An Investigation and Development of High Performance Polyimide for Flexible CIGS Solar Cell Substrate

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Introduction

$CuInGaSe_2$ (CIGS) has gained lots of attention in decades due to its extremely high absorption coefficient for solar radiation, high energy conversion efficiency, and potential lower manufacture cost compared with conventional Si solar cells. In addition, the most interesting is the CIGS solar cells can be fabricated on different flexible substrates, such as polymer. The high performance of flexibility and lightweight in solar cells have high potential to lower the manufacturing costs through roll-to-roll processing and yield a high specific power (W/kg, ratio of output power to the weight). However, the development of CIGS solar cell on polymer substrates is challenging because CIGS process temperature (Selenization temperature > 500℃) is always higher than polymer degradation temperature. In this study, we develop a high thermal stability of polyimide and fabrication of flexible solar cells on polyimide films.

Results and Discussion

In this study, the polyimide films are used as flexible substrates for CIGS solar cells that are manufactured by roll-to-roll process (figure 1). The physical properties of polyimide films are show in table 1. The types of TST and PBI polyimide have high thermal stability (above 550℃) and high mechanical strength. The most common device structure for CIGS solar cell is shown in Figure 2a. The solar cells are grown on 10 x 10 cm^2 polyimide films. For better handling during different deposition processes, the polyimide films were mounted in specially designed frames. An approximately 1 μm-thick Mo back contact was directly deposited by dc sputtering. Following Mo deposition, the CIGS absorber layers were formed under the rapid thermal processing (RTP) in an inert atmosphere and at a temperature at least 500°C. The buffer layer is typically CdS deposited via chemical bath deposition. The buffer is overlaid with a thin, intrinsic ZnO layer which is capped by a thicker, Al doped ZnO layer. Figure 2b shows a photograph of the ZnO/CdS/CIGS/Mo/polyimide/Mo stacked solar cells. The microstructure of the films was observable from the cross-sectional SEM with CIGS absorbers grown at 500 °C (figure 2c). The interface between the Mo and the CIGS is abrupt with no clear selenization of the Mo or penetration of the CIGS into the Mo observable. The CIGS layer thickness is about 2.4μm. The CIGS films were first examined using X-ray diffraction (XRD) to check the structure in the overall samples (figure 3a). It revealed that the CIGS thin film was built under the RTP growth processing. The CIGS deposition process was optimized for efficient improvement. Figure 3b shows the current-voltage characteristics of a $\eta_{AM1.5}$=8.4% efficiency on a PI film of 50μm (V_{oc}=0.37V, *FF*=59 %, J_{sc}=38.2 mA/cm^2).

Conclusions

In this study, we develop two types of high performance polyimide films for flexible CIGS solar cell substrate. The high performance polyimide films were shown high thermal stability (degradation temperature >500℃) and can be used in the high temperature process for CIGS deposition. This implies that future manufacturing of highly efficient and flexible solar cells with the polyimide substrate could lower the cost of solar electricity and become a significant branch of the photovoltaic industry.

Reference

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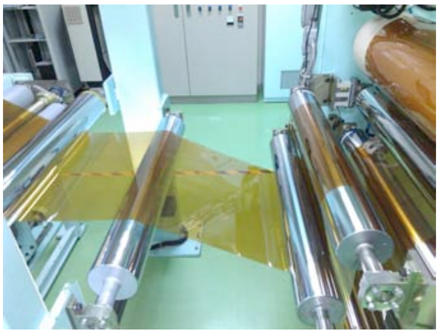

Figure 1. High performance polyimide substrate produced by roll to roll process.

Table 1. Physical properties of high performance polyimide.

Type			Unit	Value	
				TST	PBI
Thickness	Average		μm	48	50
Mechaincal (MD)	Tensile Strength		MPa	504	330
	Elongation		%	23.4	30
	Modulus		GPa	10.2	6.7
Thermal	CTE (MD/TD)	50~200℃	ppm/℃	2.3/6.4	1/4
	(Cooling)	50~400℃		2.7/7.4	1/4
	Dimensional Stability (MD/TD)		%	0.06	0.01
	Td1%		℃	581	550

(a). (b). (c).

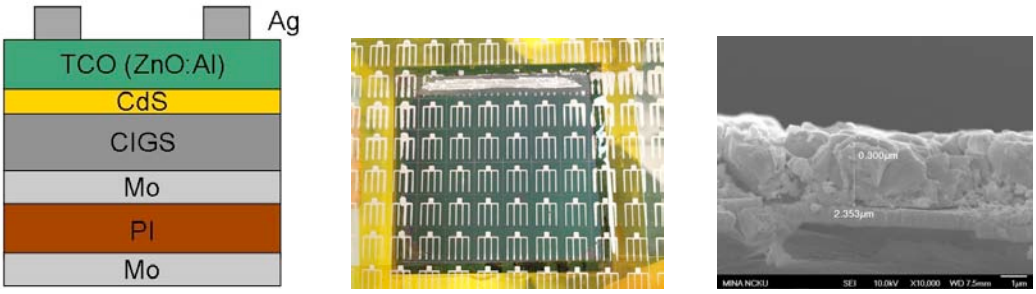

Figure2. (a). Schematic diagram of the CdS/CIGS solar cell on a polyimide substrate; (b). Photograph of the ZnO/CdS/CIGS/Mo/polyimide/Mo stacked solar cells and (c). SEM picture of a CIGS film developed on flexible molybdenum/polyimide substrate.

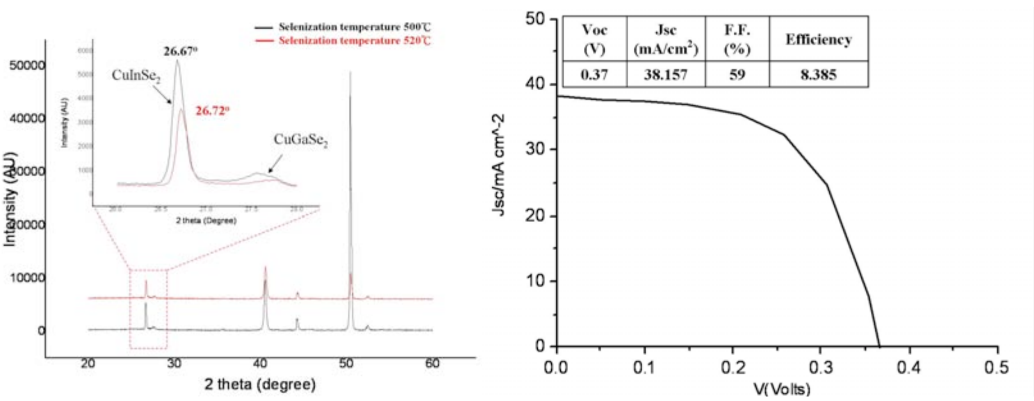

Figure3 (a). XRD spectra for the as-grown CIGS films onto polyimide substrates, and (b). *I-V* characteristic of a 8.4% efficiency CIGS solar cell on polyimide layer measured under AM1.5 illumination.