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COMMUNICATION

Tuning the plasmonic absorption of metal reflectors by zinc oxide nano particles: Application in thin film solar cells

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Abstract
The short circuit current and conversion efficiency of silicon thin film solar cells can be increased by efficient light trapping. The short circuit current is maximized if the metal back contact of the solar cells efficiently scatters and diffracts the reflected light, while optical (plasmonic) losses in the back contact are minimized. The investigations show that the optical losses in the back contact are highest if nano features are present at the dielectric/metal interface. However, large back contact features with dimensions comparable to the optical wavelength efficiently scatter and diffract the reflected light. In this study the morphology of the back contact was controlled by inserting zinc oxide nano particles. The influence of the nano particles on the quantum efficiency, short circuit current and conversion efficiency is studied.

Introduction

In order to achieve silicon thin film solar cells with high short circuit currents and conversion efficiencies the incident light has to be efficiently scattered and diffracted

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[1-13]. Light trapping can be maximized if the front and the back contact are textured [2,3]. The textured metal back contact of the solar cells allows for scattering and diffraction of longer wavelengths [2,3], but also in an enhanced optical absorption at the interface between the metal reflector and silicon p-i-n diode [4-12]. The absorption at the metal-silicon (n_{Si}=3.5-4.0) interface can be reduced by inserting a dielectric material with a low refractive index ($n_{die} < n_{Si}$). Inserting the lower refractive material shifts the plasmon resonance wavelength to shorter wavelengths. As a consequence the absorption losses for longer wavelengths can be reduced. Sputtered zinc oxide films are commonly used as interlayer material between the metal reflector and silicon p-i-n diode.

In this study the dielectric interlayer between the p-i-n diode and silver back reflector was prepared by solution processing of zinc oxide nano particles. The nano particle film can be prepared by spray coating or solution processing, so that expensive vacuum equipment is not required. Thin films based on zinc oxide nano particles exhibit excellent light scattering properties. Solar cells without interlayer and with sputtered zinc oxide interlayer were used as references. The influence of the different nanoparticle concentration on the quantum efficiency, short circuit current and conversion efficiency of the solar cell were investigated.

ZnO nanoparticle and solar cells with integrated nano particles

The ZnO nano particles were synthesized using zinc acetate solution in trioctylamine. The reaction mixture was kept under a continuous nitrogen atmosphere for 3 h at a temperature of 300 °C. Afterwards the synthesis products were centrifuged and the precipitates were filtered by membrane filters. Details of the synthesis process are described in Ref. [13]. No dopants were added during the synthesized process. Figure 1a shows an SEM image of the synthesized zinc oxide nano particles. The size of the nano particles ranges from 50 nm to 70 nm.

In the next step zinc oxide nano particle based thin films were prepared by solution processing on a glass substrate. Spin on glass (SOG) was added to the nano particles to improve the adhesion of the particles on the glass substrate. The blend was prepared by mixing 0.1%, 1%, 3%, and 5% of ZnO nanoparticles in a solution of water, ethanol and acetone (2:1:1 by volume). The AFM image of the zinc oxide nano particle film is shown Figure 1b. The total and diffuse transmission of the nano particle films are shown in Figure 2. The total and diffuse transmission was measured by an UV/VIS photospectrometer with an integrating sphere. The films exhibit a very high total transmission. The total transmission drops with increasing concentration

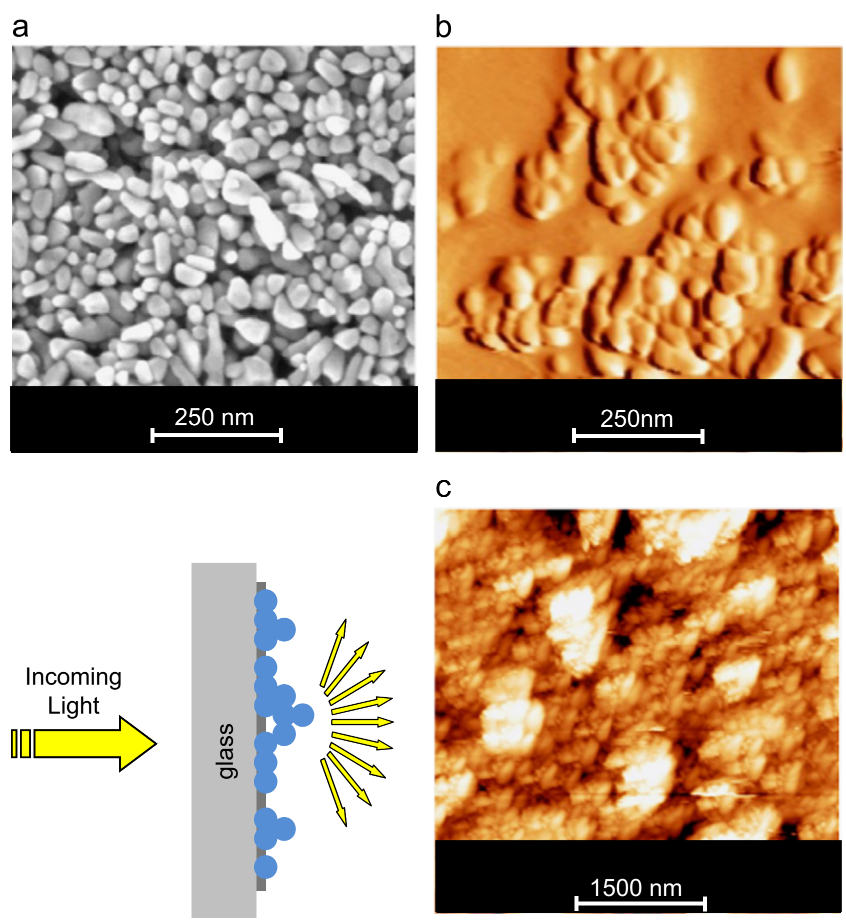

Figure 1 (a) SEM image of synthesized ZnO nano particles, (b) AFM image of ZnO nano particle film spin coated on a glass substrate, (c) AFM image of a 1% ZnO nano particle film spin coated on amorphous silicon solar cell.