doi:10.1017/S1431927610053511
Microsc. Microanal. 16 (Suppl 2), 2010

Conductive Atomic Force Microscopy Study of Doped Tin Oxide Thin Film

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Poly-crystalline Transparent Conductive Oxides such as ITO have wide applications in modern electronics, such as the back electrodes in Light Emitting Diodes, Field-effect Transistor Controlled Liquid Crystal Displays, as well as Photovoltaic Solar Panels [1-2]. In order to lower their sheet resistance and boost their performance, fine tuning of their poly-crystalline structures and doping profile may be necessary. Understanding where the dopants go and how do the grains and grain boundaries affect the electronic conductivity can assist in making improvements to the coating performance.

Conductive Atomic Force Microscopy [3], also called Current Atomic Force Microscopy or CAFM can be a useful tool to investigate local electrical properties of poly-crystalline conductive thin films. Like other regular contact mode AFM techniques, the AFM tip scans the surface of the conductive thin film by applying a very small repulsive force and using a feedback loop to keep this force constant. At the same time, a small DC voltage was applied between the conductive tip and the grounded sample, and the current flow through the AFM tip (the tip must be conductive as well) was recorded by the AFM controller and saved in the computer. We used Asylum Research's ORCA current AFM attachment to our MFP-3D Asylum AFM for this study, and this attachment showed satisfactory signal-to-noise ratio when conducting current measurement at nanoampere scale.

Herein we use doped Tin Oxide thin films [4] to show the usefulness of CAFM in visualizing local grain/grain boundary conductivities. Fig.1 shows the 1X1 μm topographic image of a doped tin oxide thin film, and the grain sizes vary between 40-100nm in effective diameter. Fig.2 shows the 1X1 μm current image of the same area for this doped tin oxide thin film, and the grain sizes vary between 20-100nm in effective diameter. During this study, it was determined that the current images revealed that not all grains have the same conductivity. Grains with higher conductivity appear bright in the current AFM images, while those grains with lower conductivity appear dark in the same image. Additionally, all grain boundaries between the conductive grains seem to be less conductive and appear as "dark" regions as well. This observation suggests that in order to improve the conductivity of the tin oxide thin film, we need to 1) add more dopant to the grains that are less conductive; 2) improve the mobility of individual grains by improve their crystallinity; 3) grow larger grains so there will be less grain boundaries.

References

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[2] J. S. Kim et al., *Synthetic Metals*, 111-112(2000), 311-314.
[3] H. Song et al., *Ultramicroscopy* 108 (2008), 1196– 1199.
[4] The tin oxide sample was supplied by Dr. R. Korotkov of Arkema Inc.

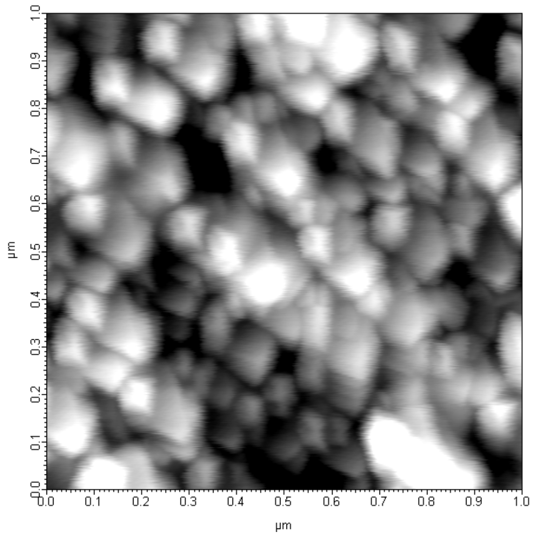

FIG. 1. 1X1 μm topographic image of a doped tin oxide thin film.

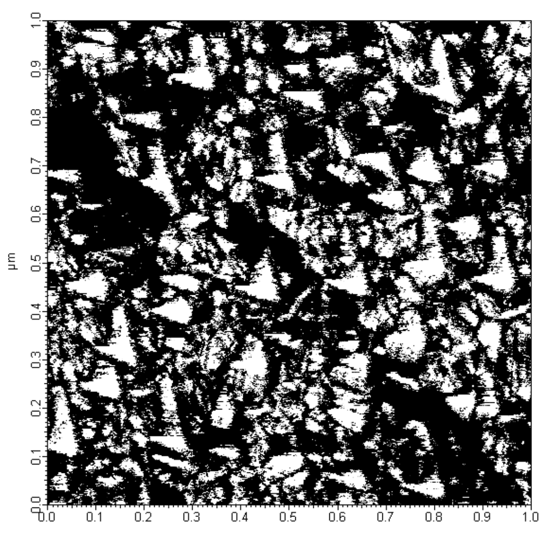

FIG. 2. 1X1 μm current image of the same area for this doped tin oxide thin film.