US010680293B2

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

(10) **Patent No.: US 10,680,293 B2**
(45) **Date of Patent: Jun. 9, 2020**

(54) **DEVICE FOR HARVESTING MECHANICAL ENERGY THROUGH A PIEZOELECTROCHEMICAL EFFECT**

(71) Applicants: **Craig B. Arnold**, Princeton, NJ (US); **John Cannarella**, Princeton, NJ (US)

(72) Inventors: **Craig B. Arnold**, Princeton, NJ (US); **John Cannarella**, Princeton, NJ (US)

(73) Assignee: **THE TRUSTEES OF PRINCETON UNIVERSITY**, Princeton, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 148 days.

(21) Appl. No.: **15/139,768**

(22) Filed: **Apr. 27, 2016**

(65) **Prior Publication Data**

US 2016/0315358 A1 Oct. 27, 2016

Related U.S. Application Data

(60) Provisional application No. 62/153,172, filed on Apr. 27, 2015.

(51) **Int. Cl.**
H01M 4/02 (2006.01)
H01M 4/13 (2010.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01M 10/46*** (2013.01); ***G01D 11/00*** (2013.01); ***H01M 14/00*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,686,974	B2 *	3/2010	Priya	C04B 35/493 252/62.9 PZ
2006/0130589	A1 *	6/2006	Jackson	B60C 23/041 73/730
2014/0342192	A1 *	11/2014	Wang	H01M 4/505 429/7

OTHER PUBLICATIONS

Barvosa-Carter, et al. "Solid-State Actuation Based on Reversible Li Electroplating", Proceedings of SPIE, vol. 5761, pp. 90-97, (2005).
(Continued)

Primary Examiner — Cynthia H Kelly
Assistant Examiner — Julian Anthony
(74) *Attorney, Agent, or Firm* — Meagher Emanuel Laks Goldberg & Liao, LLP

(57) **ABSTRACT**

Mechanical energy harvesting is an increasingly important method of providing power to distributed sensor networks where physical connection to a power source is impractical. Conventional methods use vibrations to actuate a piezoelectric element, coil/magnet assembly, or capacitor plates, thereby generating an electric current. The low charge-density of these devices excludes their application in low frequency and static load sources, with the lowest frequency reported devices limited to 10 Hz. These frequency limitations can be overcome by exploiting the piezoelectrochemical effect, a similar but physically distinct effect from the piezoelectric effect whereby an applied mechanical load alters the thermodynamics of an electrochemical reaction to produce a voltage/current. Piezoelectrochemical energy harvesters are expected to produce orders of magnitude more energy per load cycle than piezoelectrics and comparable power capabilities. These characteristics make piezoelectrochemical energy harvesters ideal for application in low-frequency and static loading scenarios for which conventional mechanical energy harvesting technology is poorly suited. Examples of such load sources include, but are not
(Continued)

