Rapid identification of Single-Walled Carbon Nanotubes using Automated Raman Spectroscopy and Supervised Machine Learning

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Abstract

Raman spectroscopy has been the leading technique to study and characterize single-walled carbon nanotubes (SWNTs)[1], basically because it is a relatively simple and non-invasive technique. However, achieving industrially relevant speeds and accuracies remains challenging due to the low signal to noise ratio (SNR) obtained at short integration time (<20 ms) and low laser power (<5 mW). Here we generate an extensive dataset of SWNTs Raman spectra and apply supervised machine learning to accurately identify the presence (Yes or No) and the types (Metallic or semiconducting) of suspended SWNTs even from ultra-low SNR spectra. With Raman settings allowing a fast screening of SWNTs (1 mW, 1 ms), we achieve a presence identification accuracy of 81.9% when using a supervised machine learning classifier while a lower accuracy of 69.5% was achieved when using a threshold classifier. Meanwhile, we achieve a *type* identification accuracy of 89.2% when using a classification based on neural networks with Raman settings of (1mW, 30ms). Our studies demonstrate that a high-speed Raman identification of SWNTs can be a key enabler for the implementation of a pick-and-place approach towards industrial applications.

References

[1] M. S. Dresselhaus, A. Jorio, and R. Saito, Annu. Rev. Condens. Matter Phys. 1(2010), 89–108.

Figures

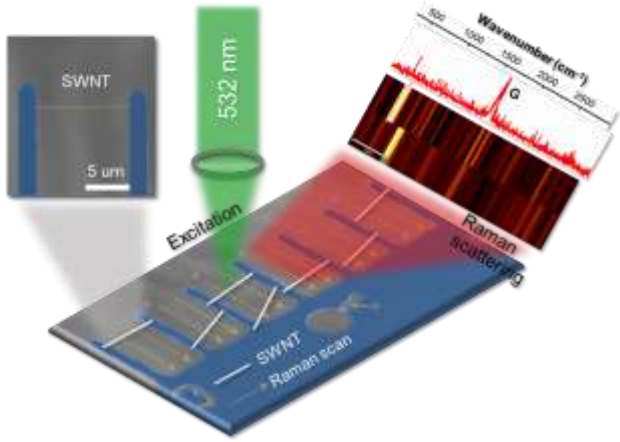

Figure 1: Overview of the automated Raman imaging of suspended SWNTs on comb-like silicon substrate.

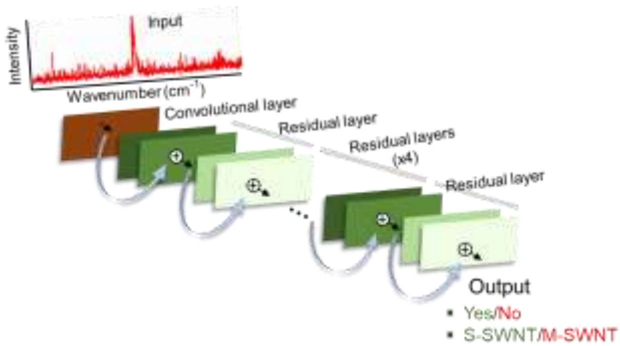

Figure 2: Architecture of a convolutional neural network.