Tunneling break-junction spectroscopy on the superconductor NdFeAs(O$_{0.9}$F$_{0.1}$)

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**ABSTRACT**

Tunnel break-junction method has been adopted to study polycrystalline samples of iron-oxypnictide superconductor NdFeAs(O$_{0.9}$F$_{0.1}$) with $T_c = 48$ K. Measurements were carried out at 4.2 K. Break-junction (BJ) conductance versus voltage curves showed gap-edge peaks with the peak-to-peak distances $V_p = 4\Delta/e = 28-40$ mV at 4.2 K, where $2\Delta(T_c)$ is the superconducting energy gap, $e > 0$ is the elementary charge. This yields $2\Delta(0) = 14-20$ meV, so that the gap ratio $2\Delta(0)/k_BT_c$ is about $4.1 \pm 0.7$. $k_B$ being the Boltzmann constant. This ratio implies strong-coupling superconductivity in the framework of Bardeen–Cooper–Schrieffer theory, being, however, much smaller than that for high-$T_c$ copper oxides. This suggests a significant difference in the pairing mechanism between those classes of materials.

Superconductivity is resistively detected; the onset being observed at 52 K. $\chi$ starts to decrease below 48 K, when the resistance is already zero. The superconducting volume fraction at 5 K is 20% estimated from the observed diamagnetic signal during the field-cooled process with the applied magnetic field of 10 Oe.

In Fig. 2 the BJ tunnel conductance, $dl/dV$, curves are displayed against bias-voltage, $V$, for the same material as in Fig. 1 at $T = 4.2$ K. We have measured several different BJs made of samples from the same batch. Conductance curves shown here are the most representative ones. The background junction resistance is 60–150 Ohms at high bias-voltages ($\pm$50 mV). Clear-cut $dl/dV$ peaks are observed corresponding to the increase of electron density of states (DOS) at the gap edges. The gap structures are quite symmetric with respect to $V$ except for the top curve exhibiting a weak asymmetry. In the BJ design, superconductor insulator superconductor (SIS) junctions are formed. In this case, very strong gap-edge peaks and well-depressed intra-gap floor should be observed because $dl/dV$ is a convolution of two singular superconducting DOSes. However, in the present series of measurements, the slope changes of the current–voltage characteristics in the gap region monitored *in situ* by fast oscilloscope traces turned out to be very weak in all cases except for the top curve, which resulted in rather weak gap-edge peaks and shallow dips in the intra-gap conductances. For the three curves from the bottom in Fig. 2, the total variation of $dl/dV$ constitutes 12–14% of the background value, and the depth of the gap being 6–7% of the high-voltage level. Such surprisingly faint gap features seem to be in contrast with a conspicuous bulk superconducting fraction. One of the plausible reasons for this controversy may be a contamination by SiO$_2$ used as...
a sealing synthesis tube. Hence, small amounts of SiO₂ would be
distributed along grain boundaries, covering the grain interfaces
during the synthesis. A subsequent breaking of those grain bound-
aries may form contaminated junctions. Despite the problems con-
cerned, the obtained curves $dI/dV$ are quite smooth and involve
superconducting features, which are worthy of consideration. For
SIS junctions, including BJ ones, the conductance peak-to-peak dis-
tance $V_{p-p}$ corresponds to $4\Delta/e$. To be specific, the coherent peaks
occurring at $\pm 14–20$ mV in Fig. 2 should be identified as $\pm 2\Delta/e$, the
gap value being $2\Delta = 14–20$ meV. Note, that the most characteris-
tic top curve in Fig. 2, in which the total variation and the gap
depth are $53–60\%$ and $40\%$ of the background, respectively, pos-
sesses extra subtle depressive structures at $\pm 40–50$ mV. Their na-
ture will be a subject of future studies (cf. [6]).