Scanning Tunneling Spectroscopy on $\text{YBa}_2\text{Cu}_3\text{O}_y/\text{PrBa}_2\text{Cu}_3\text{O}_y/\text{YBa}_2\text{Cu}_3\text{O}_y$ Sandwiched Junctions and $\text{YBa}_2\text{Cu}_3\text{O}_y/\text{Y}_{0.5}\text{Pr}_{0.5}\text{Ba}_2\text{Cu}_3\text{O}_y$ Superlattices

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The differential conductance, (dI/dV) , on $\text{YBa}_2\text{Cu}_3\text{O}_y/\text{PrBa}_2\text{Cu}_3\text{O}_y/\text{YBa}_2\text{Cu}_3\text{O}_y$ (YBCO/PBCO/YBCO) sandwiched junctions and $\text{YBa}_2\text{Cu}_3\text{O}_y/\text{Y}_{0.5}\text{Pr}_{0.5}\text{Ba}_2\text{Cu}_3\text{O}_y$ (YBCO/YPBCO) superlattices was measured with STM at various temperature ranges to investigate the proximity effects. The dI/dV curves show conductance peaks at low temperatures and the energy gap, $2\Delta_{ab}$, derived from the peaks is equal to about 46 meV for YBCO/PBCO/YBCO sandwiched junctions, which is consistent with the data obtained from reported data on YBCO single crystals whereas the YBCO/YPBCO ((120 Å/60 Å)×8) superlattices, due to the reduction of T_c , show smaller gap value.

1. Introduction

Scanning tunneling spectroscopy (STS) is a useful tool to probe the tunneling features of metal, semiconductors and superconductors [1]. Because STS is a local probe, hence, several local features, such as densities of states etc. of superconductors [2], can be studied and the energy gap parameter therefore is derived. In this work we investigated the STS on $\text{YBa}_2\text{Cu}_3\text{O}_y/\text{PrBa}_2\text{Cu}_3\text{O}_y/\text{YBa}_2\text{Cu}_3\text{O}_y$ sandwiched junctions and $\text{YBa}_2\text{Cu}_3\text{O}_y/\text{Y}_{0.5}\text{Pr}_{0.5}\text{Ba}_2\text{Cu}_3\text{O}_y$ superlattices.

2. Experiments

The c-axis YBCO/PBCO/YBCO sandwiched junctions and YBCO/YPBCO superlattices were grown in situ using off-axis sputtering technique [3]. The YBCO/YPBCO superlattices show satellite peaks around the (001) peaks which confirm the superlattice structures in the samples. The area of YBCO/PBCO/YBCO sandwiched junction was $80 \times 80 \mu\text{m}^2$ patterned by standard technique of photolithography and Ar^+ ion milling. The resistance (R) versus temperature (T) curve shows a semiconductorlike behavior for a 500 Å PBCO layer embedded between top (1500 Å thick) and bottom (3000 Å thick) YBCO layers. The resistivity of the barrier was about 800 Ω at 90 K. The differential conductance, (dI/dV) , was measured by a low temperature scanning tunneling spectroscopy via a standard lock-in technique. In the STS measurements of YBCO/PBCO/YBCO sandwiched junctions, as shown in figure 1, the voltage

lead was connected to the bottom YBCO layer of the junctions whereas the STM tip was located at the top YBCO layer. Figure 1 shows the dI/dV versus V curve for an YBCO/PBCO/YBCO junction measured at 44.5 K. The tunneling spectroscopy was asymmetric similar to that observed by Edwards et al [4]. The gap value derived from the conductance peaks is 46 meV. We attribute the observed gap value

to $2\Delta_{ab}$. We note that a gap value of $2\Delta_{ab}$, instead of

Figure 1 dI/dV versus V curve for an YBCO/PBCO/YBCO junction measured at 44.5 K. The gap value derived from the conductance peak is 46 meV attributed to $2\Delta_{ab}$.

$4\Delta_{ab}$, was observed. To understand this, we recalled that the tunneling impedance is higher than $10^6 \Omega$ between the tip and the sample, therefore the applied voltage is normally dropped between the tip and the top YBCO layer. No energy is available to shift the Fermi levels in superconducting banks. Hence the quasiparticle tunneling process between the superconducting banks is less likely. However, the YBCO layers in YBCO/PBCO/YBCO junctions can form weakly coupled junctions through the long-range proximity effect, such as junctions with planar structure [5–9]. Hence, the quasiparticle tunneling process from the tip to the coupled junction is possible. The present data reveal the tunneling spectroscopy between the tip and the coupled YBCO/PBCO/YBCO junctions.

Figure 2 shows the temperature dependence of the gap value Δ_{ab} derived from the conductance peaks in the STS curves at various temperatures for a YBCO/PBCO/YBCO junction. We found that the gap value is weakly temperature dependent below $T = 55$ K. Above $T = 55$ K the gap value tends to decrease as the temperature increases.

Figure 2 Temperature dependence of the gap value.

Figure 3 shows typically the STS curve for an YBCO/YPBCO (12 nm/6 nm)×8 superlattice at $T = 5.8$ K. The number 8 is the modulation layers in this superlattice. This sample shows $T_{c,zero} \sim 80$ K. A gap structure was observed in the STS spectrum. The energy gap derived as indicated in the Figure is $2\Delta_{ab} = 42$ meV.

Figure 3 STS curve for an YBCO/PBCO (120 Å/60 Å)×8 superlattice. The number 8 is the modulation layers of this superlattice.

3. Summary

We investigated the differential conductance, (dI/dV), on YBCO/PBCO/YBCO sandwiched junctions and YBCO/YPBCO superlattices. The present data show the evidence of the proximity coupling between the YBCO layers on YBCO/PBCO/YBCO sandwiched junctions and YBCO/YPBCO superlattices.

References

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