

ELECTRICAL CHARACTERISATION OF SEMICONDUCTOR STRUCTURES USING AFM TECHNIQUES

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1. Introduction

Many of the standard techniques of electrical characterization are becoming less useful as feature sizes drop below a micrometer scale. Conductive tips in atomic force microscopy (AFM) can be used to localize field-enhanced metal-induced solid-phase crystallization (FE-MISPC) of amorphous silicon [1] or Failure analysis combined with nanoscale doping, conductivity or resistance measurements [2]. The microscopic dimensions appear to be a fundamental limitation to many common measurement techniques. The use of Current-Atomic Force Microscopy (I-AFM) bids a possibility to acquire topography image along with the current flow mappings which can be lapped over in resulting image as presented in this paper. A current distribution on the ZnO surface of p-Si/n-ZnO diode structure with CdS or ZnS nanocrystalline quantum dot clusters at

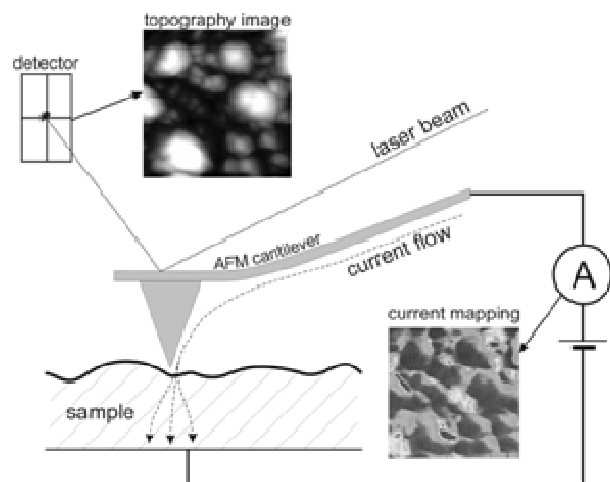


Fig.1: Schematic image of I-AFM setup.

the interface has been measured. The resulting images show a conductivity mapping different from topography what induces a conductive channels at the edges of the ZnO grains.

2. Experimental

I-AFM is a method where conductive coated AFM tip is scanning the surface of the sample in contact mode and simultaneously a bias voltage is applied to the sample and the tip. By using feedback loop to maintain the constant tip deflection in contact, a topography image is generated and in the same time I-AFM image is created by measuring the current flow between tip and sample (Fig. 1).

The samples have been prepared by diode sputtering of n-type doped ZnO (100 nm) on p-Si covered with CdS or ZnS nanocrystalline clusters by dropping CdS or ZnS nanocrystalline powder diluted in acetone on a surface. The nanocrystalline CdS and ZnS was prepared by mechanochemical dry synthesis described in [4].

