

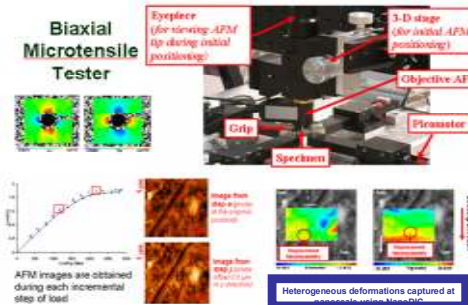
# Fabrication and Characterization of Graded Nanostructured Materials

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## Background and Motivation

- Grading nanostructured materials, such as Nickel-Titanium (NiTi) films and Dye-sensitized Titanium Dioxide Solid State Solar Cells, can enhance performance by controlling the coupling of physical properties with the distribution of stress and transport fields
- In particular, the effect of gradient architecture on the material physics of these coupling mechanisms needs to be characterized in order to optimize the processing/structure/property/performance relationship in these materials

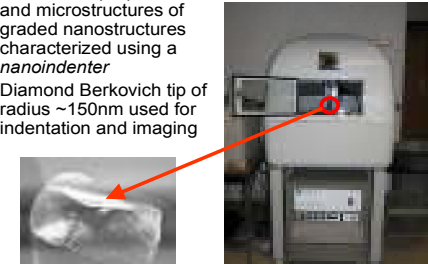
## Nanoscale Characterization of Mechanical Behavior: NanoDIC



H. Jin, PhD Thesis UMD (2004)

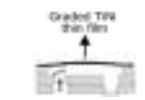
## Characterization of Graded Nanostructures: Nanoindentation

- Mechanical properties and microstructures of graded nanostructures characterized using a nanoindenter
- Diamond Berkovich tip of radius  $\sim 150\text{nm}$  used for indentation and imaging



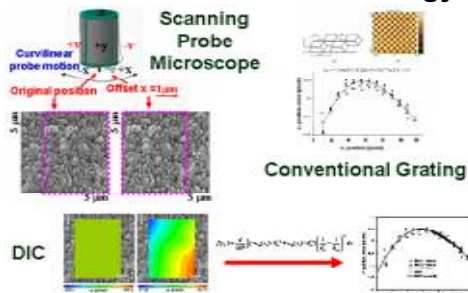
## Application example: Micropump

- Grading a NiTi film can create an intrinsic *Two-Way Shape Memory Effect* that is activated by resistively heating the film
- The actuating film can move fluid through a micromachined chamber for *bio-inspired microfluidic devices* that mimic the behavior of the heart



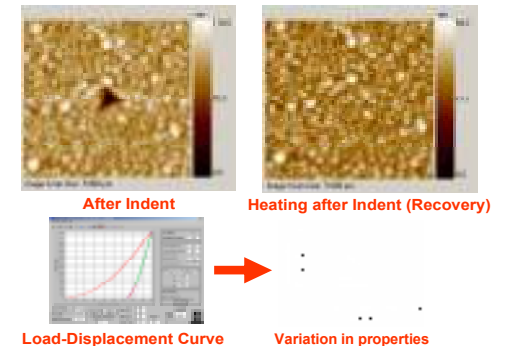
Bioinspired Micropump

## Characterizing Accuracy of Measurements: Nanometrology

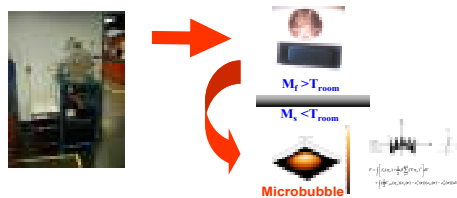


Jin and Bruck, *Nanotechnology* (2005)

## Nanoindentation Results

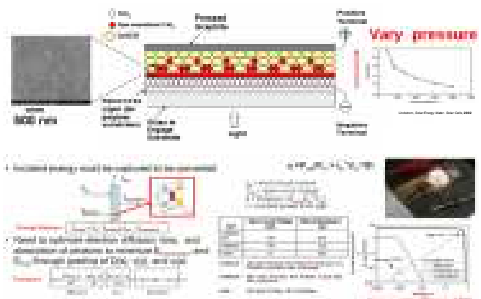


## Fabrication of Graded NiTi films



- DC magnetron sputtering system used to deposit compositionally-graded NiTi films
- Graded martensite transformation temperatures are coupled with stress distributions described by a phase-field model to create the intrinsic TWSME

## Graded Nanostructured Dye-Sensitized Solid State Solar Cells



Cole and Bruck, *Proc. of 2005 SEM Ann. Conf.* (2005)

## Conclusions

- Graded nanostructured materials are being developed via DC magnetron sputtering and powder processing technologies
- The material physics of graded NiTi thin films are being investigated to understand the processing/structure/property/performance relationship that results in an intrinsic TWSME
- Mechanical properties of films are being investigated using Nanoindentation technology and a new technique known as NanoDIC
- A technique for grading the nanostructures in dye-sensitized solid state solar cells has been developed and demonstrated to substantially improve efficiency through enhanced electron transport