**CACHE Modules on Energy in the Curriculum**

**Energy Topic: Solar Energy**

**Module Title:** Absorber Material Usage

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**Reference:** Roderick Eggert, et al. "Supply-Chain Dynamics Of Tellurium, Indium, And Gallium Within The Context Of PV Manufacturing Costs." *IEEE Journal Of Photovoltaics*,3(2):833. April 2013.

**Key concepts:** W/g of material.

**Introduction:** Solar cells based on CdTe, CIGS (Copper Indium Gallium Selenide) and GaAs are gaining popularity due to their lower cost of production as compared to the cost of production involved in conventional silicon solar cells. However, these solar cells require absorber materials having low abundance in nature. The material supply base of Te was 500-600 metric ton, In was 550-650 metric ton and Ga was 250-300 metric ton for the year 2011. Researchers have a goal to use less absorber material without compromising the efficiency of the solar cell. This module helps students to get acquainted with a relation between the output and material usage in solar cells.

**Data:** We can get the following data from the reference article:

|  |  |  |
| --- | --- | --- |
| Material | Density (g/cm3) | Mass fraction |
| Te in CdTe | 5.85 | 0.53 |
| In in CIGS | 5.75 | 0.22 |
| Ga in CIGS | 5.75 | 0.07 |
| Ga in single-junction GaAs | 5.32 | 0.48 |

**Example Problems and Solutions:**

**1)** Find the W/g Te produced in a 12% efficient CdTe solar cell if thickness of the cell is 2.5µm.

**Solution:**

$$Amount of Te in a solar cell=thickness of cell×density of Te×mass fraction of Te=2.5µm×\frac{5.85g}{cm^{3}}×0.53×\frac{1m}{10^{6}µm}×\left(\frac{100cm}{1m}\right)^{3}=7.75g/m^{2}$$

$$\frac{W}{g Te} produced=\frac{Amount of incident light per m^{2}×efficiency}{Amount of Te }=\frac{\frac{1000W}{m^{2}}×0.12}{\frac{7.75g}{m^{2}}}=\frac{15.48W}{g Te}$$

**2)** Estimate how many grams of In and Ga are used to produce 210W of electricity using CIGS solar cells with a thickness of 2µm and efficiency of 14%.

**Solution:**

$$Amount of In in a solar cell=thickness of cell×density of In×mass fraction of In=2µm×\frac{5.75g}{cm^{3}}×0.22×\frac{1m}{10^{6}µm}×\left(\frac{100cm}{1m}\right)^{3}=2.53g/m^{2}$$

$$\frac{W}{g In} produced=\frac{Amount of incident light per m^{2}×efficiency}{Amount of In }=\frac{\frac{1000W}{m^{2}}×0.14}{\frac{2.53g}{m^{2}}}=\frac{55.33W}{g In}$$

$$Amount of In used to produce 210W of electricity=\frac{210W}{\frac{55.33W}{g In}}=3.79g In$$

$$Amount of Ga in a solar cell=thickness of cell×density of Ga×mass fraction of Ga=2µm×\frac{5.75g}{cm^{3}}×0.07×\frac{1m}{10^{6}µm}×\left(\frac{100cm}{1m}\right)^{3}=0.805g/m^{2}$$

$$\frac{W}{g Ga} produced=\frac{Amount of incident light per m^{2}×efficiency}{Amount of Ga }=\frac{\frac{1000W}{m^{2}}×0.14}{\frac{0.805g}{m^{2}}}=\frac{173.91W}{g Ga}$$

$$Amount of Ga used to produce 140W of electricity=\frac{210W}{\frac{173.91W}{g Ga}}=1.21g Ga$$

**Homework Problem Statement**

1. How much Ga would have been used if a single junction GaAs solar cell of same thickness but with 20% efficiency was used in problem 2?
2. Find the thickness of a CdTe solar cell if it produces 240W of electricity by using 9g Te and has an efficiency of 11%.