Theory and modeling of optical actuation in nanocomposites through in situ electron microscopy studies

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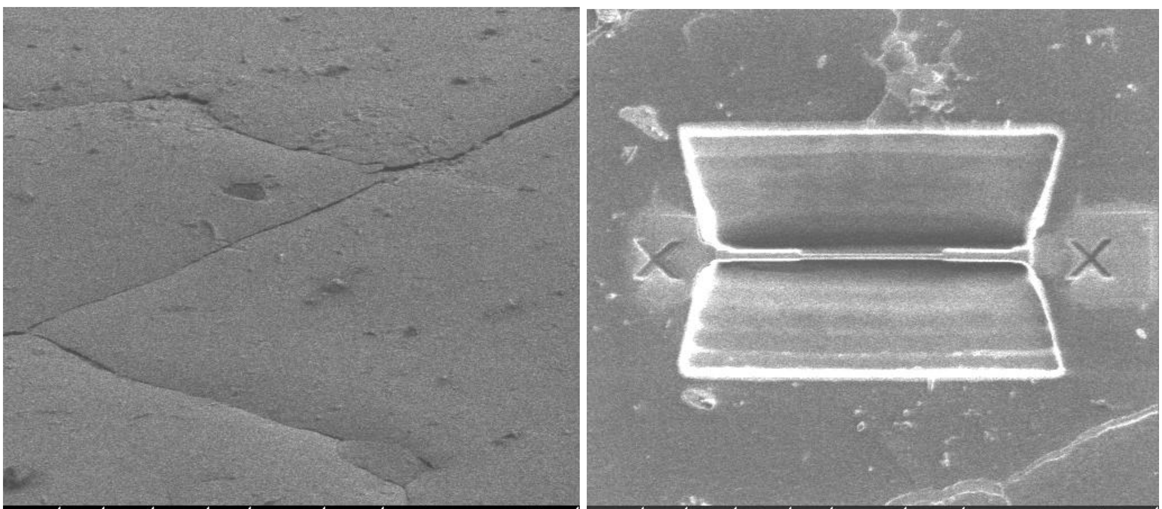
Nano-optical mechanical actuation based on nanotube-enriched polymeric materials is a much sought-after technology. In this scheme, light sources promote mechanical actuation of polymeric materials producing a variety of nano–optical mechanical systems such as tactile displays, artificial muscles, and nano-grippers among others.

Opto-mechanical actuation is preferred to electromechanical transduction in multiple environments because it is wireless, provides low noise, and allows for electro-mechanical decoupling. It also has the potential for much higher spatial resolution. However, few materials exhibit this property. Zhang[i]& Ijima [1] reported one of the earliest papers on single-wall carbon nanotube (SWCNT) actuation to visible light where bundles of SWCNTs are stretched, bent, or repelled reversibly by hundreds of microns when exposed to light. Despite large actuation effects, little interest was stirred into this subject.

Polymer Carbon Nanotube Composites (PCNCs) and Liquid Crystal Elastomers (LCEs) can also reversibly change their shape upon irradiation [2]. Indeed, Ahir and Terentjev[3] engineered PCNCs that could either compress or expand upon infrared irradiation and attributed actuation to nanotube alignment. The mechanism involved in opto-actuation was tentatively modelled as rigid nanotubes suffering orientational order imposed by uniaxially applied strain. In the proposed model photon absorption forms kinks, reversibly decreasing nanotube length. However, fundamental understanding of opto-actuation down to the atomic level is still missing and the suggested model is yet to be verified through direct experimental data.

We propose to examine photoactuation of polymer-carbon nanotubes (CNTs) composites by in-situ Transmission Electron Microscopy (TEM). Specific aspects of scanning electron microscopy of polymer nanocomposites as well as the suitability of different thinning techniques have been discussed recently [4]. We present the initial steps given to prepare a TEM sample by Focus Ion Beam (FIB) thinning (shown in Figure 1) and to retrofit a TEM holder as part of the in situ photonics set up. The expectation of TEM experimental results are also discussed.

Keywords: Polymer composites, Carbon nanotubes, photoactuation, in-situ TEM, FIB.



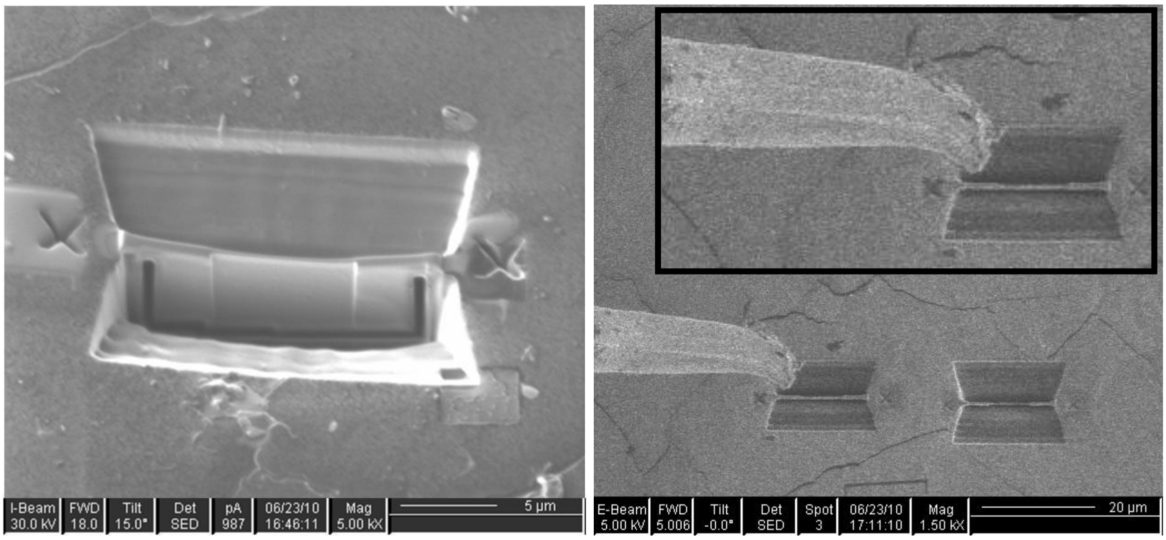


Figure 1. Focus Ion Beam Milling sequence to prepare a TEM slab for in situ experimentation. The inset shows a detailed view of the nanomanipulator in preparation for slab lift-off.

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