Thermopower of $HgBa_2Ca_{m-1}Cu_mO_{2m+2+\delta}$ under Pressure

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The thermopower *S* of $HgBa_2Ca_{m-1}Cu_mO_{2m+2+\delta}$ (Hg-12[m-1]m) has been investigated at various carrier concentration *n* and pressure *P*. At ambient pressure, *S*(290 K) changes with doping roughly following the proposed universal trend. *S* of Hg-1223 is nearly independent of *P* up to 1.6 GPa, suggesting a pressure-induced charged-transfer rate at least 10 times smaller than that of $YBa_2Cu_3O_7$. The extreme small charge transfer present a challenge to some theoretical models.

## 1. INTRODUCTION

The large $T_c$-enhancement under pressure in $HgBa_2Ca_{m-1}Cu_mO_{2m+2+\delta}$ (Hg-12[m-1]m) had drawn particular interests [1]. Charge transfer is one of the important parameters in various interpretations. Thus, we decided to determine the charge transfer of Hg-12[m-1]m under pressure by the thermopower (*S*) measurement.

## 2. EXPERIMENTS

All samples were single phase polycrystalline with a sharp superconducting transition. The hydrostatic pressure up to 1.6 GPa was generated inside a Teflon cup housed in a Be-Cu high pressure clamp. The thermopower was measured using a homemade apparatus designed to reduce the pressure-medium effects. The pressure effects of the Cu/p-Chromel thermocouples, which were used to measure the temperature gradient across the sample, was calibrated [2].

## 3. RESULTS AND DISCUSSIONS

It has been suggested that *n vs. S*(290 K) obeys a universal trend in cuprates [3]. We have measured the $T_c$ and *S* for Hg-12[m-1]m. Fig.1 shows $T_c$ *vs. n*, which was extracted from *S*(290 K) using the proposed universal trend. The curves are in very nice agreement with the universal $T_c$-*n* relationship [4]. The deviations, *e.g.* the boomerang at the overdoped region for Hg-1201 and Hg-1212, the width and the peak position of the parabola, were discussed elsewhere. The data show that *S*(290 K) is still a good measure of carrier concentration *n* for *n* < 0.18 holes/$CuO_2$.

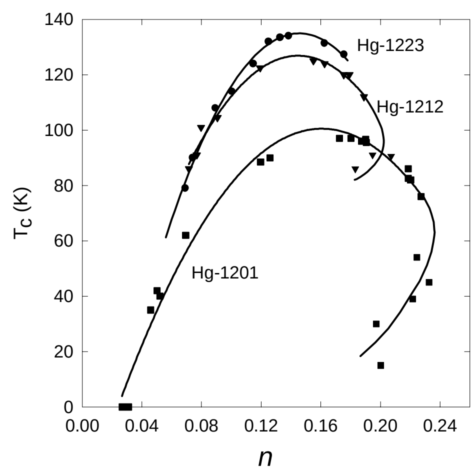


Figure 1. $T_c$ *vs. n* for Hg-12[m-1]m (m = 1-3).

Previous data of $YBa_2Cu_3O_7$ suggests that the universal *S vs. n* trend is still hold under pressure [5]. Thus, d*n*/d*P* can be deduced from d*S*(290 K)/d*P*. An underdoped Hg-1223 with $T_c$ ~ 115 K

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was measured under hydrostatic pressure up to 1.6 GPa. Two Cu/p-Chromel thermocouples were used to measure the temperature difference $\Delta T$ with the Cu-wires also serving as the voltage leads. The raw thermopower data $S^{raw}(P)$ calculated assuming $S_{p\text{-}Chromel}(P) = S_{p\text{-}Chromel}(0)$ and $S_{Cu}(P) = S_{Cu}(0)$, will be related to the actual $S(P)$ as

$$\frac{S^{raw}(P) - S_{Cu}(0)}{S_{p-Chromel}(0) - S_{Cu}(0)} = \frac{S(P) - S_{Cu}(P)}{S_{p-Chromel}(P) - S_{Cu}(P)},$$

where $S(P)$, $S_{p\text{-}Chromel}(P)$ and $S_{Cu}(P)$ are the thermopower of the sample, p-Chromel and Cu under pressure respectively. The observed $S^{raw}$ shifted parallel up with the pressure. (Fig.2, the pressures of the curves are, 0 GPa, 0.49 GPa, 1.05 GPa and 1.55 GPa.) The random data-scattering was better than 10 nV/K, or, 0.00002 holes/$CuO_2$. However, a large systematic uncertainty may be caused by $S_{p\text{-}Chromel}(P)$-$S_{Cu}(P)$. By carefully calibrating $S_{p\text{-}Chromel}(P)$-$S_{Cu}(P)$ against two home-made Pt-thermometers, we reduced the total uncertainty to < 0.3 μV/(K·GPa) or 0.0007 holes/($CuO_2$·GPa). The d$n$/d$P$ of -0.0004 holes/($CuO_2$·GPa) for Hg-1223 is at least 10 times smaller than that of $YBa_2Cu_3O_7$ [5].

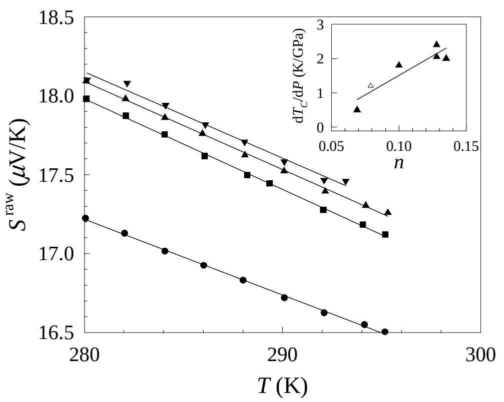


Figure 2. Thermopower raw data near room temperature under pressure for Hg-1223 ($T_c$ = 115 K, the curves shift up with increasing pressure). Inset: d$T_c$/d$P$ *vs.* carrier concentration for Hg-1223.

The charge-transfer model suggests that d$n$/d$P$ is proportional to $\partial^2 T_c/\partial P \partial n$ [6]. d$T_c$/d$P$ of Hg-1223 are plotted against $n$ in the inset of Fig.2, gives a d$n$/d$P$ = -0.0013 holes/($CuO_2$·GPa)[7]. Although these two estimated d$n$/d$P$ values are within the experimental resolution, the smaller value of -0.0004 seems to be more reasonable based on the observed universal $\Delta T_c(P)$ [1].

Novikov and Singh calculated d$n$/d$P$ of Hg-1223 (Fig.3) [8]. Apparently their theoretical values are much greater than our experimental results.

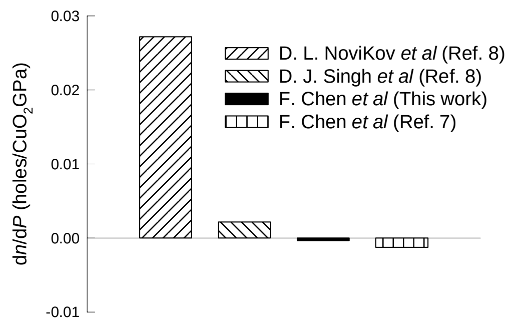


Figure 3. Comparison of d$n$/d$P$ from different methods.

In summary, we extracted the charge transfer d$n$/d$P$ from thermopower measurement. The very small charge transfer we get present challenge to some theoretical models and may help to understand the unusual pressure effect of Hg-12[m-1]m.

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