Common features in the tunneling spectra of $Ba_{0.6}K_{0.4}Fe_2As_2$

The reproducibility and reliability of experiments is always the most pivotal issue before any conclusion could be drawn. Therefore, it is necessary to find the common features of the experimental data in order to avoid contingency. After continuous measurements on the single crystals synthesized with improved conditions, we can find the universal features on the tunneling spectra of optimally doped $Ba_{0.6}K_{0.4}Fe_2As_2$. As shown in Fig. 1, the blue lines are the data often obtained in the beginning (some of them are presented in Ref [1]), the red lines were obtained in the subsequent lots of measurements (some of them are presented in Ref [2]). In any case, two superconducting gaps can be distinguished and consistent gap values can be determined from almost all the data we obtained. The only thing which is not understood very well is that the contribution from each gap seems to be random in real space. But a reasonable explanation is the combined effects of surface scattering and tunneling matrix element. By comparing the data indicated by red lines with that by blue lines, the coherence peaks are sharper and the conductance around zero bias can touch zero with a flat bottom. This indicates that the cleaved surfaces in the subsequent experiments are cleaner and all the measurements related to this Letter were performed on such surfaces.

In our previous studies (as presented in Ref [2]), we did not pay attention to the bosonic features outside the gaps because the studied energy window is limited between 20 mV in order to avoid serious disturbance of higher voltage to the junctions. Nonetheless, if we re-

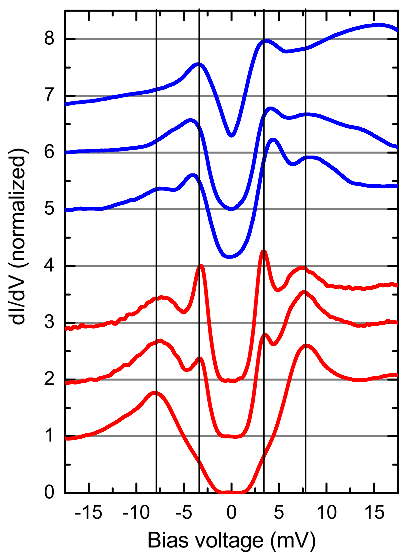

FIG. 1: Typical spectra obtained on various samples.

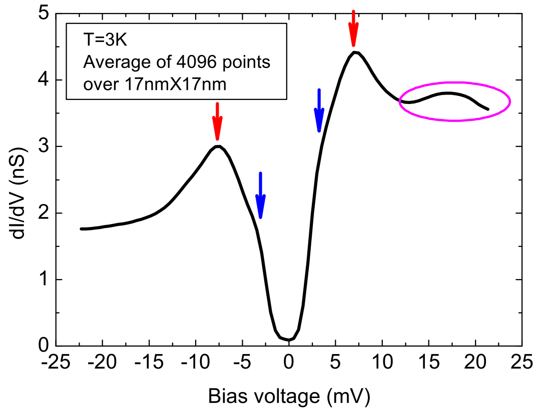

FIG. 2: Tunneling spectrum averaged over an area of 17nm × 17nm, which was measured previously [2]. Blue arrows and red arrows indicate the features of small and large gaps, respectively. The feature enclosed by the magenta ellipse is the initial part of the mode feature.

