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# Morphology and Conductivity Characteristics of Polycrystalline Silicon Thin Film Deposited by Plasma-Enhanced Vapor Deposition in Textured Substrate

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**Abstract**. We investigate the characteristics of polycrystalline Silicon (poly-Si) thin films for solar cells produced by very high frequency (VHF) plasma enhanced chemical vapor deposition using a conductive scanning probe microscope (SPM). We measure the surface morphology and local current images are simultaneously of the poly-Si layers with a thickness, d=2 μm, formed on textured Ag/$SnO_2$/glass in the range of RMS based-textured substrate (a) σ=85nm, (b) σ=42nm and (c) σ=2nm respectively. Influences of the substrate texture on the crystal growth as well as the local current flow are discussed. Where we found that the average of local current proportional with crystallinity, where the poly-Si layer that has rich crystallinity indicated low conductivity that yield high local current.

## Introduction

One of the breakthroughs in producing inexpensive and stable photovoltaic materials is the low temperature growing polycrystalline silicon (poly-Si) thin film produced by VHF plasma-enhancing chemical vapor deposition (PECVD). In several reports it was stated that poly-Si thin films prepared using PECVD fabrication showed variations in microstructural properties from mixed-crystal-amorphous states to crystalline states that reached 100% with different crystallographic orientations. [1-5].

In addition, the microstructure of poly-Si is very heterogeneous, so it is necessary to investigate the electrical properties monoscopically. The method used is to measure local conductivity using a scanning probe microscope (SPM), where the SPM method can measure electrical quantities in nanoscale. [6, 8, 9, 11-15].

In this work, surface morphology and local current images evaluated by a conductive scanning probe microscope (SPM) technique are shown for the photovoltaic poly-Si thin films deposited by VHF-PECVD, and also, we performed the microscopic analysis of poly-Si microstructure by microstructure of crystalline volume fraction, $X_c$.

## Material and Method

We prepared the sample with structure was glass / Ag / poly-Si / ZnO:Al. Sputtering technique has been utilize to coat the 10-nm-thick ZnO:Al transparent electrodes and the 100-nm thick Ag layer. The undoped poly-Si layers for all samples are identical with those of i-layer in 9% efficiency p-i-n solar cells [7,10]. The thicknesses of poly-Si were 2 μm.

