

Kesterite $\text{Cu}_2\text{Zn}(\text{Sn},\text{Ge})(\text{S},\text{Se})_4$ Thin Film with Controlled Ge-doping for Photovoltaic Application

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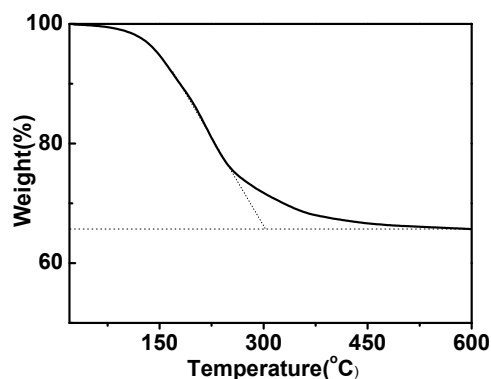


Figure 1. The TGA of CZTGSSe precursor.

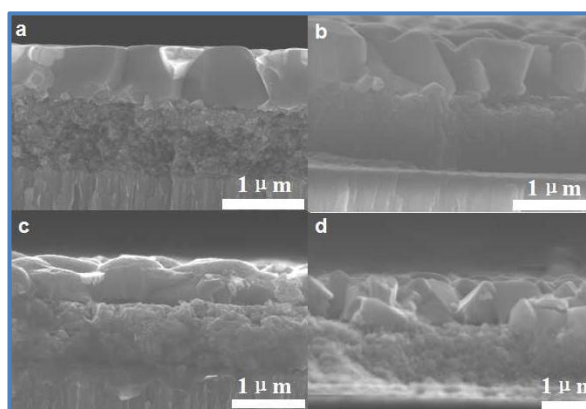


Figure 2. Cross-section images of CZTGSSe thin film coated on Mo substrate with different Ge contents (a) 20%, (b) 40%, (c) 60%, (d) 80%.

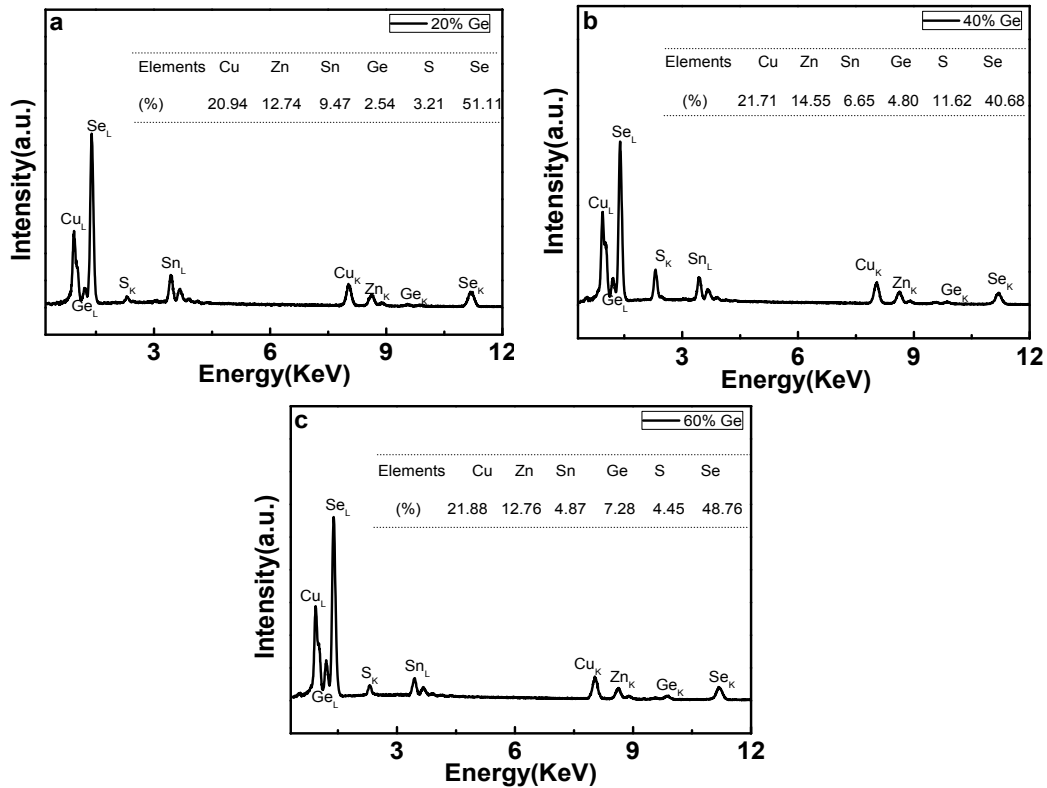


Figure 3. EDS spectra and chemical compositions of CZTGSSe thin film with different Ge addition (a) 20%, (b) 40%, (c) 60%.

Table 1. metal ratios based on different Ge doped CZTGSSe thin film

Ratio	Cu/(Zn+Sn+Ge)	Zn/(Sn+Ge)	Ge/(Sn+Ge)
20%	0.85	1.06	0.21
40%	0.83	1.27	0.42
60%	0.88	1.05	0.60

In addition, the composition of the CZTGSSe thin film with 80% Ge doping was not given due to its poor coverage, resulting to uneven element distribution in large grain and small grain.

