HL 76: Carbon nanotubes

Time: Thursday 11:30–13:00 Location: EW 015

HL 76.1 Thu 11:30 EW 015

Wafer-level fabrication and characterization of photosensitive CNT-FETs — •Laura Kasper[1,2], Thomas Blaudeck[1], Sascha Hermann[1,3], and Stefan E. Schulz[1,2,3] — [1]Technische Universität Chemnitz, Zentrum für Mikrotechnologien, 09107 Chemnitz — [2]Fraunhofer-Institut für Elektronische Nanosysteme (ENAS), 09126 Chemnitz, Germany — [3]DFG Cluster of Excellence "Center for Advancing Electronics Dresden" (cfaed), Carbon Path, 09107 Chemnitz, Germany

We report on the wafer-level fabrication and a quantitative analysis of the light detection properties of carbon-nanotube field-effect transistor (CNT-FET) arrays. We determine parameter ranges for the optical and electrical properties for achieving relevant photocurrents (> 100 pA) and responsivities (~ 1 uA/W). Aside of the dynamic range of the sensor devices, the noise-equivalent power varies clearly with the applied source-drain voltages. Local intensity scans of the sensor response (source-drain current as a function of the locus of incidence) along the transistor channel reveal the fundamental Schottky behavior of the device related to the CNT-metal contacts. The results are reported for two batches of CNT-FETs varying the number of semiconducting CNTs as transistor channel. Especially the illumination of FETs with high-density CNT transistor channels show a smoothing of their transfer characteristics. Illumination of single-CNT channels shows signs of power dissipation. The influence of a CNT sidewalls functionalization with metal nanoparticles acting as light-sensitive floating gates is discussed as well.

HL 76.2 Thu 11:45 EW 015

Optimizing Dispersion Preparation for the Wafer-Level Deposition of CNTs — •Toni Hille[1,2], Thomas Blaudeck[1], Sascha Hermann[1,3], and Stefan E. Schulz[1,2,3] — [1]Technische Universität Chemnitz, Zentrum für Mikrotechnologien, 09107 Chemnitz, Germany — [2]Fraunhofer-Institut für Elektronische Nanosysteme (ENAS), 09126 Chemnitz, Germany — [3]DFG Cluster of Excellence "Center for Advancing Electronics Dresden" (cfaed), Carbon Path, 09107 Chemnitz

In this work, we show systematic studies on the CNT dispersion preparation comprising homogenization, ultrasonication, and centrifugation and their optimal parameters for the wafer-level fabrication of CNT-FETs as building blocks of high-frequency and sensor components. With an in-situ monitoring of the optical absorption, a detailed analysis of the dispersion process for different surfactants (sodium lauryl sulfate, sodium deoxycholate, etc.), concentrations, and preperation conditions was possible. It turns out that the degree of debundeling can be tuned using an intermittent ultrasonication, varying the waiting times for the dispersion constituents to settle down between recurrent sonotrode pulses. The influence of temperature during centrifugation and storage of the dispersion is discussed as well.

HL 76.3 Thu 12:00 EW 015

A wafer-level test platform for statistical TEM analysis of the structural properties of integrated carbon nanotubes — •Martin Hartmann[1,2], Sascha Hermann[1,2], Darius Pohl[3], Bernd Relinghaus[3], and Stefan E. Schulz[1,2,4] — [1]Center for Microtechnologies (ZFM), TU Chemnitz,Chemnitz, Germany — [2]Center for Advancing Electronics Dresden (cfaed), TU Chemnitz, Chemnitz, Germany — [3]Leibniz Institute for Solid State and Materials Research (IFW), Dresden, Germany — [4]Fraunhofer Institute for Electronic Nano Systems (ENAS), Chemnitz, Germany

A carbon nanotube-based field-effect transistor (CNT-FET) is a promising building block in many electronic and sensor applications. However, the actual performance of those devices has not reached predicted values yet. This can be related to the high sensitivity of the nanomaterial to its environment as well as its structural and compositional configuration. Thus better methods for the investigation of nanomaterials under application-close conditions are required. We demonstrate an in-depth analysis of the FET channel structure by high-resolution transmission electron microscopy (HRTEM). Therefore, a special test platform was developed that facilitates electrical and transmission studies of integrated nanomaterials like CNTs. In this approach, special emphasis was laid on a wafer-level technology used for high-throughput FET fabrication enabling statistical studies. The concept as well as first investigations on exposed CNT-FET channel regions are going to be presented giving insights into chiral and elementary composition.

