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Influence of water concentration on the growth kinetics and M/SC selectivity of individual SWCNTs from *in situ* optical microscopy

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Introduction

Chiral selective synthesis of SWCNTs has been one of the main drawbacks that have hindered their application, specially in electronics, where high chiral purity is required. The control of chirality, length and density of synthesized CNTs has been studied by varying synthesis parameters, such as catalyst systems, temperature, pressure, carbon precursors and etchants [1]. Here, we studied the influence of pressure of the etchant (water) on the SWCNT growth kinetics during alcohol catalytic chemical vapor deposition (CVD). A water-assisted CVD coupled with an *in situ* optical imaging set-up was used.

Methods

Homodyne polarization microscopy was used for imaging long aligned individual SWCNTs during their growth, as reported in [2].

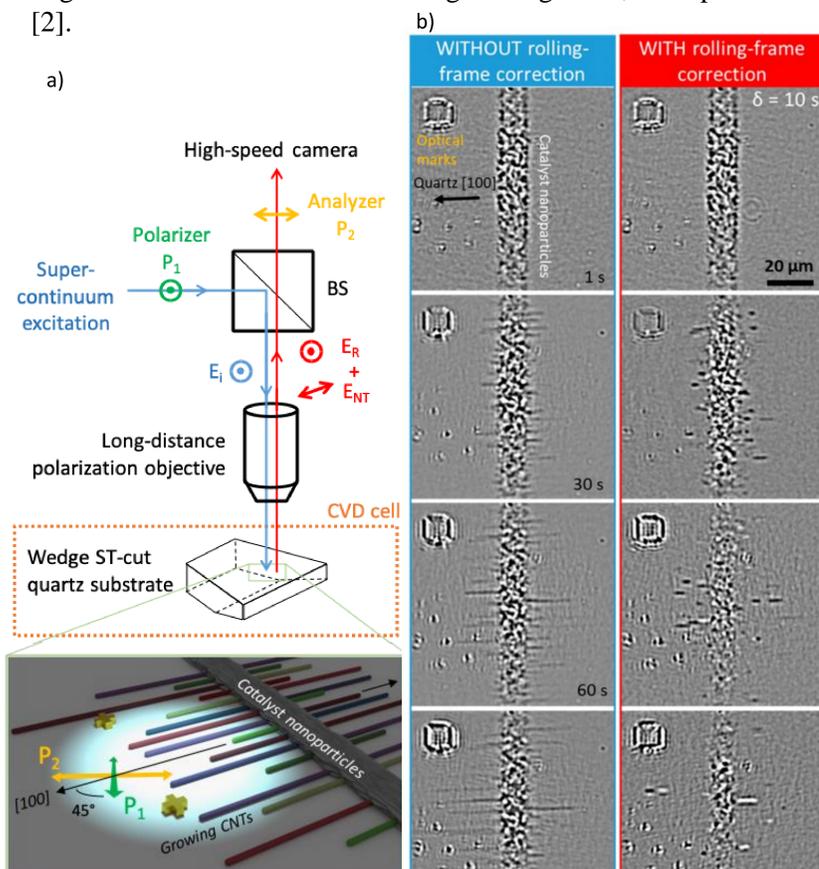
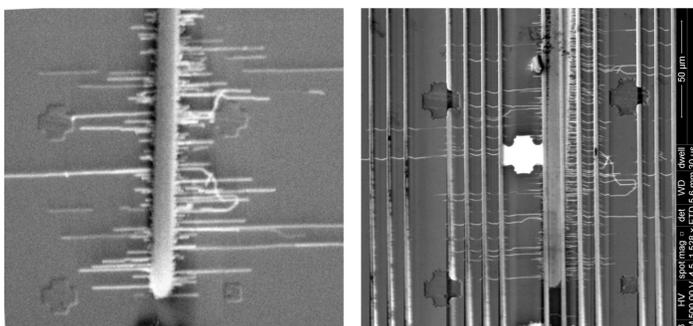


Figure 1. *In situ* imaging of CNT growth. a) Principle of the *in situ* optical imaging of individual CNTs and b) video snapshots of a growth sequence.

Figure 2. SEM pictures a) before and b) after electrodes deposition.

a) Metallic NTs

b) All NTs



M/SC contrast enhanced after electrodes deposition, facilitating the correlation of growth kinetics with metallicity.

