# Exercise 5: Synthesis and measurement of carbon nanotubes

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Based on the discussion occurred during the lab course with the assistant (Dr. Anastasios Karakasidis) and after reading the documents of PHY-E0411(2023) and review of FCCVD films, please provide your answers below. Supplementary videos 1 and 2 (made in 2020) about CNTs and FCCVD process, video 3 (made in 2021) about the FCCVD reactor and press transfer are also provided for extra information.

Send your Lomake (or Report) to the assistant (anastasios.karakasidis@aalto.fi) as .pdf file and name the report as 'Lomake (Report)-*2023-group number-author surname*'.

# Lomake

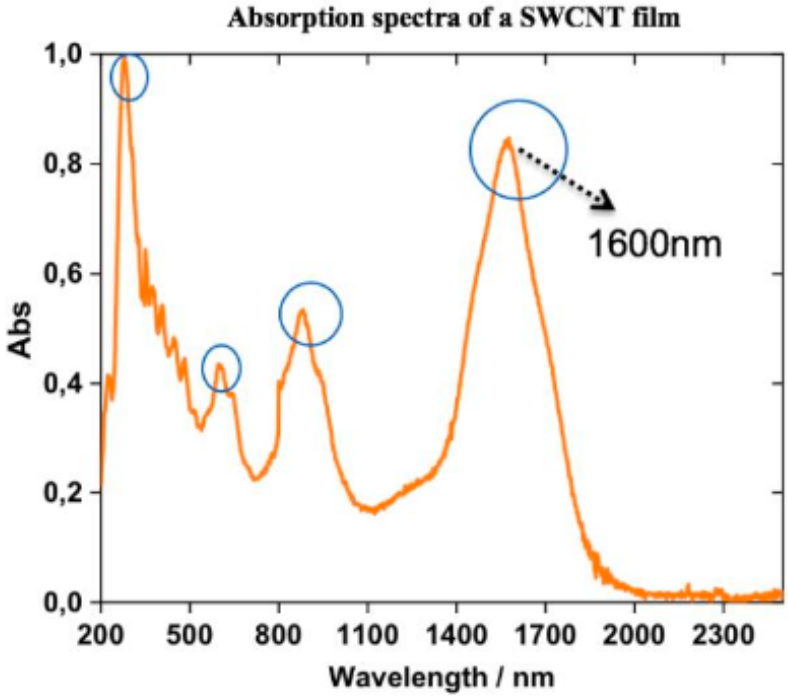
1. What is a single-walled carbon nanotube (SWCNT)? How SWCNTs are different from other carbon materials e.g. graphene, diamond, and Fullerene?

2. Discuss three types of SWCNTs (i.e. Zig-zag, chiral and armchair)? What's difference between metallic SWCNTs and semiconducting SWCNTs?

3. Write a note on different synthesis techniques for SWCNTs. Why floating catalysts chemical vapor deposition technique is more preferable for the synthesis of SWCNTs?

4. A typical absorption spectra of SWCNT film shown below.

   Describe the 4 absorption peaks marked by blue circles and explain the corresponding physical processes. Calculate the mean diameter from the absorption spectra.




5. How to evaluate the performance of materials as transparent electrodes? Define a figure of merit (FOM) of transparent conductive materials.

# Report

The report should be related to the SWCNT transparent conductive films (TCF) and contains the below information

### 1. Introduction

Describe the single-walled carbon nanotube (SWCNT) in general, including definition, structure, electronic structure.

Describe SWCNT transparent conductive films (TCF) and also think of some applications.

### 2. Experimental setup and materials used

Discuss synthesis of SWCNTs and SWCNT TCFs from FC-CVD reactor including all necessary experimental conditions. Compare the liquid methods and FCCVD methods for SWCNT films fabrication.

Describe how the absorption peaks of SWCNTs correlated to its transition energy. Briefly describe the Raman scattering process in general, and then discuss the resonant Raman scattering of SWCNT materials. Describe the RBM and G modes of SWCNTs and how the RBM peaks related to the structure and properties of SWCNTs.

### 3. Results and Discussion

Compare SWCNT TCFs with other TCFs (e.g. ITO, graphene and metal mesh).

Explain why the conductivity of SWCNT films much lower than that of individual SWCNTs.

How to improve the conductivity of SWCNT TCFs.

Calculate the transmittance (at 550nm) of the fabricated films, based on the UV-VIS measured spectra.

Calculate the diameter range of the fabricated SWCNTs using UV-VIS data (Kataura plot) and provide an appropriate table.

Make the plot of the transmittance vs thin sheet resistance data.

### 4. Conclusion

Discuss briefly main findings of yours experimental results.