True-Colour Real-Time Imaging of Single-Walled Carbon Nanotubes via Enhanced Rayleigh Scattering

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1. Formatting of main text and page layout

Single-walled carbon nanotubes (SWCNTs) illuminated by white light should appear coloured due to resonance Rayleigh scattering. However, true colour imaging of SWCNTs on substrate has not been reported, because of the extremely low scattering intensity of SWCNTs and strong substrate scattering. Here we show that Rayleigh scattering can be greatly enhanced by interface dipole enhancement effect. Consequently colourful SWCNTs on substrates can be directly imaged under an optical microscope by wide field supercontinuum laser illumination, which facilitates high throughput chirality assignment of individual SWCNTs [1].

For a better understanding of the enhanced Rayleigh scattering, the optical effect of a nanometer or sub-nanometer interfacial layer of condensed molecules surrounding individual nanomaterials such as single-walled carbon nanotubes (SWCNTs) has been studied theoretically and experimentally. This interfacial layer, when illuminated by light, will behave as an optical dipole lattice and contribute an instantaneous near field to enhance the local field on neighbouring atoms, molecules, or nanomaterials, which may lead to enhanced Raleigh scattering, Raman scattering, and Fluorescence. The theory of this interface dipole enhanced effect (IDEE) predicts that a smaller distance of nanomaterials to the plane of the interfacial layer, or a larger ratio of the dielectric constants of the interfacial layer to surrounding medium, will result in a larger field enhancement factor. This prediction is further experimentally verified by several implementations of enhanced Rayleigh scattering of SWCNTs as well as in-situ Rayleigh scattering of gradually charged SWCNTs. The interface dipole enhanced Rayleigh scattering not only enables true-colour real-time imaging of nanomaterials, but also provides an effective mean to peer into the subtle interfacial phenomena [2].

This approach, true-colour real-time imaging of single-walled carbon nanotubes via enhanced Rayleigh scattering, which is also termed “Rayleigh imaging microscopy”, is not restricted to SWCNTs, but widely applicable to a variety of nanomaterials, which enables people to explore the colourful nano-world under optical microscopes.

2. Figures and tables

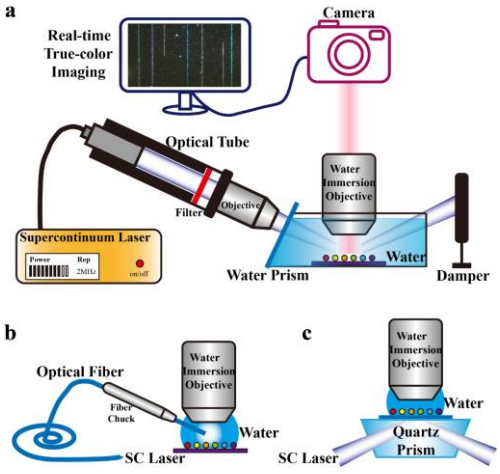

Fig. 1. Schematic illustration of Rayleigh imaging microscopy for true-color real-time imaging of SWCNTs, a, b, c, three different experimental setups.

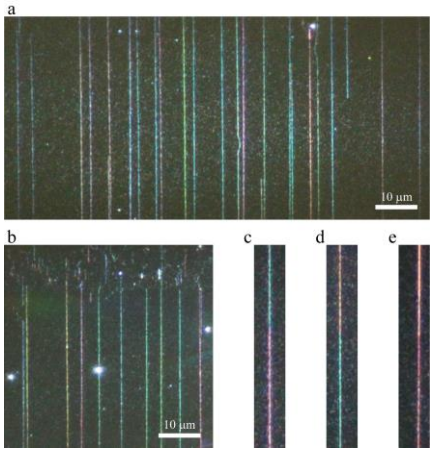

Fig. 2. True color imaging of SWCNTs. a, b,Typical true color image of horizontally aligned SWCNTs on Si wafer with 100 nm SiO2. c-e, Typical true color images of three individual SWCNTs with intramolecular junctions.

3. References

[1] W. Y. Wu, J. Y. Yue, X. Y. Lin, D. Q. Li, F. Q. Zhu, X. Yin, J. Zhu, J. T. Wang, Y. Chen, X. H. Wang, T. Y. Li, Y. J. He, X. C. Dai*, P. Liu, Y. Wei, J. P. Wang, W. Zhang, Y. D. Huang, L. Fan, L. N. Zhang, Q. Q. Li, S. S. Fan, and K. L. Jiang*, Nano Research, **8,** 2721 (2015).

[2] W. Y. Wu, J. Y. Yue, D. Q. Li, X. Y. Lin, F. Q. Zhu, X. Yin, J. Zhu, X. C. Dai*, P. Liu, Y. Wei, J. P. Wang, H. T. Yang, L. N. Zhang, Q. Q. Li, S. S. Fan, and K. L. Jiang*, Nano Research, **8**, 303 (2015).