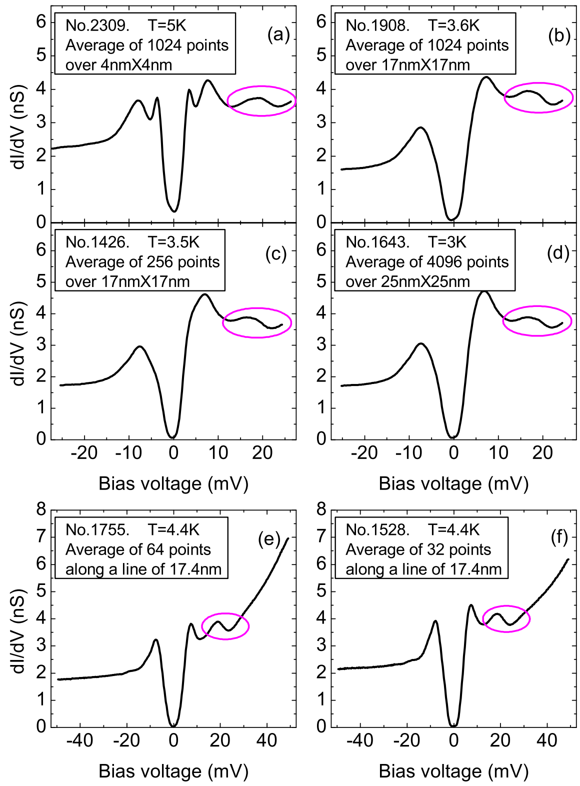

FIG. 3: Each panel presents a tunneling spectrum averaged over a square area or along a straight line as indicated by the caption in the panel. The bosonic (or mode) features are enclosed by the magenta ellipses.

view those data, the initial part of the bosonic feature can be distinguished as a hump (see Fig. 2 showing the average of the tunneling spectra measured in a 17nm X 17nm region studied in Ref [2]). According to our experience, such bosonic features will show up as long as

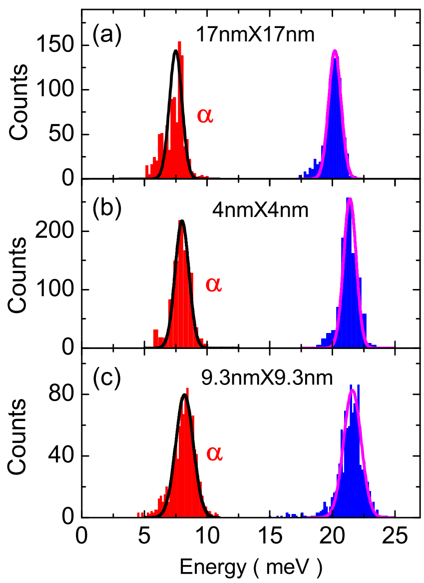

FIG. 4: Statistics of superconducting gap and mode energy in various regions.

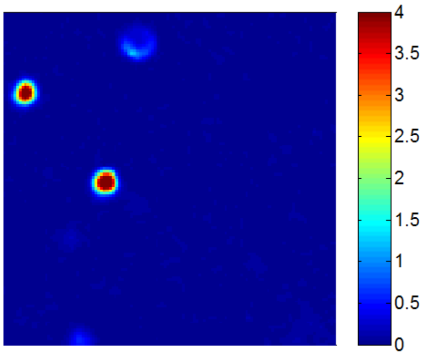

FIG. 5: Conductance map of an area of 17nm × 17nm taken with a bias of 0 mV. The bright dots indicate impurities.

superconductivity is good, i.e., superconducting DOS is clean enough (see the examples in Fig. 3), indicating a high reproducibility of the bosonic features. Furthermore, similar analyses to that presented in Fig.2(b) of the Letter have been done for various regions as shown in Fig. 4). Same conclusion can be made from all these analyses.

Impurities in $Ba_{0.6}K_{0.4}Fe_2As_2$

As to the sample quality, on the one hand, the optimally doped BaKFeAs studied here is one of the materials with best quality among iron-based superconductors for the time being, the high quality of the single crystalline samples has been demonstrated by various measurements such as XRD, Resistivity, Specific heat, Neutron scattering, etc. On the other hand, our STS measurements did find some impurities which can not be identified at present. However, as shown in Fig. 5, only 3 impurities can be observed in a region of 17nm X 17nm, indicating that the effective number of such impurities is around 0.0015 per unit cell in ab-plane. We believe that such impurities will not change the bulk properties of the sample very much.

[1] L. Shan *et al.*, Nature Physics **7**, 325 (2011).
[2] L. Shan *et al.*, Phys. Rev. B **83**, 060510(R) (2011).