Low-Temperature Thermal Properties of Carbon-Based Nanomaterials: Exploration of Graphene Oxide and Fullerene Composites

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This study investigates the heat capacity of thermally reduced graphene oxide (TRGO-300) combined with fullerene C60 (HyFn) within the temperature range of 2 K to 300 K, utilizing a Physical Property Measurement System (PPMS) with a Heat Capacity Module. In addition to these materials a reference tests with commercial samples from SigmaAldrich were performed both for pure fullerene C60 and graphene oxide. The research aims to uncover how structural disorder influences thermal behavior, focusing on identifying anomalies such as the boson peak – a feature associated with vibrational density of states in disordered systems, crucial for understanding low-temperature thermal properties in nanostructured materials.

Samples:

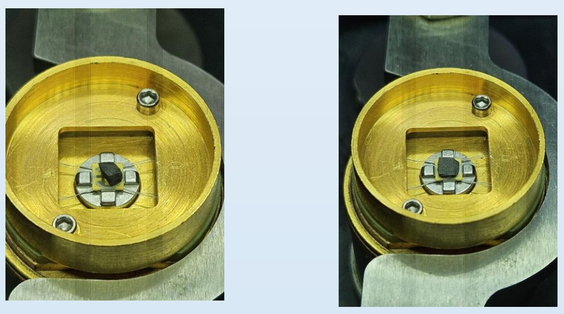

Fig. 1 Examples of investigated materials on the sample platform (PPMS)

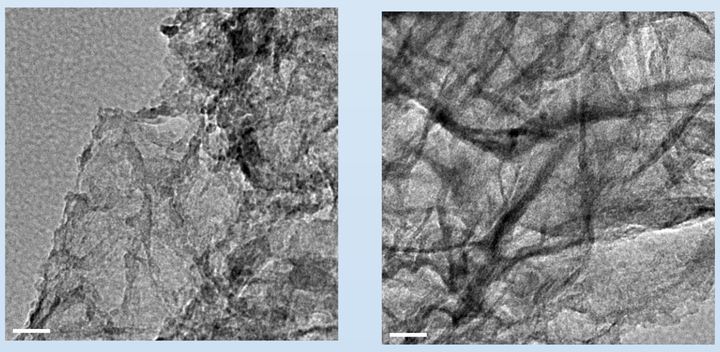

Fig. 2 Experimental data from TEM (20 nm).

Raman spectra

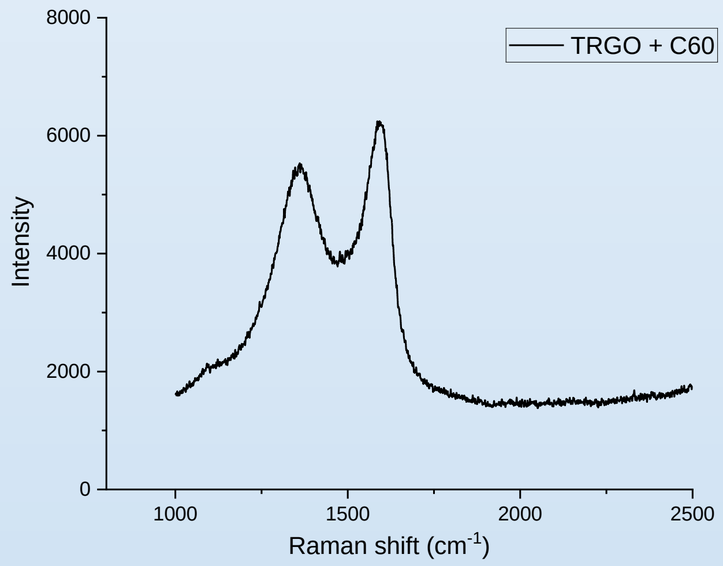

Fig. 3 Raman-spectroscopy data for TRGO with C60.

Measurement setup

Fig.4 The specific heat was determined using the method of thermal relaxation on a commercially available Physical Properties Measurement System (PPMS, Quantum Design Inc.)

Experimental results:

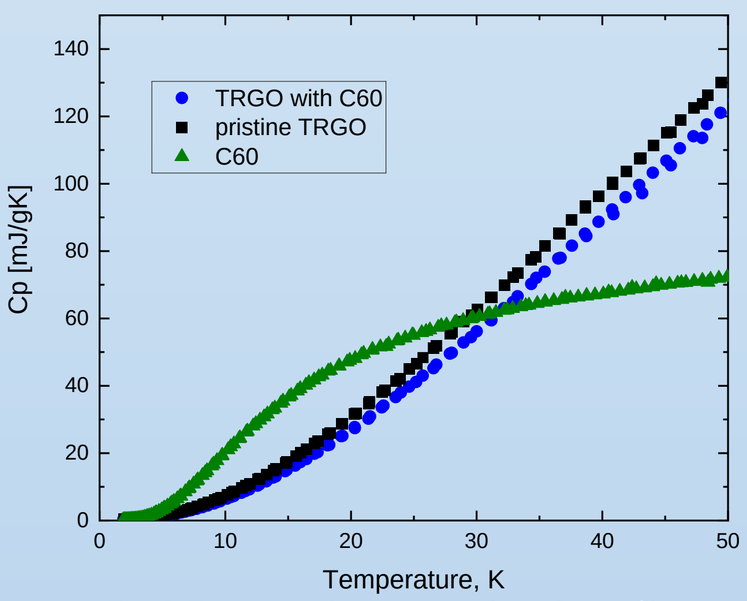

Fig. 5. Experimental temperature dependence of heat capacity for TRGO with C_{60}, pristine TRGO, and pure C_{60}.

