Integration of covalent and non-covalent functionalized SWCNTs in FETs

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Motivation

Metal nanoparticles (M-NPs) attached to carbon-based nanostructured materials enable new nansoelectronic solutions for, e.g. energy storage, as fuel cells or supercapacitors [1, 2] and also for chemical, biochemical [3, 4] and optical sensors [5-8]. A requirement for electronic sensors is the design of a versatile nansoelectronic transducer. In the ideal case, such a component can be functionalized with nanoscopic building blocks in a modular manner that allows selective response and tuning of the sensitivity of the device. Nanoelectronic field-effect transistors (FETs) using individualized single-walled carbon nanotubes (SWCNTs) have been proposed as a FET channel material [5-6].

Recently, we presented a scalable on-chip functionalization approach for SWCNTs between palladium electrodes in the geometry of a FET with preformed Au-NPs based on the Hirsch-functionalization of SWCNTs [5]. This method is water-level compatible and comprises two stages of flow chemistry. In a new chemical approach, we propose the deposition of dispersed SWCNTs by using alkylthioate functionalized pyrene which allows selective attachment of M-NPs.

Non-covalent functionalization

(a) N-bromosuccinimide, CHCI₃ 6 h, RT; (b) n-BuLi, Et₂O, 30 min, 0°C; Br; (c) CH₃COBr, 2 h, 35 °C; (c) Potassium tetrathionate, Me₂SO, 48 h, 60 °C

Scheme 1: Synthesis protocol for the preparation of 1.

• Preparation of SWCNT dispersions (Sigma Aldrich (6.5)-SWCNTs, 80 % purity) in a CHCl₃-solution of 1
• No debundling of SWCNTs by using ultrasonic bath sonication (BS, Fig. 1, blue line)
• Absorption band at 1000 nm for tip sonication (TS, Fig. 1, green line) → Indication of CNT debundling (S₂, transition of semiconductor SWCNTs)

Summary & Outlook

Summary:
• Debundling of SWCNTs in organic solvents supported by alkylthioate functionalized pyrene through non-covalent interaction → Access to stable SWCNT dispersions for integration in FETs
• Au-NP functionalization of SWCNTs by usage of azidobenzyl formates → Interaction of Au-NPs with ethylene glycol chains
• Formation of hexagonal gold agglomerates by redoxchemical reactions in water dispersion of Cu-NPs → Scalable synthesis of hexagonal Au nanostructures

Outlook:
• Selective attachment of Au-NPs by usage of alkylthioate functionalized pyrene on SWCNTs and integration on wafer-level → Take advantage of thiophilic behavior of Au-NPs

References


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