Exciton-Polaritons, Plexcitons and Trion-Polaritons in Single-Walled Carbon Nanotube Thin Films and Devices

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Exciton-polaritons are mixed light-matter quasiparticles that form upon strong coupling between electronic excitations of a material and photonic states of a surrounding microcavity. Highly purified, monochiral (6,5) single-walled carbon nanotubes (SWCNTs) exhibit optical and electronic properties that make them ideal for strong light-matter coupling in combination with fast charge transport, thus enabling optically and electrically pumped near-infrared exciton-polaritons at room temperature [1,2]. While exciton-polaritons can be observed in simple metal-clad or high-quality distributed Bragg reflector microcavities, coherent coupling of carbon nanotube excitons with hybrid plasmon-photonic modes (supported by plasmonic crystals formed by diffractive coupling of periodically arranged gold nanorods) results in plasmon-exciton polaritons ('plexcitons') [3] that can propagate over 20-30 micrometers during their short lifetime (~100 fs).

Further, doped (6,5) SWCNTs also exhibit stable trions (positively or negatively charged excitons) at room temperature with red-shifted absorption and emission. We demonstrate the formation of emissive trion-polaritons (indicated by splitting of the lower polariton mode into a new lower and middle polariton, see Fig. 1) via electrochemical hole-doping of a thick film of (6,5) SWCNTs in a suitable metal-clad microcavity [4]. These charged trion-polaritons might be interesting for enhanced charge transport due to their low effective mass.

[1] A. Graf et al., Nature Comm. **7**, 13078 (2016).
[2] A. Graf et al., Nat. Mater. **16**, 911 (2017).
[3] Y. Zakharko, A. Graf, and J. Zaumseil, Nano Lett. **16**, 6504 (2016).
[4] C. Möhl et al., submitted.

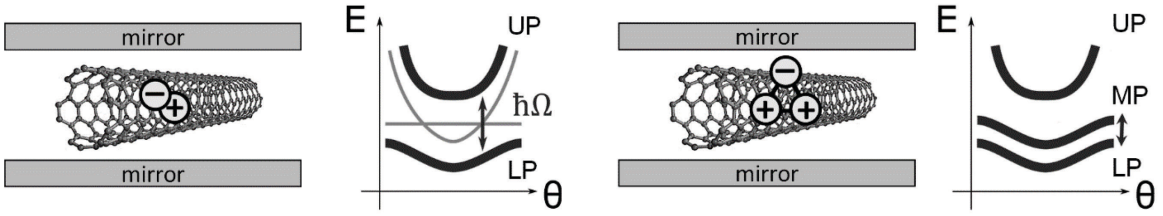

Fig.1 Schematic illustration of (6,5) SWCNT excitons in a simple microcavity leading to exciton-polariton formation (UP: upper polariton, LP: lower polariton), corresponding schematic for nanotube trions resulting in additional splitting of the LP mode (MP: middle polariton) and thus formation of charged trion-polaritons.