Investigations of the proximity-induced superconductivity in the topological insulator Bi_2Te_3 by microRaman spectroscopy

Daniel Kiphart[1], Yaroslav Harkavyi[1], Maciej Wiesner[1]

[1]Faculty of Physics. Adam Mickiewicz University, Poznań, Poland

A high-temperature superconductor (HTSC) was used to induce a high-temperature, proximity-induced superconductivity in Bi_2Te_3 via proximity to $YBa_2Cu_3O_{7-\delta}$ (YBCO) with T_c=95K.

Δ_i the proximity-induced gap in the Bi_2Te_3

Δ_r the reduced gap of the YBCO superconductor

$$\Delta_{sc}(T) = \Delta_{sc}(T=0)\tanh\left(1.74\sqrt{\frac{T_C}{T}-1}\right) \qquad (1)$$

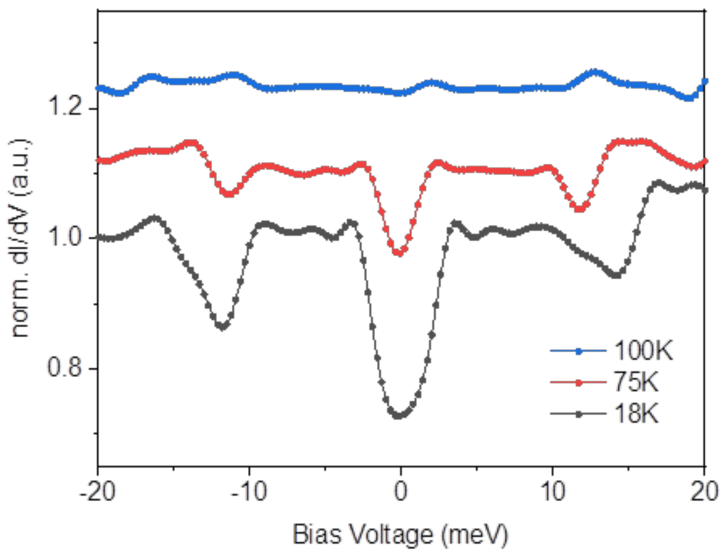


Fig.1 Differential conductance vs. bias voltage at selected temperatures.

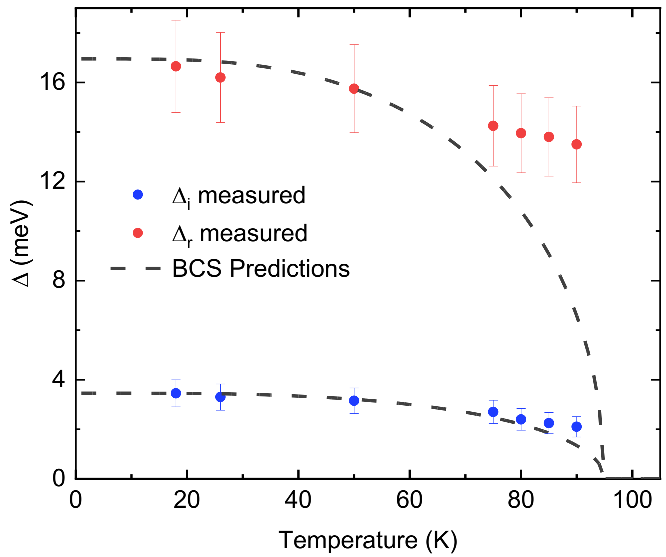


Fig.2 Temperature dependencies of Δ_i and Δ_r . Dashed lines (eq.1) do not fit to experimental data – the HTSC is not the BCS-type superconductor[1].

Raman scattering on the Bi_2Te_3/YBCO

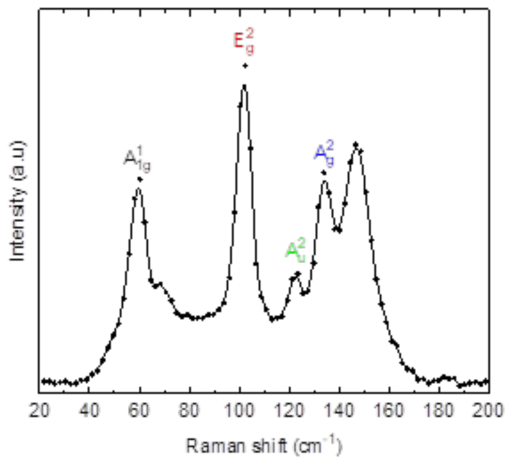


Fig.3. Characteristic Raman modes for the Bi_2Te_3/YBCO at T=87K.

