The properties of heterojunctions n+-ZnO:Al/n-Si and n+-ZnO/n-$ZnO_{1-x}S_x$/p-$CuIn_{0.8}Ga_{0.2}Se_2$

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For investigation of the compatibility of transparent electrodes based on highly doped ZnO:Al films with Si they were deposited on n-type Si substrates (isotype heterojunction). The n+-ZnO films were deposited by ALD technology using diethylzinc and water vapour as zinc and oxygen precursors. The growth temperature was 200 ^{0}C. Ellipsometric measurements at 633 nm wavelength were used in order to determine the thickness of films which was within 260-420 nm.

Spectral dependences of external quantum efficiency (EQE) were investigated in the spectral range 400-1200 nm in the regime of constant quantity for incidence photons on the sample. These dependences were oscillating ones due to interference in the n+-ZnO layer (optical film thickness was 550-840 nm). The short wavelength fall of inner quantum efficiency (IQE) was calculated by the equation $IQE(\lambda)= EQE(\lambda)/T(\lambda)$ and had the magnitude about 10-20 %. The last testifies to low rate of surface recombination and therefore to the high enough quality of interface n+-ZnO/n-Si. Transparency spectrum of the n+-ZnO film $T(\lambda)$ was obtained by elipsometric measurements of thickness and refractive index in a supposing that ZnO films do not absorb light in the studied spectral interval.

Obtained results jointly with literature data allowed to construct band diagram of the heterojunction n+-ZnO/n-Si. The calculated widths of the space charge area for prepared structures are different ones for different samples and are about ~230 nm (99,9 % of this area is situated in Si). Contact potential difference which was not less than 181-268 mV was determined out of the open circuit voltage in the conditions of irradiance intensity of illumination of 1000 W/m^2. As a result the near surface zone bend essentially decreased what allowed us to evaluate the low boundary of n+-ZnO work function which appeared about 2.45± 0.1 eV for different samples.

Thus we were able to determine the important characteristics of transparent electrode n+-ZnO:Al which are necessary for further investigations and for optimization of characteristics for photovoltaic devices using ZnO:Al.

Solar cells prototypes with efficiency of 8-13% based on $ZnO_{1-x}S_x$ solid solution and CIGS with the use of transparent ZnO:Al electrodes were processed. Uniform single phase $ZnO_{1-x}S_x$ solid solutions are characterized by linear dependence of lattice period (Vegard law) and unusual (parabolic) dependence of E_g on sulfur content that makes these films of better choice for photovoltaic applications compared to ZnCdO where phase separation and spinodal decomposition were observed. Developed solar cells heterojunctions with structure n+-ZnO/n-$ZnO_{1-x}S_x$/p-$CuIn_{0.8}Ga_{0.2}Se_2$ demonstrated similar photovoltaic characteristics as CdS/CIGS heterojunctions and are perspective for development cadmium-free solar cells.

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