nano-tera.ch
swiss scientific initiative in health / security / environment systems

CabTuRes RTD 2009

FNSNF

Growth of Individual Carbon Nanotubes with Precise location

Massimo Spina[1], Axel Fanget[1], Primož Rebernik Ribič[2], László Forró[1], Arnaud Magrez[1]

[1]*Laboratory of Physics of Complex Matter, École Polytechnique Fédérale de Lausanne, Switzerland*

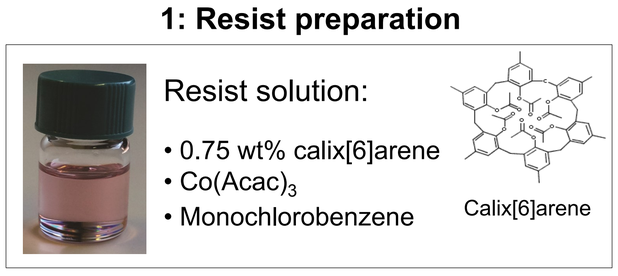
[2]*Laboratory of Physics of X-rays, École Polytechnique Fédérale de Lausanne, Switzerland*

Abstract

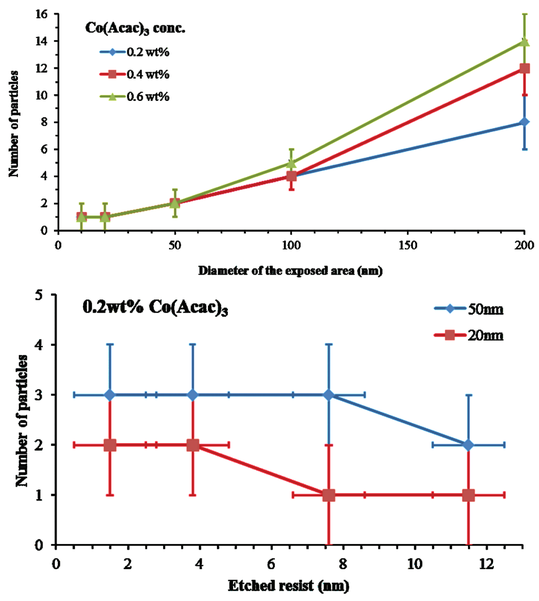
Electronic devices based on individual single-walled carbon nanotubes (SWCNTs) remain at the prototype level because of the limited reliability of the growth processes and the absence of control over electrical properties and positioning of the obtained nanotubes. To improve the location and narrow the electronic property distribution of the SWCNTs, we have developed a method based on a negative-tone e-beam resist doped with Co. At the end of the process, individual particles with a diameter of 1.2±0.2nm are localized within an area of 80nm^2. From these particles, high-quality SWCNTs are grown by a Chemical Vapor Deposition (CVD) with high yield from ethanol. The process is being integrated into the fabrication process of the nano electro-mechanical system (NEMS) developed by our partners at ETHZ.

Catalyst formation process

1: Resist preparation | **2: Spin coating** | **3: E-beam Lithography** | **4: Reactive Ion Etching** | **5: Annealing** | **6: Oxidation**

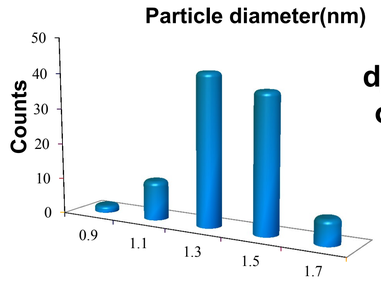


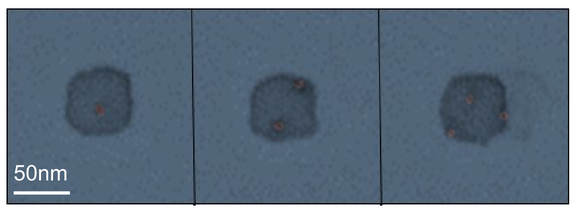
Characterization of the Catalyst Particles



AFM analysis

Particle diameter(nm)



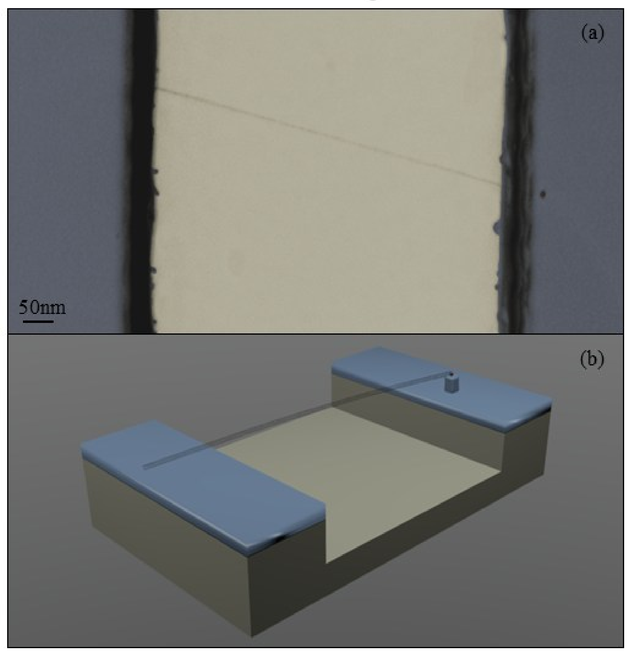


Colored HRSEM micrographs of three pillars with a diameter of 50nm. The number of particles varies according to the RIE time and the Co concentration in the calix[6]arene resist.