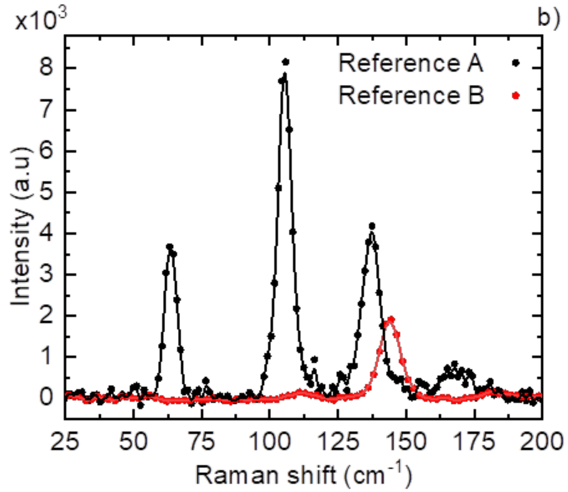
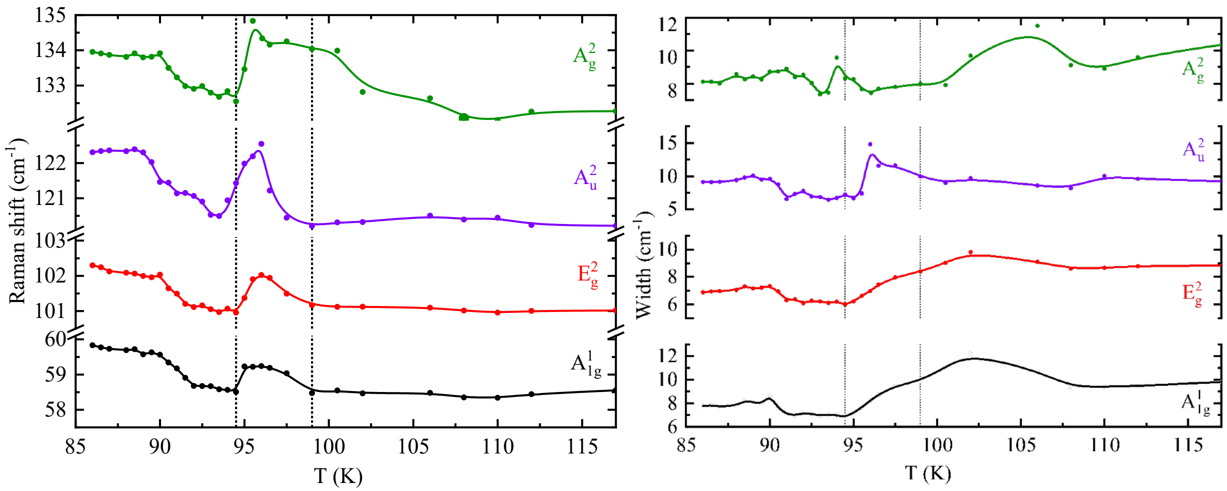


Fig.4. Raman spectra of Reference A (40nmTI/sapphire) and Reference B (500nmYBCO/sapphire) at T=87K.



Raman spectra collected at the TI/YBCO interface reflected processes taking place in the TI only.

Fig.5. Temperature dependencies of Raman shifts and FWHM of Raman active modes of the Bi_2Te_3.

Conclusions

Charge transport experiments have been performed to confirm emergence of the reduced gap Δ_r=16.7meV in the YBCO and the proximity-induced gap Δ_i=3.6meV in the TI. Both showed the same critical temperature T_c=95K.

Raman peaks at 61, 102, 120 and 134 cm^{-1} (A^1_{1g}, E^2_g, A^2_g and A^2_u, respectively) (fig.3) were detected at the interface of the TI/YBCO and were identified as characteristic modes for the Bi_2Te_3

.

- At temperature range 96K<T<100K, dependencies of Raman shifts of A^1_{1g}, E^2_g, A^2_u and A^2_g peaks increased. It can be attributed to emergence of a proximity-induced pseudogap in the TI corresponding to the pseudogap of the YBCO. Such hardening of the Raman modes implies that the energy of the pseudogap was smaller when compared to the energies of the Raman modes[2].

- Softening of the Raman modes at temperatures ranging between 96K and 95K can be due to thermodynamic fluctuations of the superconducting order parameter at T_c [3].

- Upon further cooling below T_c, the Raman shifts increased again as a result of the emergence of the proximity-induced gap in the TI. The hardening implies that its energy was smaller when compared to the energy of the modes.

[1] Božović, et al.,. Can high- Tc superconductivity in cuprates be explained by the conventional BCS theory? *Low Temp. Phys.* **44**, 519 (2018).
[2] Krieger, J. A. *et al.* Proximity-Induced Odd-Frequency Superconductivity in a Topological Insulator. *Phys. Rev. Lett.* **125**, 026802 (2020).
[3] Wirngo et al.,Crossover effects and finite-size scaling on the temperature dependence of paraconductivity in $YBa_2Cu_3O_{6.9}$ and $Bi_2Sr_2CaCu_30_x$ compounds. *Phys. Lett. Sect. A Gen. At. Solid State Phys.* **383**, 259–263 (2019).