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Probing the mechanical properties of nanostructures in the TEM

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In situ transmission electron microscopy (TEM) provides dynamic observations of the physical behavior of materials in response to external stimuli such as temperature, environment, stress, and applied fields. In many cases, research is driven by the development of novel instrumentation and testing methodologies. Over the last few years we have used a quantitative *in situ* TEM mechanical testing device to probe the mechanical properties of different nanostructured volumes inside a TEM. By correlating the measurement of the imposed forces with a particular deformation event, we can improve our understanding of the data for both in situ and ex situ testing.

Recent progress in both in situ and ex situ small-scale mechanical testing methods has greatly improved our understanding of mechanical size effects in volumes from a few nanometers to a few microns [1-5]. Besides the important results related to the effect of size on the strength of small structures, the ability to systematically measure the mechanical properties of small volumes through mechanical probing allows us to test samples that cannot easily be processed in bulk form, such as a specific grain boundary or a single crystal. In the case of individual nanostructures, the need to address the nanostructure in an direct manner is even more acute, and in situ TEM in many cases makes this possible.

This talk will demonstrate how individual nanostructures or individual microstructural features can be tested directly with mechanical probing techniques, allowing us to explore the fundamental origins of strength and ductility. Specifically, results will be presented from in situ nanoindentation of thin films [4], in situ nanocompression of microfabricated pillars [5,6], in situ nanocompression of individual nanoparticles [7], and in situ bending of nanowires [8]. In addition, progress on the development of new techniques for quantitative in situ tensile testing of individual nanostructures will also be presented, including a discussion of the advantages and disadvantages of the various techniques.

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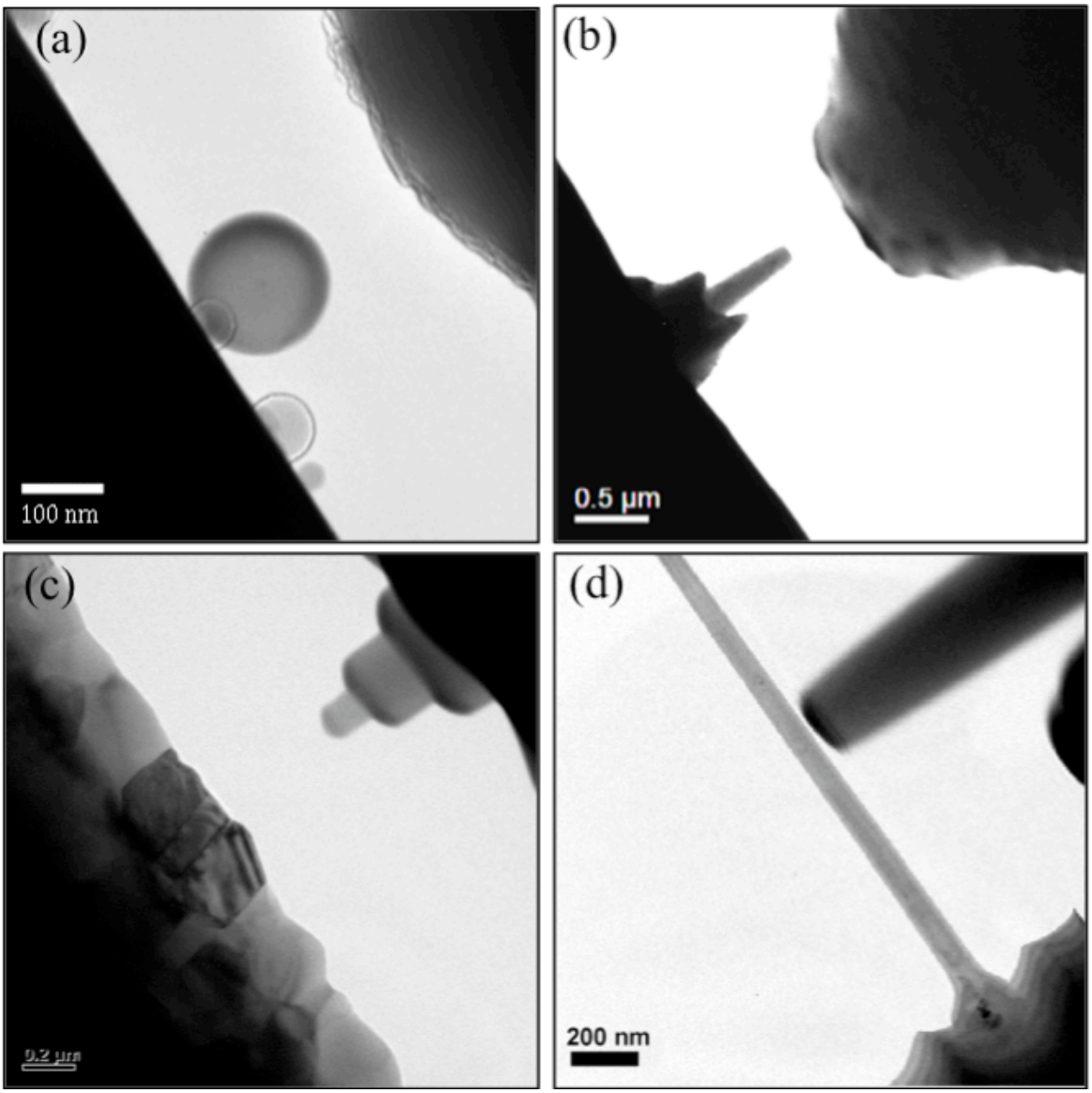

FIG 1. Example test configurations from different in situ TEM mechanical probing experiments. In all 4 examples, the probe approaches the nanostructure from the top right of the image frame: (a) Si nanoparticle, (b) metallic nanopillar, (c) Al thin film, (d) Si nanowire.

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