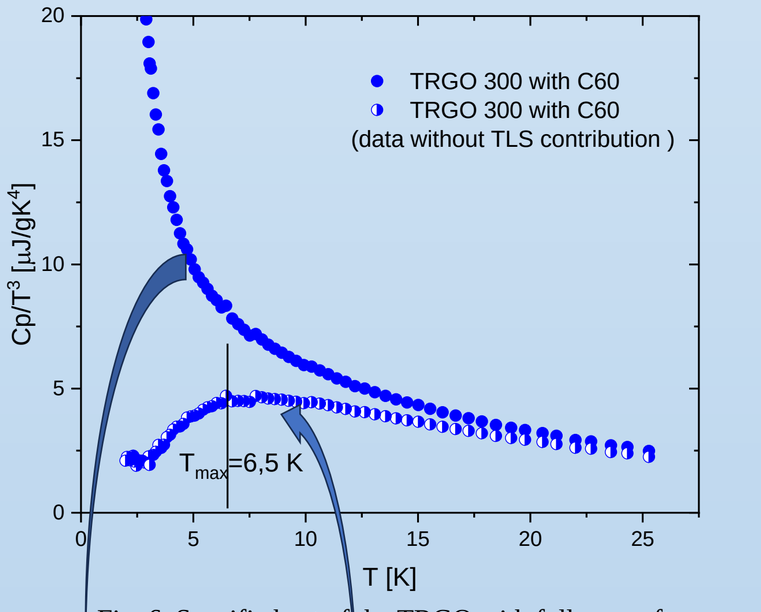

Fig. 6. Specific heat of the TRGO with fullerene after deducting the contribution of tunnelling two-level systems plotted as C/T^3 vs T.

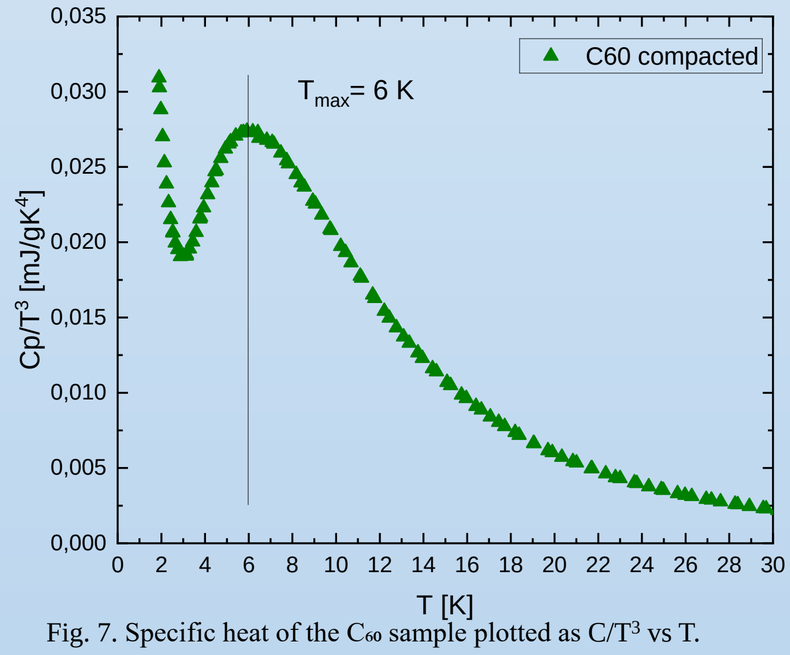

Fig. 7. Specific heat of the C_{60} sample plotted as C/T^3 vs T.

