



US008022004B2

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

(10) **Patent No.:** **US 8,022,004 B2**
(45) **Date of Patent:** **Sep. 20, 2011**

(54) **MULTI-COATED ELECTRODE AND METHOD OF MAKING**

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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 253 days.

(21) Appl. No.: **12/432,454**

(22) Filed: **Apr. 29, 2009**

(65) **Prior Publication Data**

US 2009/0288856 A1 Nov. 26, 2009

(51) **Int. Cl.**

H01M 4/88 (2006.01)
H01M 4/90 (2006.01)
H01M 4/92 (2006.01)

(52) **U.S. Cl.** **502/101**; 204/206.1; 204/290.01;
204/290.14; 204/290.12; 204/290.13

(58) **Field of Classification Search** 204/284,
204/286.1, 290.01, 290.14, 290.12, 290.03,
204/290.08, 290.09, 290.1, 290.13, 291;
502/101
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,869,312 A 3/1975 Moss
3,878,083 A 4/1975 De Nora
3,948,751 A 4/1976 Bianchi
RE28,820 E 5/1976 Beer
4,003,817 A 1/1977 Bianchi
4,112,140 A 9/1978 Heikel
4,203,810 A 5/1980 Warne
4,214,971 A 7/1980 Heikel
4,223,049 A 9/1980 Murray
4,331,528 A 5/1982 Beer
4,384,939 A 5/1983 Kim
4,411,762 A 10/1983 Kline
4,460,450 A 7/1984 Koziol
4,481,097 A 11/1984 Asano
4,502,936 A 3/1985 Hayfield
4,517,068 A 5/1985 Hindeu
4,528,084 A 7/1985 Beer
4,585,540 A 4/1986 Beer
4,642,173 A 2/1987 Koziol
4,696,731 A 9/1987 Tenhover
4,708,888 A 11/1987 Mitchell
4,797,182 A 1/1989 Beer
4,913,973 A 4/1990 Geusic
5,004,626 A 4/1991 Dong

5,031,290 A 7/1991 Brereton
5,098,546 A 3/1992 Kawashima
5,156,726 A 10/1992 Nakada
5,290,415 A 3/1994 Shimamune
5,294,317 A 3/1994 Saito
5,354,444 A 10/1994 Shimamune
5,451,307 A 9/1995 Bennett
5,503,663 A 4/1996 Tsou
5,560,815 A 10/1996 Sekimoto
5,672,394 A * 9/1997 Hardee et al. 204/290.13
6,103,093 A 8/2000 Nidola
6,103,299 A 8/2000 Shimamune
6,165,331 A 12/2000 Hughes
6,210,550 B1 4/2001 Nidola
6,217,729 B1 4/2001 Zolotarisky
6,231,731 B1 * 5/2001 Kondo et al. 204/290.03
6,527,939 B1 3/2003 Hardee
6,936,155 B1 8/2005 Morimitsu
7,247,229 B2 7/2007 Hardee
7,258,778 B2 8/2007 Hardee
2009/0288958 A1 * 11/2009 Sandoval et al. 205/576

FOREIGN PATENT DOCUMENTS

JP 4099294 A2 3/1992
JP 10287998 A2 10/1998
JP 2002158013 5/2002
JP 2002275697 9/2002
JP 2004238697 8/2004
JP 2007-146215 6/2007
JP 2007146215 * 6/2007
JP 2009293117 12/2009
JP 2010001556 1/2010

OTHER PUBLICATIONS

“Stability of Iridium Oxide-Tantalum Oxide Coated Titanium Electrodes for Oxygen Evolution in Alkaline Solutions.”; M. Morimitsu, C. Murakami, K. Kawaguchi, R. Otogawa, and M. Matsunaga; <<http://www.polytml.ca/newmaterials/eng/journal/ejournal/oct2004/art10.pdf>>.

Titanium Anodes with Active Coatings Based on Iridium Oxides: The Chemical Composition of the Coatings and the Distribution of Their Components over Depth on Anodes Made of IrO₂, IrO₂ + TiO₂, IrO₂ + RuO₂ + TiO₂, and IrO₂ + RuO₂ + TiO₂ + Ta₂O₅; vol. 39; Publication date: Oct. 2003; <<http://www.springerlink.com/content/h2466442v8770747/>>.

The International Search Report and Written Opinion from corresponding PCT Application No. PCT/US09/044341 dated Aug. 28, 2009.

* cited by examiner

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(57) **ABSTRACT**

Various embodiments provide an electrode comprising a conductive substrate, a first layer of a mixture comprising iridium oxide in a crystalline phase and tantalum oxide in an amorphous phase on a portion of an outer surface of the conductive substrate, and a second layer of the mixture comprising iridium oxide in an amorphous phase and tantalum oxide in an amorphous phase on an outer surface of the first layer.

6 Claims, 9 Drawing Sheets