HL 76.4 Thu 12:15 EW 015

Carbon nanotubes under strain: Electronic and Optical properties — •Christian Wagner[1], Jörg Schuster[2], Michael Schreiber[3], and Thomas Gessner[1,2] — [1]Center for Microtechnologies, TU Chemnitz, Germany — [2]Fraunhofer Institute ENAS, Chemnitz, Germany — [3]Institute of Physics, TU Chemnitz, Germany

Carbon nanotubes (CNTs) are becoming interesting for applications as they show some very unique properties upon strain: On load, their whole electronic band structure is shifting (according to their chiralities) and that makes them suitable for electronic and optical strain sensing at the nano scale.

We show the results of electronic structure calculations of strained CNTs (DFT and beyond) and the link to their electronic and optical properties. It can be shown that an empirical model can account for the CNT bands and their strain-dependent properties.

Based on the electronic structure, we derive transport properties of strained CNTs and their mixtures in a transistor configuration. For the modeling of the optical properties, we show optical spectra derived from electronic structure calculations. The optical spectra of unstrained CNTs are described by empirical models [1]. We aim to incorporate strain effects into these models by comparison to electronic structure calculations.

[1] K. Liu et al., Nat. Nanotech. 7, 325 (2012)

HL 76.5 Thu 12:30 EW 015

Carbon nanotube based field-effect transistors: comparison between atomistic quantum transport and numerical device simulation — •Florian Fuchs[1], Andreas Zienert[2], and Jörg Schuster[1] — [1]Fraunhofer Institute for Electronic Nano Systems (ENAS), Chemnitz, Germany — [2]Center for Microtechnologies, Technische Universität Chemnitz, Chemnitz, Germany

We study carbon nanotube based field-effect transistors (CNTFETs) by means of two different approaches: numerical device simulation (NDS) based on the effective mass Schrödinger equation and atomistic quantum transport simulation based on the non-equilibrium Green's function formalism (NEGF). The required parameters for the NDS model are extracted from density functional theory data. An all-carbon CNTFET with n-doped source- and drain-electrodes in a gate-all-around geometry is investigated. The NDS predicts a band-to-band tunnel current once the valence band edge is shifted to the Fermi energy. This increases the off-current and leads to slightly ambipolar behavior. Using the NEGF on the other hand, localized states inside the channel can be observed because a potential well is created by the gate. As a result, the band-to-band tunnel current is suppressed and improved transistor properties are predicted by NEGF calculations. By varying the channel length, we demonstrate the potential of the studied CNTFET for future applications, which shows an on/off current ratio above 10^6 and a subthreshold swing below 80 mV/dec down to channel lengths of about 8 nm.

HL 76.6 Thu 12:45 EW 015

Ramanspektroskopie an gekreuzten Kohlenstoffnanoröhren — •Norman Susilo[1], Asmus Vierck[1], Florentina Gannott[2], Manuel Schweiger[2], Jana Zaumseil[2] und Janina Maultzsch[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]Lehrstuhl für Angewandte Physikalische Chemie, Physikalisch-Chemisches Institut, Ruprecht-Karls-Universität Heidelberg

Eine der etabliertesten Methoden zur Untersuchung von Kohlenstoffnanoröhren (CNTs) ist die Ramanspektroskopie. Vielfach werden die Untersuchungen allerdings an Ensembles bzw. dünnen Bündeln von CNTs durchgeführt. Um den Einfluß von elektronischen und mechanischen Wechselwirkungen zwischen zwei CNTs besser zu verstehen, untersuchen wir definierte Kreuzungspunkte von CNTs.

Wir präsentieren eine statistische Analyse der Ramanspektren von sich in einem Winkel von 90° kreuzenden, individuellen, einwandigen CNTs. Wir diskutieren die Veränderungen der Ramanspektren an den Kreuzungspunkten bzgl. elektronischer und mechanischer Effekte. Es wird u.a. gezeigt, dass die Intensität der Defekt-induzierten D-Mode am Kreuzungspunkt der Kohlenstoffnanoröhren steigt.