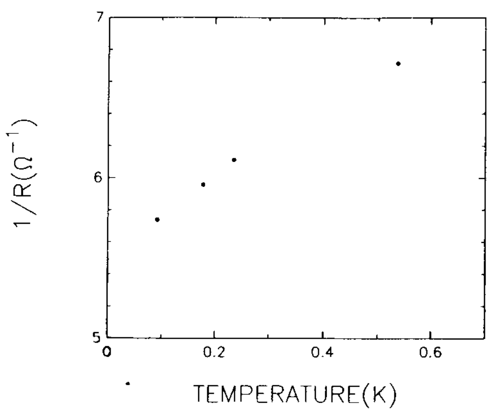

FIGURE 2
The conductance of the 8% Zn specimen as a function of temperature in a field of 2 tesla.

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field of 2 tesla. The reason for the magnetic field is that even in the 8% Zn specimen the resistance at low T is affected by superconducting fluctuations which are destroyed by a small field. In the other specimens the fluctuations are more substantial, as illustrated on Fig. 3 for the 3.3% Zn specimen at 124 mK. The figure also shows the negative magnetoresistance in the normal state which is characteristic for electron localization.

We cannot tell with certitude that the specimens will not undergo a superconducting transition at much lower temperature. For this to happen the linear trend of T_c with

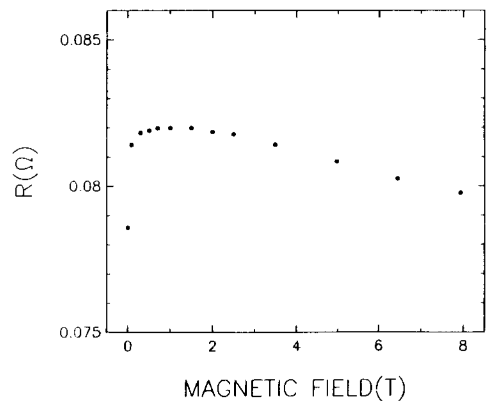

FIGURE 3
The resistance of the 3.3% Zn specimen as a function of magnetic field at 124 mK.

percentage of Zn would have to change drastically. Our results point rather to the conclusion that in this system the occurrence of superconductivity is suppressed in the vicinity of the metal-insulator (M-I) transition on the metallic side, so as to leave a metallic but non-superconducting range of impurity concentration. In this respect the behavior is similar to that near the localization-induced metal-insulator transition in granular aluminum (3).

We emphasize that a truly insulating specimen has a resistance whose temperature dependence is unmistakably different. For a specimen with 10% Ga, for example, the resistance is closely proportional to exp $(T_o/T)^{1/2}$, and reaches 2 x 10^7 ohms at 0.6 K.

We can estimate the Zn-concentration of the M-I transition from data like those of Figs. 2 and 3. We extrapolate the high-field magnetoresistance R(H,T) of Fig. 3 to zero field to obtain the normal-state resistance $R_N(0,T)$, and hence the value of $R_N(0,0)$, the quantity which diverges at the M-I transition. Our results indicate that the M-I transition may be expected to occur above 10% Zn.

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