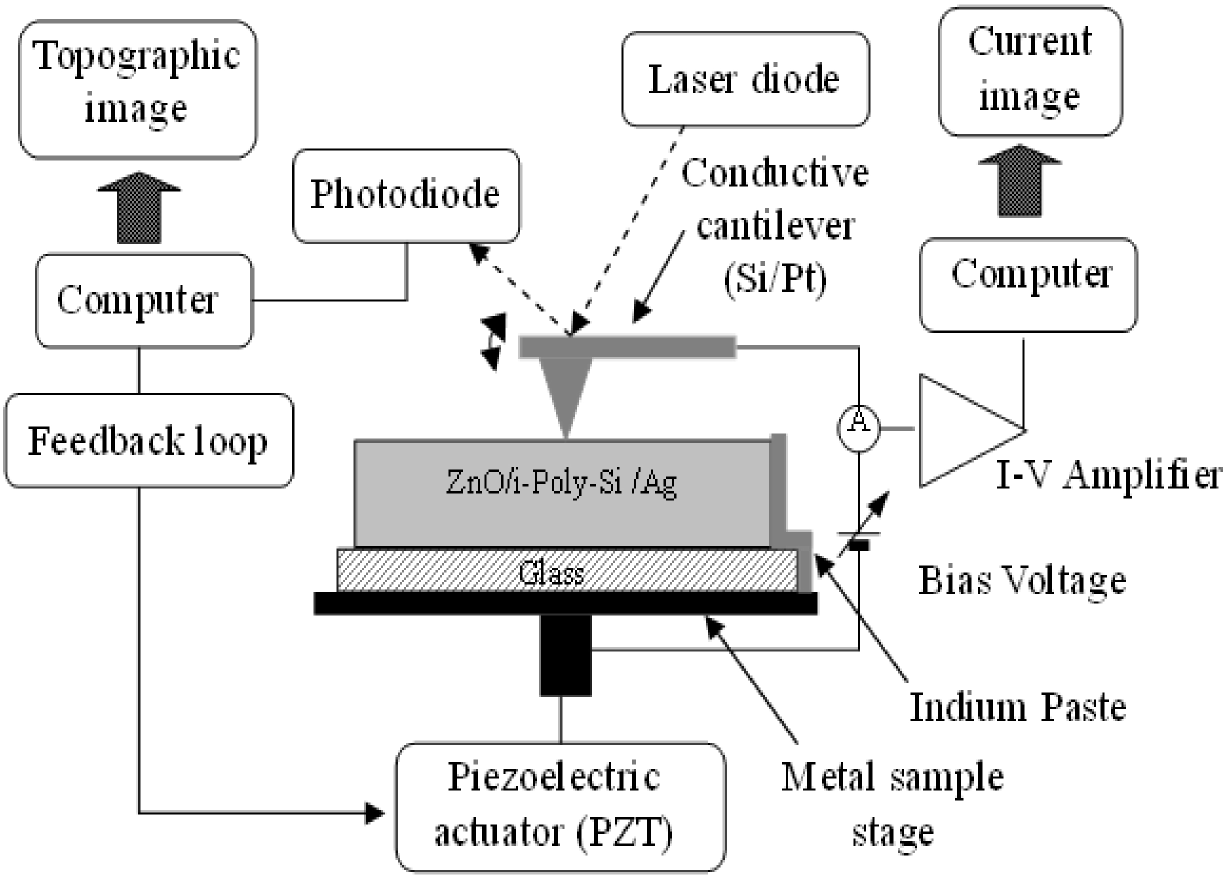


Fig. 1: Schematic Diagram of Conductive SPM

A SPM system (Park Scientific Instrument CP-R) is utilized to evaluate the topological and local current images. A schematic diagram of conductive SPM used in this study is shown in Fig. 1. A conductive cantilever made of highly doped silicon coated with Pt was used for observing the surface topography in the contact atomic force microscope (AFM) mode and the local current image simultaneously. The SPM measurements were performed in ex-situ, so that, to minimize influences of the surface oxidation after the deposition of the poly-Si layer, the sample was kept in vacuum, and the coated by ZnO:Al for observing the current image, and then measured as soon as possible. After the second time scanning, the local current tends to markedly decrease. The dc current was obtained by applying a bias voltage of 1 V onto the ZnO:Al electrode when the counter Ag electrode was set as ground. The crystalline volume fraction, $X_c$, was evaluated from the Raman scattering spectrum was the 514.5 -nm line of $Ar^+$ ion laser.

**Results and Discussion**

Fig 2 shows the topological images of the poly-Si thin films are compared to the local current maps as a function RMS roughness of based-textured substrate (a) σ=85nm, (b) σ=42nm, (c) σ=2nm respectively, and the thickness of poly-Si thin films is kept 2. The scanned area was a 2 μm square and a half of which is shown. The scale bars are markers for the topological height and the current magnitude. The surface topography shows a monotonous increase in the surface roughness, i.e., the maximum height and the lateral length of the half-spherical region to be assemblages of some grains increase as d increases.