HIGHLIGHTS:

- **Localisation of one particle within an area of 80nm²**
- **Narrow Particle Diameter Distribution**

Growth of Single-walled carbon nanotubes

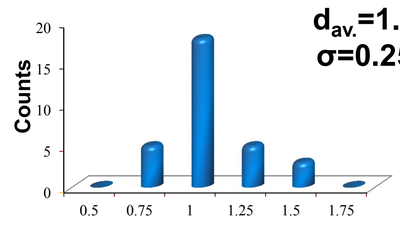


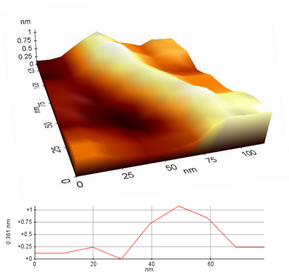
Colored high resolution SEM micrograph and its schematic representation. A SWCNT is grown by CVD from ethanol over a 2µm deep trench from one patterned Co nanoparticles. It has a diameter of 1.2±0.25nm corresponding to the diameter of the Co nanoparticles.

- **Growth temperature: 800°C**
- **Carbon source: Ethanol**

AFM analysis

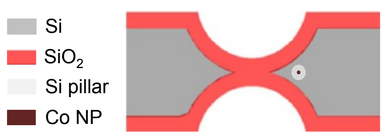
CNT diameter (nm)

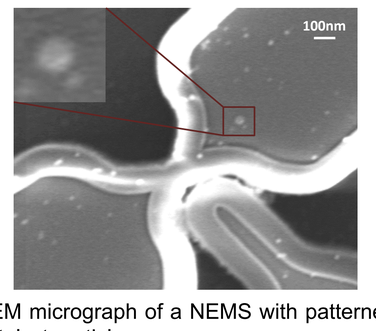




- **100% of the particles yield a SWCNT**

Integration into NEMS process flow

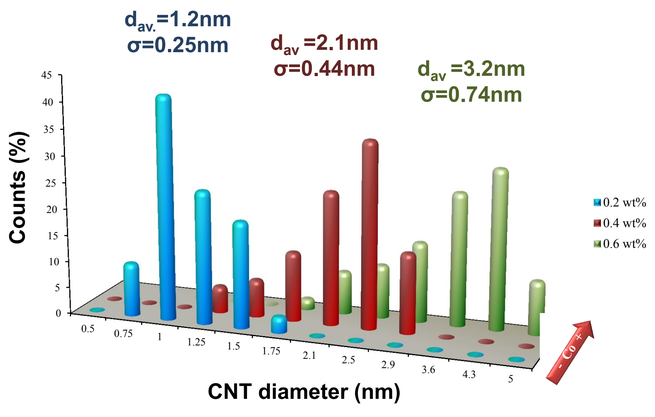




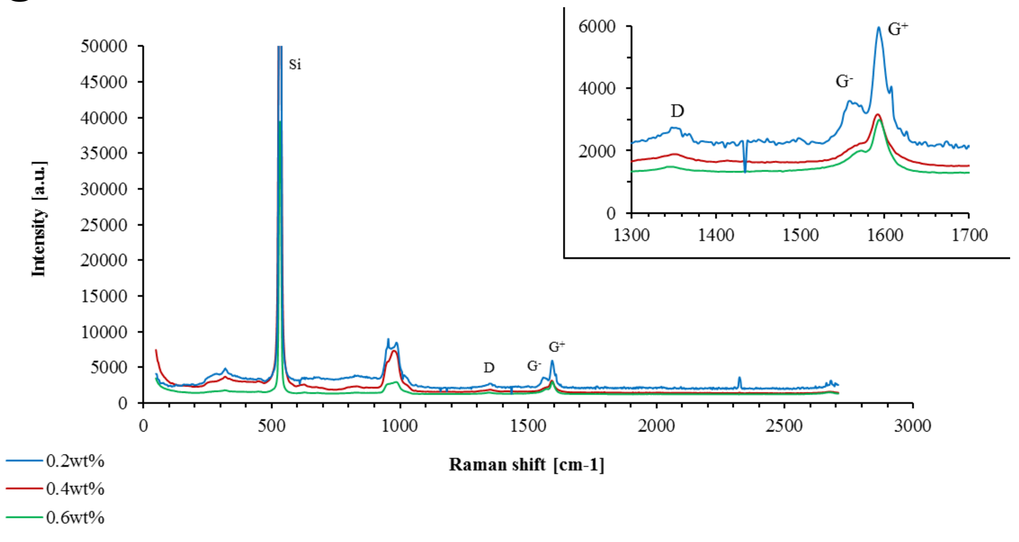
SEM micrograph of a NEMS with patterned catalyst particle.

- **1 Cobalt nanoparticle (NP) in a 250nm² area**

Characterization of the Growth of Single Walled Carbon Nanotubes



Diameter distribution of the grown SWCNTs, established by AFM analysis, for different Co concentrations in the calix[6]arene resist.



Raman spectra of the grown SWCNTs for three concentrations of Co in the resist. Nanotube structure contains limited defects. Despite the increase of the metal concentration, their average diameter remains in the 1.2nm range.

- **For a defined patterned area, the increase of the Co concentration in the resist leads to the growth of bundles of 1.2nm SWCNTs.**

Acknowledgements

This research has been funded by Nano-Tera.ch, a program of the Swiss Confederation, evaluated by SNSF.

Contacts:

E-mail: massimo.spina@epfl.ch; arnaud.magrez@epfl.ch

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

EMPA Materials Science & Technology

CabTuRes Carbon nanoTube Resonators