The metal-insulator transition and low-temperature conduction behavior of Al-Pd-(Re,Ru) quasicrystals

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計畫編號：NSC88-2112-M-006-001

執行日期：87 年 8 月 1 日 至 88 年 10 月 31 日

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ABSTRACT

A series of Al\textsubscript{70}Pd\textsubscript{22.5}(Re\textsubscript{1-x}Ru\textsubscript{x})\textsubscript{7.5} quasicrystals with x = 0.13, 0.2, 0.4, 0.6, 0.8 have been prepared. Replacement of Re by Ru is seen to decrease the resistivity and the resistivity ratio \( r = \frac{\rho_{4.2K}}{\rho_{300K}} \). The magnetoconductivity (MC) of the samples with \( r \leq 10.3 \) was analyzed using the quantum interference theory. The obtained results suggest that more resistive sample suppresses not only the weak localization contribution but also the electron-electron interaction contribution through the reduction of \( g^* \) value. For the samples with \( x = 0.2^a \) and \( 0.4^a \), the observed positive MC at low fields and low temperatures indicates that these samples are already in the hopping regime, but the anomalous behavior concerning the decrease of magnitude of positive MC with the fall of temperature is in contradiction with the predictions of theories.

Keyword: A.quasicrystal, D.electronic transport

1.INTRODUCTION

Icosahedral Al-Pd-Re quasicrystals (QCs) have the highest resistivity \( \rho_{4.2K} \) and resistivity ratio \( r = \frac{\rho_{4.2K}}{\rho_{300K}} \) among the QCs having been found. For example, the reported highest \( \rho \) and \( r \) is 20 (\( \Omega \cdot \text{cm} \)) [1] and 180 [2], respectively, for Al\textsubscript{70}Pd\textsubscript{30}Re\textsubscript{10} and Al\textsubscript{70}Pd\textsubscript{30}Re\textsubscript{5}. These \( \rho \) and \( r \) values are much larger than the value of \( \rho = (1-2) \times 10^2 (\Omega \cdot \text{cm}) \) and \( r = 1-4 \) for...
Al-Cu-(Fe,Ru) [3,4] and Al-Pd-Mn QCs [5,6]. Al-Pd-Re QCs are also noted for their $r$ values being able to be increased greatly by low-T annealing (600 ~ 650°C) [7]. Increasing $r$ is seen to increase the $\rho_{4.2K}$, indicating the increase of the electron localization.

The low-T magnetoconductivity (MC) for Al$_{70}$Pd$_{22.5}$Re$_{7.5}$ QCs with smaller value of $r$ ($\leq$ 16) is negative and their MC behaviors qualitatively follow the predictions of the quantum interference theory (QI theory), while for samples with larger $r$ ($\geq$ 20), the appearance of positive MC at low fields may suggest that these samples have been through the metal-insulator transition[8].

Al-Pd-Re QCs reveal some newly physical properties such as large annealing effect on $\rho$ and $r$, positive and negative MC appearing in the samples with $r$ $\geq$ 20, and the possible correlation of the observed paramagnetism at low temperature with the resistivity of the sample with larger value of $r$ [9]. But most of these properties still cannot be understood well and therefore deserve further studies.

In this work, a new series of icosahedral Al$_{70}$Pd$_{22.5}$(Re$_{1-x}$Ru$_x$)$_{7.5}$ QCs have been formed and their electron transport properties are studied. QI theory was employed to analyze the $\sigma(T)$ and MC data of the samples with $r$ up to 10.3. The anomalous MC behavior exhibited in the samples with large value of $r$ is briefly discussed.

2. RESULTS
3. SUMMARY

(1) Substitution of Ru for Re in Al$_{70}$Pd$_{22.5}$($Re_{1-x}$Ru$_x$)$_{7.5}$ QCs decreases the resistivity and reduces the thermal stability of the samples with $x \geq 0.8$.

(2) In Al$_{70}$Pd$_{22.5}$($Re_{1-x}$Ru$_x$)$_{7.5}$ with $x \leq 0.4$, the increase of the resistivity and resistivity ratio caused by low-T annealing may be related to finely structural rearrangements during annealing.

(3) Based on the QI theory, we find that more resistive samples suppress the $\Delta\sigma_{EEI}(H)$ contribution as well as the $\Delta\sigma_{WL}(H)$ contribution to the MC.

(4) For Al-Pd-Re-Ru QCs in the hopping regime, the anomalous decrease of positive MC with the decrease of temperature at low field may be correlated with spin effects.

REFERENCES

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30. C. R. Wang, Z. Y. Su and S. T. Lin to be published