Low Optical Reflection at Intermediate Adhesive Layer for Mechanically Stacked Multi-Junction Solar Cells

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I. Motivation

We have developed transparent and conductive adhesive layer for fabricating mechanically stacked multi-junction solar cells [1]. A low connecting resistivity below 1 Ωcm^2 was achieved using 20-μm-sized Indium Tin Oxide (ITO) conductive particles dispersed in commercial epoxy-type Cemedine adhesive. Although the adhesive was transparent in visible and infrared regions, there is a problem of optical reflection loss at the interfaces between semiconductor and adhesive layer caused by difference of their refractive indexes [2]. In this meeting, we report reduction in optical reflection loss at the intermediate layer in the case of stacking of GaAs and Si substrates. Transparent and conductive Indium Gallium Zinc Oxide (IGZO) layers are used to achieve antireflection at the interfaces of GaAs/adhesive and Si/adhesive [2].

II. Experimental procedure

We prepared 3-inch diameter 500-μm-thick 10 Ωcm n-type crystalline GaAs and 4-inch diameter 500-μm-thick 17 Ωcm n-type Si substrates. The band gap energy and wavelength of the absorption edge were 1.43 eV and 890 nm for GaAs, and 1.12 eV and 1150 nm for Si, respectively. 130-nm-thick IGZO layers with a resistivity of 0.01 Ωcm were formed on the surfaces of GaAs and Si substrates by spattering. The refractive index of the IGZO layers was 1.85. Transparent conductive adhesive with a refractive index of 1.3 was fabricated by dispersing 3.8 wt% ITO conductive particles in the Cemedine adhesive. Then it was pasted on the IGZO surfaces of IGZO/GaAs and IGZO/Si substrates. IGZO/GaAs and IGZO/Si were stacked and kept in a pressure proof chamber with N_2 gas at 8.0×10^5 Pa for 2 h for solidifying the adhesive jell to make samples with a structure of GaAs/IGZO/adhesive/IGZO/Si. Optical reflectivity spectra of the samples were measured. We also calculated optical reflectivity spectra using a finite element numerical analysis program including multiple reflection and Fresnel type optical interference effect to evaluate antireflection effect.

III. Results and discussion

Figure 1 shows experimental (solid curves) and calculated (dashed curves) optical reflectivity spectra for the samples with structures of GaAs/IGZO/adhesive/IGZO/Si and GaAs/adhesive/Si. Calculated optical reflectivity spectrum component of the GaAs top surface is also presented by a dotted curve. All of the cases show the same optical reflectivity spectra between 250 and 890 nm because of strong optical absorption of GaAs substrate. The optical reflectivity was determined by complex refractive indexes of GaAs. On the other hand, the experimental optical reflectivity of the sample with the structure of GaAs/adhesive/Si increased ranging from 34.1 to 50.4% in the wavelength between 890 and 1040 nm because GaAs was transparent and optical reflection at GaAs/adhesive and adhesive/Si interfaces substantially contributed to the optical reflectivity. The low refractive index of 1.3 of the adhesive caused high optical reflection at GaAs and Si interfaces, which resulted in high optical reflection loss in the wavelength range of light absorption of Si between 890 and 1040 nm. The optical reflectivity further increased to 57.0% for wavelength longer than 1040 nm because GaAs and Si were transparent and the optical reflection of Si at rear surface additionally contributed to the optical reflectivity. On the other hand, the sample with the structure of GaAs/IGZO/adhesive/IGZO/Si had low optical reflectivity ranging from 34.5 to 40.2% in the wavelength between 890 and 1040 nm. This result indicates that the 130-nm-thick IGZO anti-reflection layers effectively reduced the optical reflection at the interfaces among GaAs, Si and adhesive layers. The calculated spectra of the samples agreed well with experimental spectra. The effective absorption ratio A_{eff} was estimated by the ratio of the integration of subtraction of optical reflectivity of samples R_{sample} from 100 in the wavelength between 890 and 1040 nm to the integration of subtraction of optical reflectivity of the top surface component of GaAs R_{top} from 100 as,

$$A_{eff} = \int_{890}^{1040} \left(100 - R_{sample}\right) d\lambda \Big/ \int_{890}^{1040} \left(100 - R_{top}\right) d\lambda \qquad (1).$$

A high A_{eff} of 0.93 was achieved in the case of GaAs/IGZO/adhesive/IGZO/Si structure which was much higher than that of GaAs/adhesive/Si of 0.79. The present results show that IGZO antireflection layer is effective to reduce the optical reflection loss at the intermediate layer for semiconductor stacking solar cells. In the presentation, we report the plane distribution of A_{eff} for 3-inch GaAs/IGZO/adhesive/IGZO/Si sample to demonstrate the reduction of reflection loss for sample with wide area.

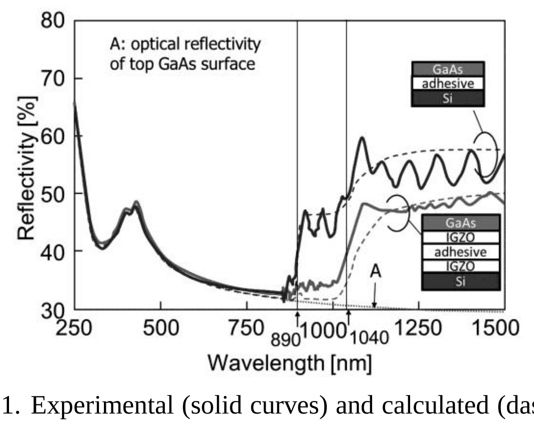

Fig.1. Experimental (solid curves) and calculated (dashed curves) optical reflectivity spectra for the samples.

References

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