Growth kinetics

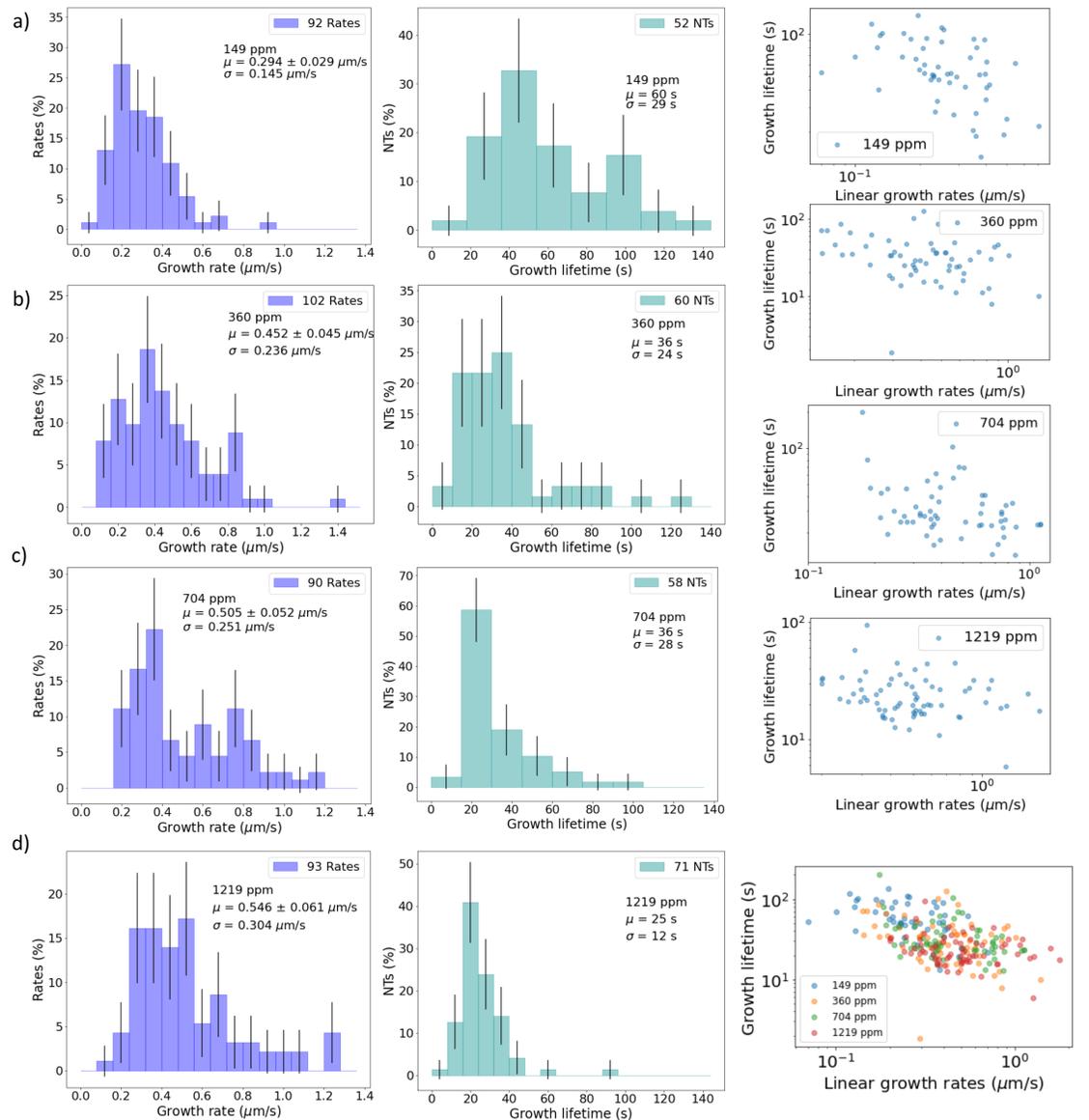


Figure 3. Distributions of growth rates, growth lifetime and lifetime versus linear growth rates for a) 149 ppm, b) 360 ppm, c) 704 ppm and d) 1219 ppm of water. The confidence interval for the mean growth rates was set to 95%.

Etching kinetics

Water concentration	Etching Probability(%)	Mean etching rate (mm/s)	Mean etching time (s)
149 ppm	7	0.296 ± 0.015 (sd = 0.153)	17 (sd=15)
360 ppm	16	0.192 ± 0.060 (sd= 0,097)	18 (sd=23)
704 ppm	30	0,460 ± 0.102 (sd= 0,239)	23 (sd = 16)
1219 ppm	26	0.416 ± 0.136 (sd= 0.278)	19 (sd =15)

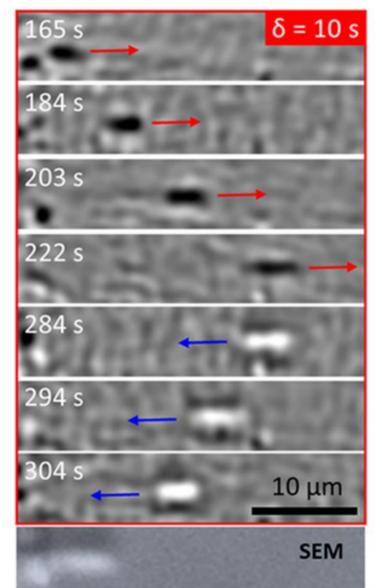


Figure 4. Snapshots of growth and etching of a CNT

Conclusions and perspectives

When increasing water concentration

- The average growth rate increase, as well as the broadness of the distribution
 - New fast rates appear: new type of nanotubes? New type of edges? New type of catalyst particles?
- Growth lifetime (for linear growth NTs) decreases
- The probability of spontaneous switch from growth to etching tends to increase.

References

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- [3] FÖRSTER, Georg Daniel, et al. Swinging Crystal Edge of Growing Carbon Nanotubes. *ACS nano*, 2023, vol. 17, no 8, p. 7135-7144.

Acknowledgments

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