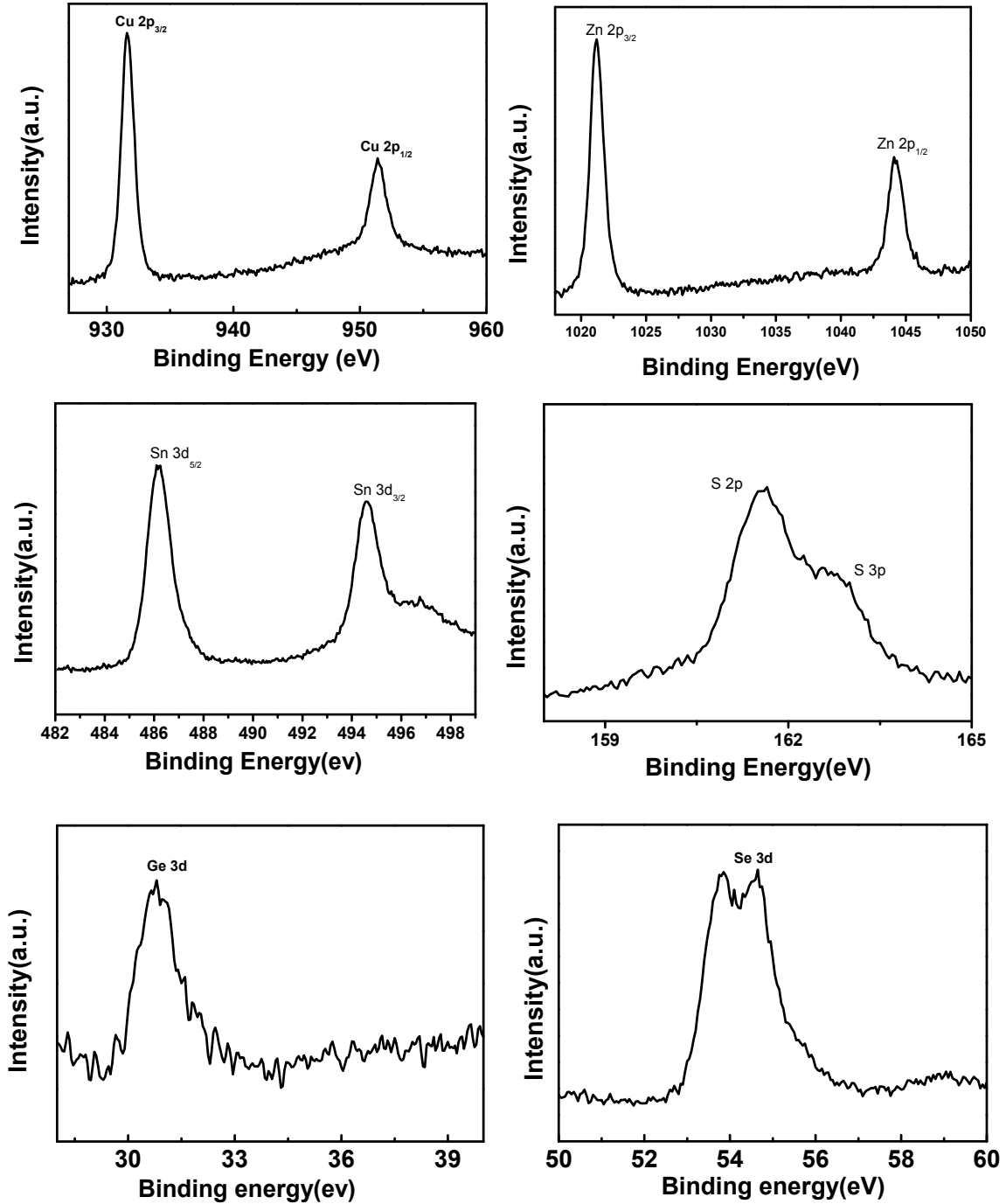


Figure 4. X-ray photoelectron spectroscopy (XPS) spectra of Cu, Zn, Sn, Ge, Zn, S, Se in the selenized CZTGSSe thin film.

Please note the XPS spectra of Se in the thin film, A obvious split peak appeared, which was corresponding to the element of selenium located in 55-56 eV. It may be due to the deposition of during the cooling process.

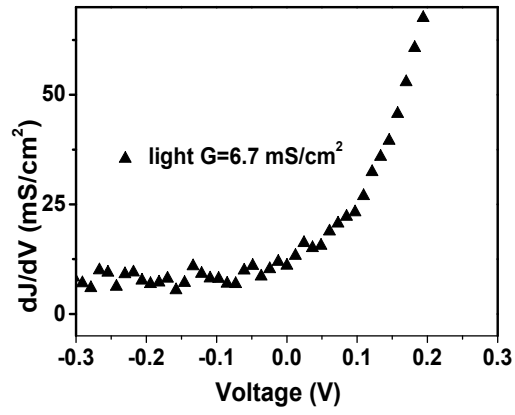


Figure 5. Light J-V curve was used to determine shunt resistance (R_{sh}) of completed CZTGSSe thin film solar cell.