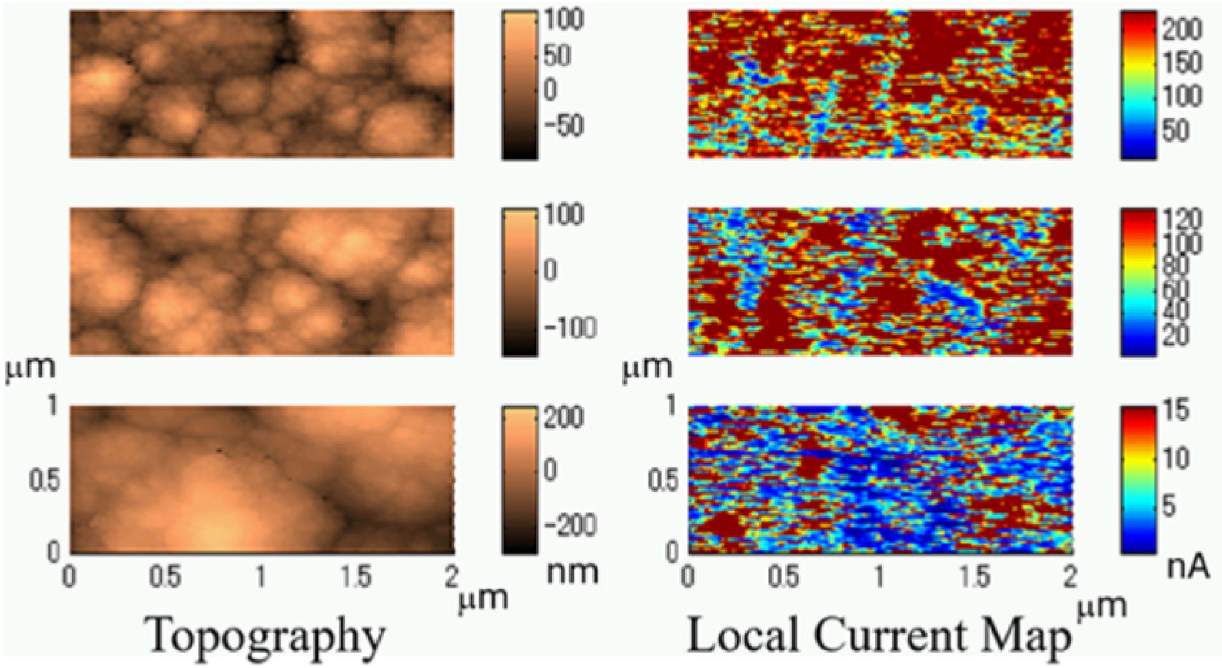


Fig. 2: Surface Morphology (left), and Local Current (right) images as a function as a function of RMS Roughness Based-substrate (a) σ=85nm, (b) σ=42nm and (c) σ=2nm respectively.

The local current maps of the samples as shown in Fig. 2, homogeneous current flow is found for the samples with RMS based-textured subtracted σ=2nm that shows majority high current around 200nA occupancy the image and then decrease when RMS based-textured subtracted increase continuously.

Figure 3 summarizes (a) the RMS roughness of the poly-Si surface, (b) Crystallinity and (c) the average local current estimated from the images in Fig. 2, as a function RMS roughness of based-textured substrate, σ. As found in Fig. 3 (a), with increasing σ, the surface roughness monotonously increases. In contrast, in the Fig 3 (c) the average current rapidly decreases by one orders of the magnitude with increasing σ. Also we found in Fig. 3 (b) that the crystallinity decrease as the average current rapidly decrease. Reduce the crystallinity implies that more the amorphous phase occurred in poly-Si layer, increase the amorphous phase make increasing the conductivity, this can explain the average current decrease in highly textured substrate. Another report confirms this that poly-Si that deposited in highly textured substrate occurs collisions between the columnar crystal with neighbor grains, and then creates a grain boundary and related defects [6, 8, 9, 12, 13, 15]