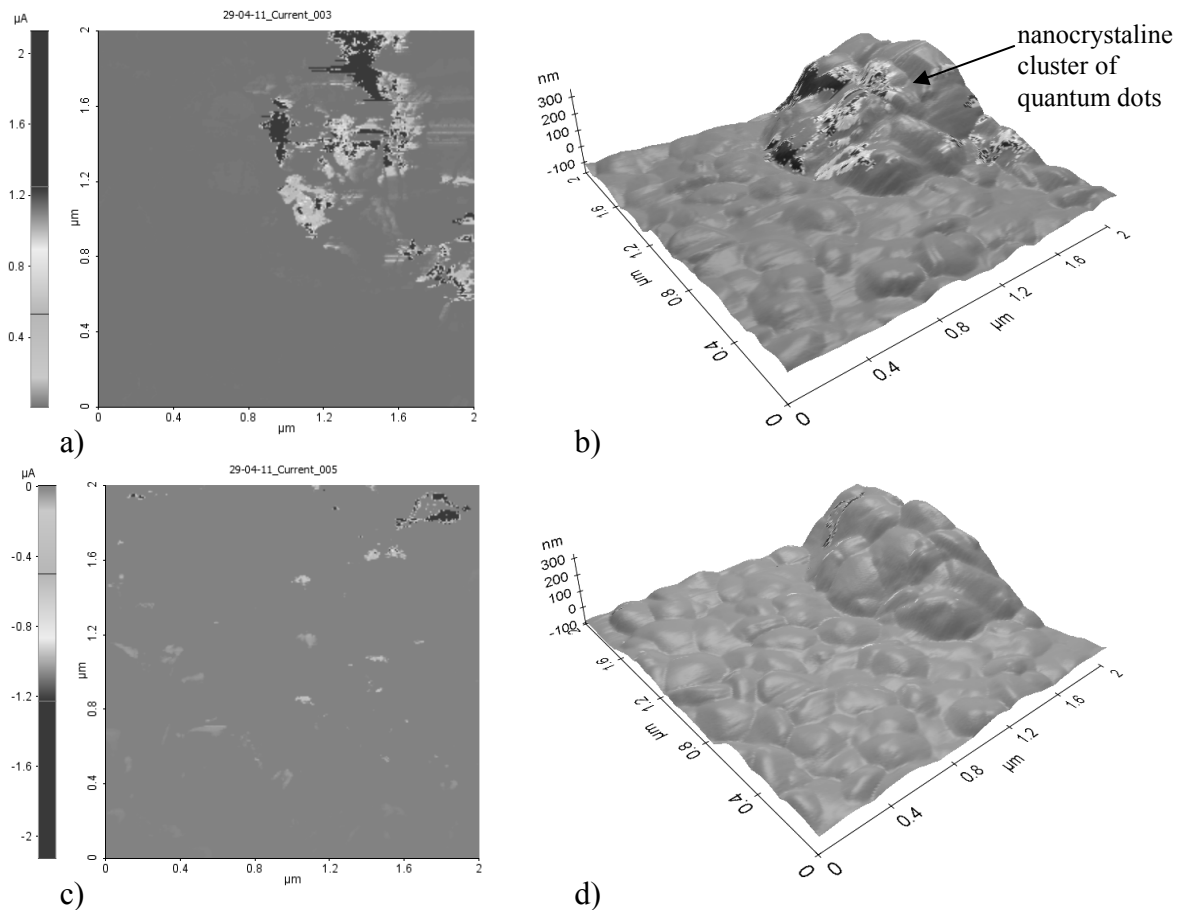


Fig.2: Current mappings and corresponding topography images of Si/ZnO heterostructure including ZnS nanocrystalline clusters - a), b) forward biased; c), d) reverse biased.

The p-Si/n-ZnO structure shows rectifying diode heterostructure as described in [3]. The Park XE-100 AFM system equipped with internal current amplifier has been utilized for the measurements. The voltage source is connected to the p-Si substrate and to the tip. For the current measurement a conductive tip covered by Ti-Pt has been used with typical tip curvature radius of <40 nm. The AFM tip in contact with the ZnO film is pressed with compressive force in the range of 100-500 nN to reach the optimal current flow for measurement. The maximum measured current is limited to 2 μ A, which is due to current delimiter of the internal current amplifier. Higher applied current is possible by an external current amplifier unit.

The measured current mappings of samples with ZnS nanocrystalline clusters and corresponding topography with current mapping textures are shown in Fig. 2 a), b), c) and d). In topography image there is obvious a nanocrystalline cluster below the ZnO layer. As the quantum dots are intrinsic semiconductors, their conductance is expected to be very low and therefore the current flows through a conductive channels between the clusters when the sample is forward biased (Fig. 2 a) and b)). A drift generated in p-n junction was recorded at approximately the same location when the sample was reverse biased (Fig. 2 c) and d)). It is most likely to be generated inside the nanocrystalline clusters while the sample has been exposed to halogen-tungsten light during the measurement.

Topography images (3D) of similar diode structure with CdS nanocrystalline clusters combined with the forward biased current mapping textures are shown on Fig. 3 a) and b). The electrical response of the device is comparable with previous results and conductive channels between grains are obvious as well.

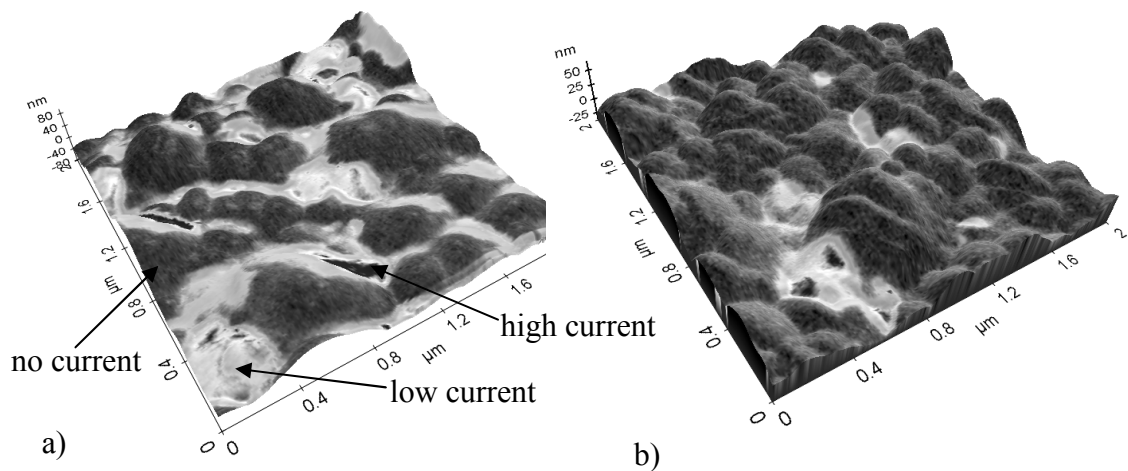


Fig.3: *p-Si/n-ZnO diode structure with CdS quantum dots clusters topography images with forward biased current mapping textures on the surface at different locations.*

3. Conclusion

We have successfully used I-AFM method where conductive AFM tip is scanning over the surface of the sample to create a topography image along with a current flow mapping of p-Si substrate covered with CdS or ZnS nanocrystalline clusters overlapped by 100 nm thick n-ZnO layer. The measured current mappings of both samples revealed a formation of conductive channels between the clusters of quantum dots when the sample is forward biased. We are able to create 3D topography images of combined with the forward biased current mapping textures which gives complex information about local conductivity and using this method it should be possible to find hidden current leaks in the samples for example defects in most semiconductor materials. A drift current generated in p-n junction was recorded when the sample was reverse biased while the sample has been exposed to light. Possible UV light source should cause a higher reverse current due to high bandgap of ZnS clusters which is a motivation to further research. The devices fabricated from these structures have the potential applications for solar cells or broadband photodetectors.

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