High-Speed Automatic Raman Imaging of Suspended Carbon nanotubes with Supervised Machine Learning

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High-speed optical characterization of nanomaterials at low costs is critical for technology transfer of nanoscale devices[1]. Here we demonstrate the automation of high speed carbon nanotubes (CNTs) detection and localization on prong-like substrates[2] with automatic Raman imaging and supervised machine learning (SML)[3]. A strategy for an automatic Raman imaging of suspended CNTs[4] on comb-like silicon substrate is investigated. A two-lines' (TL) Raman scan is implemented to explore the presence and the orientation of CNTs on the growth substrate. An optical analysis speed of up to 680 prong pairs/hour was demonstrated. We show that SML can be used to build robust predictive models for CNTs (G peaks) monitoring with a high accuracy of 97.5%. This work will explore the speed limit of optical characterization by combing the high-speed Raman imaging strategies and SML approach.

References

[1] T. Dieing and O. Hollricher, Vib. Spectrosc. 48(2008), 22-27.
[2] K. Chikkadi, M. Muoth, V. Maiwald, C. Roman and C. Hierold, Appl. Phys. Lett. 103(2013), 223109.
[3] D. Bzdok, M. Krzywinski and N. Altman, Nat. Methods, 15(2018), 5-6.
[4] M. S. Dresselhaus, A. Jorio, and R. Saito, Annu. Rev. Condens. Matter Phys. 1(2010), 89–108.

Figures

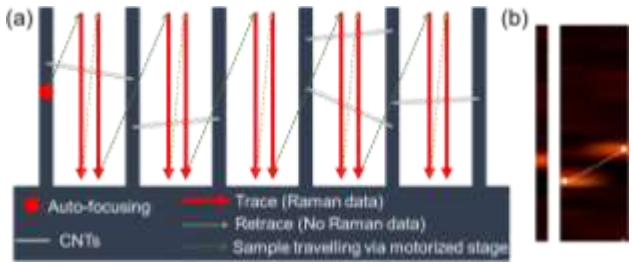

Figure 1: A strategy of high-speed Raman imaging. (a) Schematic strategy of TL Raman scan of suspended CNTs on comb-like silicon substrate (dark blue). (b) TL Raman scan to explore the presence and the orientation of CNTs.

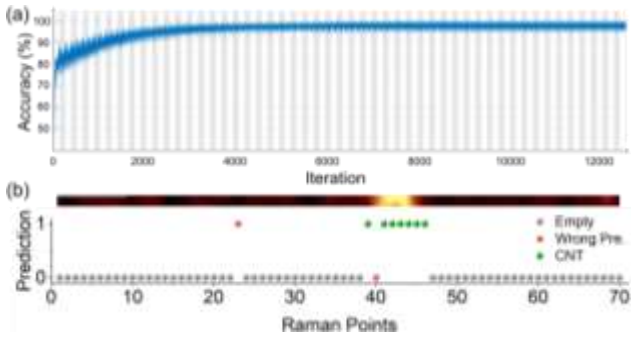

Figure 2: Raman data analysis with SML. (a) Training process with 15000 labelled spectra. An accuracy of 97.5% was achieved after 12000 iterations. (b) An example of classification with a Raman line data showing there is a CNT presence. The upper inset shows a Raman line scan image determined from the intensity of the G band as a function of sample location.