

The Electronic Specific Heat of $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ from 2K to 380K.

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Using a differential technique, we have measured the specific heats of polycrystalline $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ samples with $x = 0, 0.1$ and 0.3 , between 2K and 380K and in magnetic fields 0 to 13 Tesla. From this data we have determined the electronic specific heat coefficient $\gamma (\equiv C_{el}/T)$ over the entire range for the three samples. The most heavily doped sample ($x = 0.3$) exhibits a large superconducting anomaly $\Delta\gamma(T_c) \sim 48 \text{ mJ/mol K}^2$ at $T_c = 35\text{K}$, and we determine the energy gap, condensation energy, superfluid density and coherence length. In the normal state for the $x = 0.3$ sample, $\gamma \sim 47 \text{ mJ/mol K}^2$ is constant from T_c to 380K. In the parent compound ($x = 0$) there is a large almost first order anomaly at the spin density wave (SDW) transition at $T_o = 136\text{K}$. This anomaly is smaller and broader for $x = 0.1$. At low T , γ is strongly reduced by the SDW gap for both $x = 0$ and 0.1 , but above T_o , γ for all three samples are similar.

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The electronic specific heat contains a wealth of quantitative information on the electronic spectrum over an energy region $\pm 100\text{meV}$ about the Fermi level, crucial to the understanding of high temperature superconductivity. Measurements of the electronic specific heat played an important role in revealing key properties of the copper-oxide based ‘cuprate’ high-temperature superconductors (HTSCs). Some examples include the normal-state “pseudogap” [1–4], the bulk sample inhomogeneity length scale [5], and more recently the degree to which the superconducting transition temperature is suppressed due to superconducting fluctuations [6]. In this work we extend such measurements to the recently discovered iron-arsenide based ‘pnictide’ HTSCs. Here we present results obtained from polycrystalline samples of $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ ($x = 0, 0.1$ and 0.3) using a high-resolution differential technique [7].

With this technique we directly measure the difference in the specific heats of a doped sample and the undoped reference sample (BaFe_2As_2). This eliminates most of the large phonon term from the raw data and yields a curve which is dominated by the difference in electronic terms between the sample and reference. After making a small correction for any residual phonon term, this difference in electronic specific heats can be determined with a resolution of $\sim 0.1 \text{ mJ/mol K}^2$ at temperatures from 1.8K to 380K and magnetic fields from 0 to 13T. During a measurement run the total specific heats of the sample and reference are also measured.

The polycrystalline samples of $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ were prepared by a solid state reaction method similar to that reported by Chen *et al* [8]. First, Fe_2As , BaAs , and KAs were prepared from high purity As (99.999%), Fe (99.9%), Ba (99.9%) and K (99.95%) in evacuated quartz ampoules at 800, 650 and 500°C respectively. Next, the terminal compounds BaFe_2As_2 and KFe_2As_2 were synthesized at 950 and 700°C respectively, from stoichiometric amounts of BaAs or KAs and Fe_2As in alu-

mina crucibles sealed in evacuated quartz ampoules. Finally, samples of $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ with $x = 0.1$ and 0.3 were prepared from appropriate amounts of single-phase BaFe_2As_2 and KFe_2As_2 . The components were mixed, pressed into pellets, placed into alumina crucibles and sealed in evacuated quartz tubes. The samples were annealed for 50 h at 700°C with one intermittent grinding, and were characterized by room temperature powder X-ray diffraction using $\text{Cu K}\alpha$ radiation. The diffraction patterns were indexed on the basis of the tetragonal ThCr_2Si_2 type structure (space group I4/mmm). Lattice parameters calculated by a least-squares method agree well with those reported by Chen *et al* [8]. Traces of FeAs as an impurity were detected for compositions with $x = 0.1$ and 0.3 . The samples for heat capacity measurement weighed $\sim 0.8\text{g}$.

The total specific heats of the three samples are plotted as $\gamma^{tot} \equiv C^{tot}/T$ in Fig. 1. In the $x = 0$ sample there is a sharp and almost first order anomaly at the magneto-structural transition at $T_0 = 136\text{K}$, in agreement with published single crystal data [9]. For the $x = 0.1$ sample the corresponding anomaly at $T_0 = 135\text{K}$ is broader and considerably reduced in magnitude, in agreement with the data of Rotter *et al.* [10] who have tracked T_0 in the specific heat down to 105K in a sample with $x = 0.2$. The magnetic field dependence of this anomaly is extremely weak for both samples. We see no evidence for a structural transition in the $x = 0.3$ sample (the very weak anomaly at 67K in the differential data (Fig. 2(a)) is probably due to an FeAs impurity phase [11]). The superconducting transition in this sample is clearly visible in γ^{tot} at 35K, and the field dependence is shown in the inset to Fig. 1.

In the temperature range $2 - 8\text{K}$, $\gamma^{tot} = \gamma(0) + \beta(0)T^2$ at zero field with $\gamma(0) = 5.1, 9.3$ and 1.8 mJ/mol K^2 and $\beta(0) = 0.45, 0.37$ and 0.57 mJ/mol K^4 for the $x = 0, 0.1$ and 0.3 samples respectively. On the assumption that $\beta(0)$ is entirely due to phonons we obtain Debye temper-