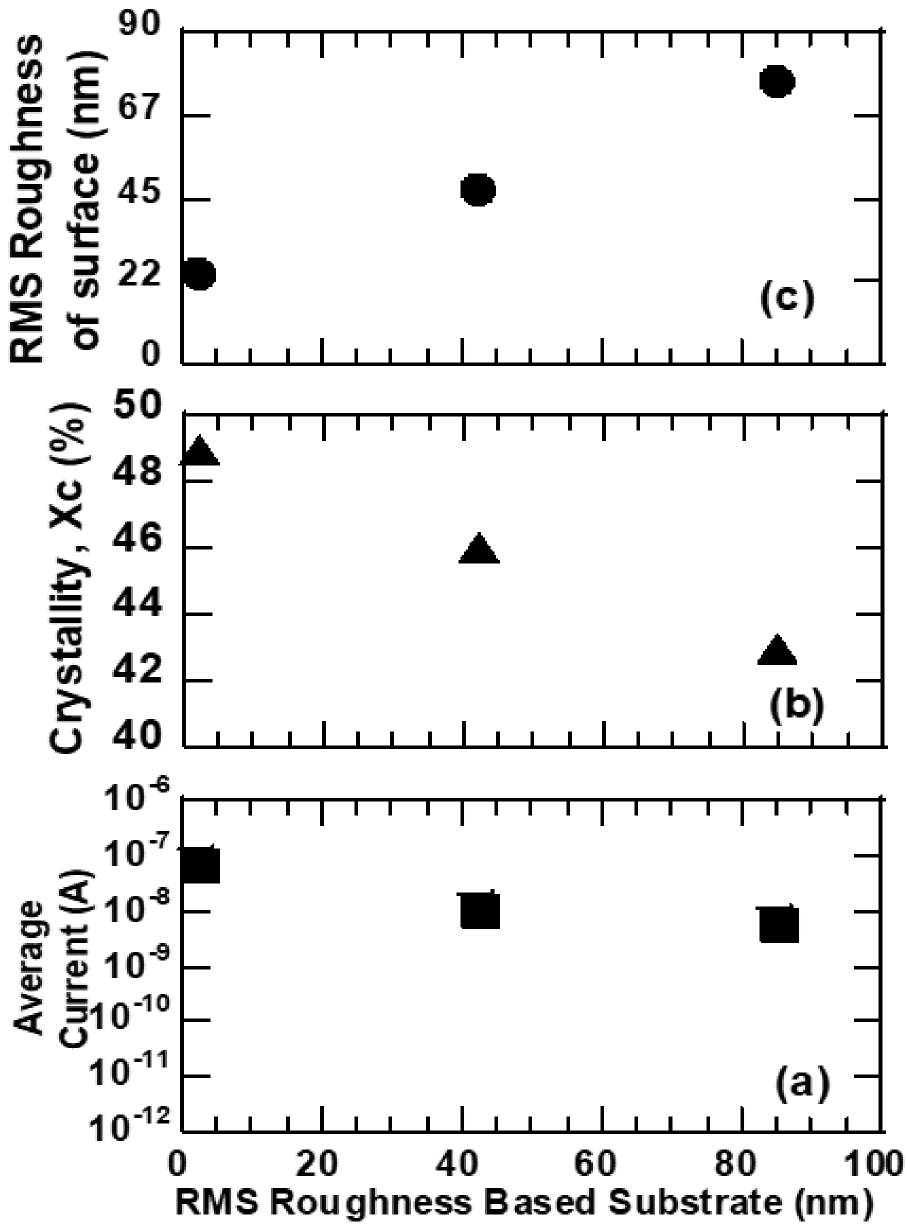


Fig. 3: Local Average Current (a) Crystallite (b) and RMS Roughness of surface (c), as a function of RMS Roughness Based-substrate.

## Conclusions

A series investigation has been formed to find correlation between local electric current, and crystallinity on polycrystalline Silicon (poly-Si) thin films for solar cells produced by very high frequency (VHF) plasma enhanced chemical vapor deposition as function of textured substrate using a conductive scanning probe microscope (SPM). This investigation revealed that conductivity of the poly-Si layer proportional with the crystallinity of poly-Si. Where poly-Si with rich of crystallinity show has low conductivity where more current can flow. Otherwise, poly-Si with poor of crystallinity show has high conductivity and difficult current can flow in poly-Si layer.

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