# Optical imaging of carbon nanotubes and graphene

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Since their discovery carbon nanotubes (CNTs) have fascinated many researchers due to their unprecedented electrical, optical, thermal, and mechanical properties. Recently, a complete computer based on CNT circuits has been demonstrated[1]. However, a major drawback in utilizing CNTs for practical applications is the difficulty in positioning or growing them at specific locations or in locating them on the substrate such that the circuit can be built around them.

Here we present a simple, rapid, non-invasive, and scalable technique that enables optical imaging of CNTs, graphene, and others 2 dimensional van der Waals materials[1]. The scaffold of these materials may serve as a seed for nucleation and growth of small size, optically visible, organic nano-crystals made of p nitrobenzoic acid (pNBA) molecules. Since the surface is not used to bind the molecules they can be removed completely after imaging, leaving the surface intact and thus preserving the electrical and mechanical properties of these 1 and 2 dimensional structures.

The successful and robust optical imaging allowed us to develop a dedicated image processing algorithm through which we are able to demonstrate a fully automated circuit design resulting in field effect transistors and inverters.

Moreover, we demonstrate that this imaging method allows not only to locate CNTs but also, as in the case of suspended ones, to study their dynamic mechanical motion. The decorated tubes exhibit linear as well as non-linear Duffing type behavior, and for the first time transition from hardening to softening is observed.

## References

[1] Shulaker, M. M. et al., Nature 501, (2013) 526-530
[2] Zeevi, G. et al., Nature Communication 7, (2016) 12153

## Figures

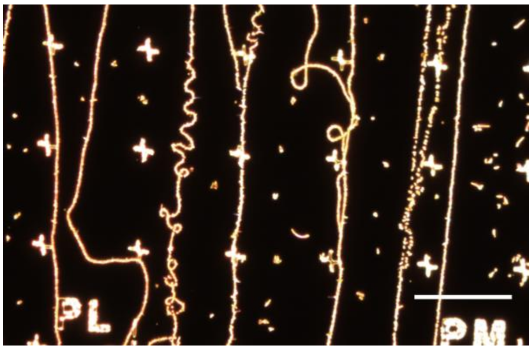


**Figure 1:** Dark field image of decorated CNTs

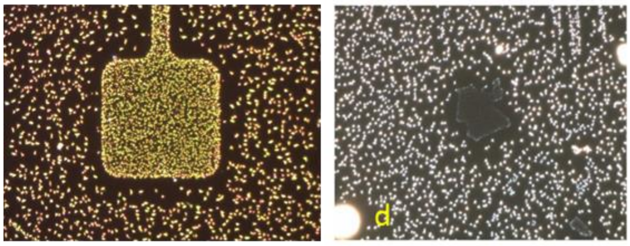


**Figure 2:** Dark field images of single layer graphene on 285 nm (left) and 10 nm (right) of $SiO_2$