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Applicants: ENRG INC



(12) **United States Patent**  
**Olenick et al.**

(10) **Patent No.: US 10,580,914 B2**  
(45) **Date of Patent: Mar. 3, 2020**

(54) **FLEXIBLE KESTERITE PHOTOVOLTAIC DEVICE ON CERAMIC SUBSTRATE**

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/856,884**

(22) Filed: **Dec. 28, 2017**

(65) **Prior Publication Data**

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**Related U.S. Application Data**

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(51) **Int. Cl.**  
**H01L 31/00** (2006.01)  
**H01L 31/032** (2006.01)  
**H01L 31/18** (2006.01)  
**H01L 31/0216** (2014.01)  
**H01L 31/0392** (2006.01)

(52) **U.S. Cl.**  
CPC .... **H01L 31/0326** (2013.01); **H01L 31/02168** (2013.01); **H01L 31/03926** (2013.01); **H01L 31/1864** (2013.01); **Y02E 10/50** (2013.01); **Y02P 70/521** (2015.11)

(58) **Field of Classification Search**  
CPC ..... H01L 31/0326; H01L 31/1864  
See application file for complete search history.

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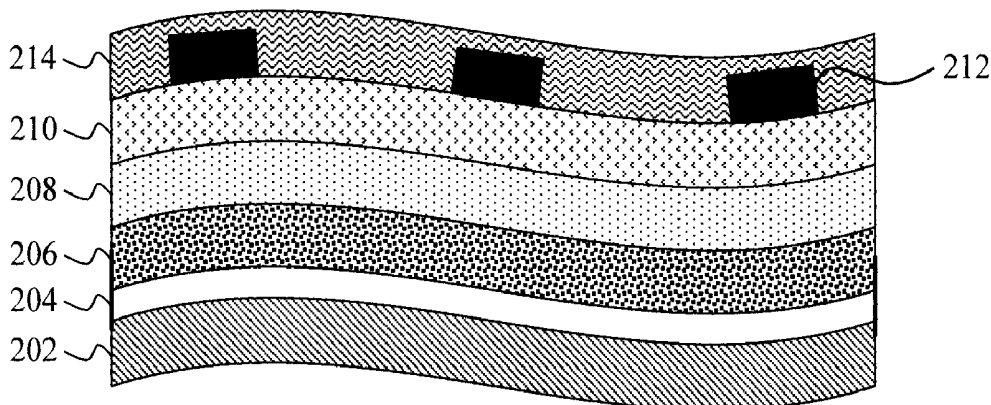
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(57) **ABSTRACT**

Kesterite-based photovoltaic devices formed on flexible ceramic substrates are provided. In one aspect, a method of forming a photovoltaic device includes the steps of: forming a back contact on a flexible ceramic substrate; forming a kesterite absorber layer on a side of the back contact opposite the flexible ceramic substrate; annealing the kesterite absorber layer; forming a buffer layer on a side of the kesterite absorber layer opposite the back contact; and forming a transparent front contact on a side of the buffer layer opposite the kesterite absorber layer. A roll-to-roll-based method of forming a photovoltaic device and a photovoltaic device are also provided.

**18 Claims, 5 Drawing Sheets**

200





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(54) **OPERATION OF AN ELECTROLYSIS CELL**

**Publication Classification**

(75) Inventor: **James S. Newkirk, Leroy, NY (US)**

(51) **Int. Cl.**  
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(52) **U.S. Cl. .... 429/23; 205/334; 205/349; 205/464; 204/277**

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(21) Appl. No.: **12/464,529**

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(57) **ABSTRACT**

An electrolysis cell is controlled for operation under varying electrical power supply conditions. A flow of feed stock to the cell includes an electrolysis reactant at a controlled concentration. A varying amount of electrical power is supplied to the cell to produce an electrolysis reaction that generates a first reaction product at a first side of the cell and a second reaction product at a second side of the cell. The reactant concentration is adjusted as the electrical power varies to substantially maintain the cell at its thermal neutral voltage during cell operation. The cell may be used in an electrolysis system powered by a renewable energy source with varying power output (e.g., wind, solar, etc.).

**Related U.S. Application Data**

(60) Provisional application No. 61/052,618, filed on May 12, 2008.

