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Comparative alternative materials assessment to screen toxicity hazards in the life cycle of CIGS thin film photovoltaics

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HIGHLIGHTS

- Comparative alternatives assessment of thin film manufacturing technologies.
- Development of chemical alternatives assessment in a life cycle context.
- Screening of manufacturing and solar cell hazardous substances simultaneously.

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ABSTRACT

Copper–indium–gallium–selenium–sulfide (CIGS) thin film photovoltaics are increasingly penetrating the market supply for consumer solar panels. Although CIGS is attractive for producing less greenhouse gas emissions than fossil-fuel based energy sources, CIGS manufacturing processes and solar cell devices use hazardous materials that should be carefully considered in evaluating and comparing net environmental benefits of energy products. Through this research, we present a case study on the toxicity hazards associated with alternative materials selection for CIGS manufacturing. We applied two numeric models, The Green Screen for Safer Chemicals™ and the Toxic Potential Indicator. To improve the sensitivity of the model outputs, we developed a novel, life cycle thinking based hazard assessment method that facilitates the projection of hazards throughout material life cycles. Our results show that the least hazardous CIGS solar cell device and manufacturing protocol consist of a titanium substrate, molybdenum metal back electrode, $CuInS_2$ p-type absorber deposited by spray pyrolysis, ZnS buffer deposited by spray ion layer gas reduction, ZnO:Ga transparent conducting oxide (TCO) deposited by sputtering, and the encapsulant polydimethylsiloxane.

1. Introduction

Policy makers and manufacturers advocate photovoltaic (solar) panels as a sustainable alternative to fossil fuel-based energy sources [1]. Energy conversion efficiencies for copper–indium–gallium–selenium–sulfide (CIGS) solar cells (found within solar panels) of greater than 19% have already been achieved, making CIGS a feasible solar material for future industrial competition with the incumbent mono- and polycrystalline silicon-based solar cell technologies [2,3]. CIGS solar cells are comprised of nanometer to micrometer thick layers of materials deposited during manufacture. Each layer provides a specific function, where their combination creates a semiconductor that converts light to energy. The relative thickness and material content of each layer varies among manufacturers. Six different layers are used in CIGS solar cells, as illustrated in Table 1: substrate, metal back electrode, p-type absorber, buffer, transparent conducting oxide (TCO) (also referred to in the literature as an n-type window), and encapsulant [4]. The layered nature of CIGS solar cells allows for significant variation in material composition and manufacturing processing between solar cells. This, compounded with the search for new materials and processes that improve CIGS solar cell efficiency, mechanical properties, economic viability, and sustainability [3], creates a wide diversity of CIGS manufacturing processing and solar cell material composition options.

The recent European Union directive on the Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) [5], and the impending Safer Consumer Products Law in the State of California are examples of legislative initiatives that motivate for the removal of toxic substances from fabricated

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