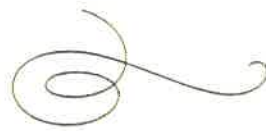
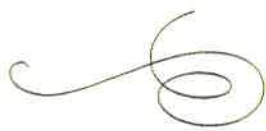


United
States
of
America



To Promote the Progress

of Science and Useful Arts

The Director

of the United States Patent and Trademark Office has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this United States

Patent

grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America, and if the invention is a process, of the right to exclude others from using, offering for sale or selling throughout the United States of America, products made by that process, for the term set forth in 35 U.S.C. 154(a)(2) or (c)(1), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b). See the Maintenance Fee Notice on the inside of the cover.

Ander Lane

DIRECTOR OF THE UNITED STATES PATENT AND TRADEMARK OFFICE



US010411142B2

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

(10) **Patent No.:** **US 10,411,142 B2**
(45) **Date of Patent:** **Sep. 10, 2019**

(54) **METHOD FOR PRODUCTION OF COMPONENTS COMPRISING A SCHOTTKY DIODE BY MEANS OF PRINTING TECHNOLOGY**

(52) **U.S. Cl.**
CPC *H01L 29/872* (2013.01); *H01L 21/02532* (2013.01); *H01L 21/02538* (2013.01);
(Continued)

(71) Applicant: **UNIVERSITAT DUISBURG-ESSEN, Essen (DE)**

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

(72) Inventors: **Niels Benson, Duisburg (DE); Roland Schmechel, Darmstadt (DE); Marc Hoffmann, Dinslaken (DE); Thomas Kaiser, Duisburg (DE); Daniel Erni, Duisburg (DE)**

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,305,766 B2 * 4/2016 Samuelson B82Y 10/00
2005/0235869 A1 * 10/2005 Cruchon-Dupeyrat B82Y 10/00
106/31.29

(Continued)

FOREIGN PATENT DOCUMENTS

DE 10 2011 122091 A1 6/2013

OTHER PUBLICATIONS

International Search Report prepared by the European Patent Office dated Jun. 3, 2016, for International Application No. PCT/EP2016/056315.

(Continued)

Primary Examiner — Michael Lebentritt

(74) *Attorney, Agent, or Firm* — Sheridan Ross P.C.

(57) **ABSTRACT**

The invention concerns a method for production of components comprising a Schottky diode by means of printing technology. The method involves a step of application and deposition of a semiconductor-nanoparticle dispersion on a first electrode, which is disposed on a substrate, the step of exposure to laser light of the deposited semiconductor-nanoparticle dispersion to form a mu-cone with a bottom and a tip, wherein the bottom of the mu-cone is joined to the first electrode, the step of embedding the thus-formed mu-cone in an electrically insulating polymer matrix, and the

(Continued)

(73) Assignee: **UNIVERSITY DUISBURG-ESSEN (DE)**

(*) 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.: **15/560,544**

(22) PCT Filed: **Mar. 23, 2016**

(86) PCT No.: **PCT/EP2016/056315**

§ 371 (c)(1),

(2) Date: **Sep. 22, 2017**

(87) PCT Pub. No.: **WO2016/150988**

PCT Pub. Date: **Sep. 29, 2016**

(65) **Prior Publication Data**

US 2018/0114867 A1 Apr. 26, 2018

(30) **Foreign Application Priority Data**

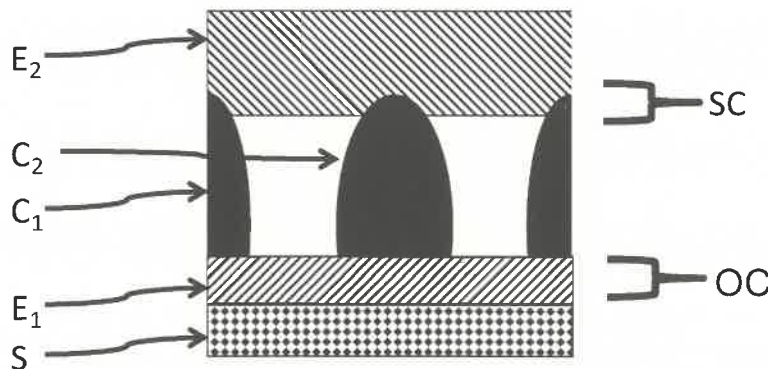
Mar. 23, 2015 (DE) 10 2015 205 230

(51) **Int. Cl.**

H01L 29/20 (2006.01)

H01L 29/872 (2006.01)

(Continued)



step of applying a second electrode, so that the tip of the mu-cone is joined to the second electrode.

9 Claims, 3 Drawing Sheets

(51) Int. Cl.

H01L 21/268 (2006.01)
H01L 29/66 (2006.01)
H01L 29/06 (2006.01)
H01L 21/02 (2006.01)
H01L 29/16 (2006.01)

(52) U.S. Cl.

CPC .. *H01L 21/02623* (2013.01); *H01L 21/02664* (2013.01); *H01L 21/268* (2013.01); *H01L 29/0649* (2013.01); *H01L 29/0657* (2013.01); *H01L 29/16* (2013.01); *H01L 29/20* (2013.01); *H01L 29/66143* (2013.01); *H01L 29/66212* (2013.01); *H01L 29/66969* (2013.01)

(56)

References Cited

U.S. PATENT DOCUMENTS

2006/0103060 A1* 5/2006 Kawakami B01J 19/0013
 266/202
 2007/0128905 A1* 6/2007 Speakman H05K 1/0265
 439/161
 2008/0280104 A1* 11/2008 Komori B82Y 30/00
 428/149

2008/0286488 A1* 11/2008 Li B22F 1/0074
 427/541
 2010/0321044 A1* 12/2010 Sheu B82Y 10/00
 324/691
 2011/0056543 A1* 3/2011 Ackermann H01L 51/0068
 136/255
 2013/0234160 A1 9/2013 Matsuno
 2014/0175372 A1* 6/2014 berg H01L 31/022466
 257/9
 2015/0093516 A1* 4/2015 Araga B05C 9/12
 427/542
 2015/0382476 A1* 12/2015 Zenou G03F 7/40
 427/510
 2016/0370316 A1* 12/2016 Ndukaife G02B 5/008

OTHER PUBLICATIONS

N. Sani et al: "All-printed diode operating at 1.6 GHz", Proceedings of the National Academy of Sciences, Bd. 111, Nr. 33, Jul. 7, 2014.
 Bet S et al: "Thin film deposition on plastic substrates using silicon nanoparticles and laser nanoforming", Materials Science and Engineering B, Elsevier Sequoia, Lausanne, CH, Bd. 130, Nr. 1-3, Jun. 15, 2006.
 Sandmann Alice et al: "Continuous wave ultraviolet-laser sintering of ZnO and TiO₂ nanoparticle thin films at low laser powers", Journal of Applied Physics, American Institute of Physics, US, Bd. 113, Nr. 4, Jan. 28, 2013.
 Ko Seung et al: "Air stable high resolution organic transistors by selective laser sintering of ink-jet printed metal nanoparticles", Applied Physics Letters, A I P Publishing LLC, US, Bd. 90, Nr. 14, Apr. 3, 2007.

* cited by examiner