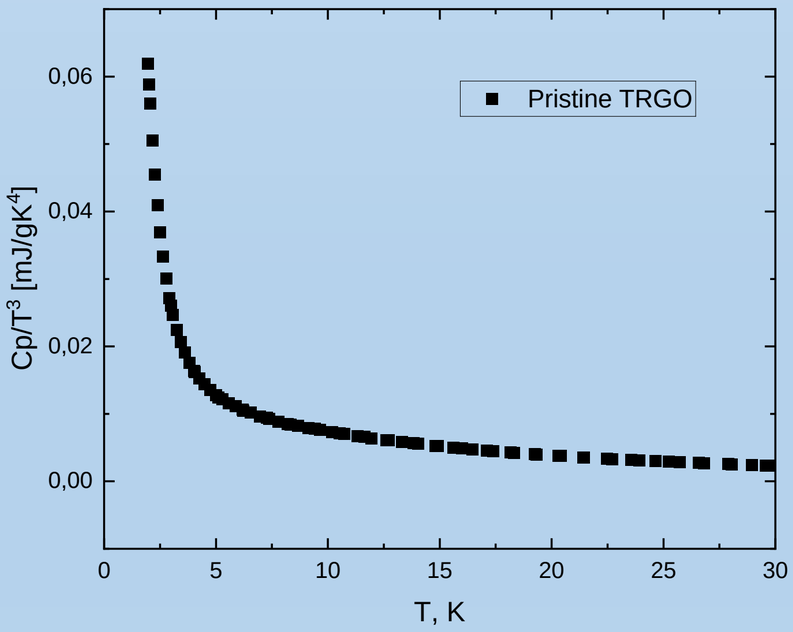

Fig. 8 Specific heat of the TRGO sample plotted as C/T^3 vs T

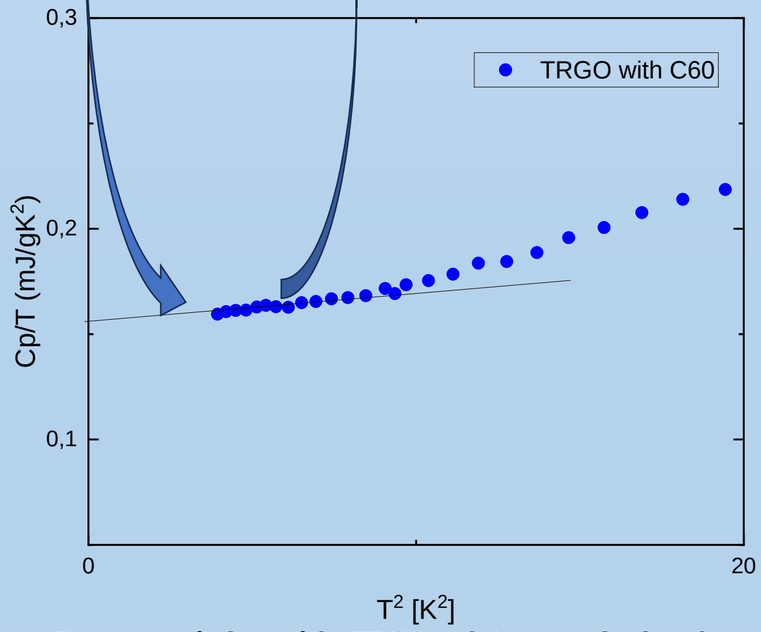

Fig. 9. Specific heat of the TRGO with C60 sample plotted as C/T vs T^2.

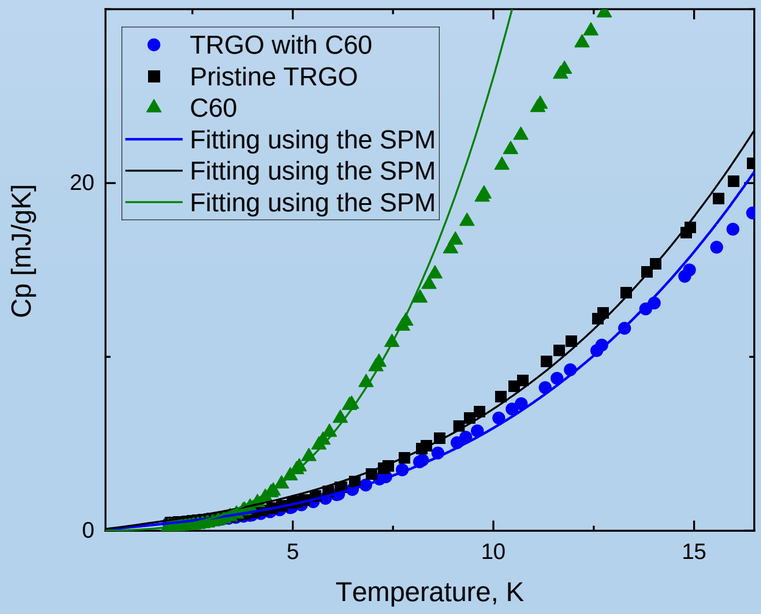

Fig. 10. Low-temperature specific heat data with fitting data using the soft potential model.

The main outcome of this study is the detection of a pronounced boson peak in TRGO–C60 composites, revealed upon subtraction of the TLS (linear) contribution from the specific heat data. This study not only enhances understanding of heat transport mechanisms in carbon-based nanostructures but also provides valuable insights for applications in nanotechnology and cosmic science, where efficient thermal management is vital for performance and material stability. The findings underscore the importance of material synthesis methods in tailoring thermal properties, paving the way for future research on advanced carbon composites in extreme environments.

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