



US007532397B2

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

(10) **Patent No.:** **US 7,532,397 B2**  
(45) **Date of Patent:** **May 12, 2009**

(54) **OPTICAL MATERIAL, OPTICAL DEVICE  
FABRICATED THEREFROM, AND METHOD  
FOR FABRICATING THE SAME**

(75) Inventors: **Takuo Tanaka, Wako (JP); Satoshi  
Kawata, Wako (JP)**

(73) Assignee: **Riken, Saitama (JP)**

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 352 days.

(21) Appl. No.: **11/455,092**

(22) Filed: **Jun. 19, 2006**

(65) **Prior Publication Data**

US 2007/0014006 A1 Jan. 18, 2007

(30) **Foreign Application Priority Data**

Jun. 20, 2005 (JP) ..... 2005-179621

(51) **Int. Cl.**  
**G02B 5/30** (2006.01)

(52) **U.S. Cl.** ..... **359/487; 333/219.1; 333/219.2;**  
977/834

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

(56) **References Cited**

**OTHER PUBLICATIONS**

T. Tanaka, A. Ishikawa, S. Kawata, 'Unattenuated light transmission through the interface between two materials with different indices of refraction using magnetic metamaterials', Phys. Rev. B, vol. 73, Mar. 23, 2006, 125423.\*

C. Fu, M. Zhang, P. First, 'Brewster angle with a negative-index material', Appl. Opt., vol. 44, No. 18, Jun. 20, 2005, pp. 3716-3724.\*  
Y. Tamayama, T. Nakanishi, K. Sugiyama, M. Kitano, 'Observation of Brewster's effect for transverse-electric electromagnetic waves in metamaterials: Experiment and theory', Phys. Rev. B, vol. 73, May 17, 2006, 193104.\*

\* cited by examiner

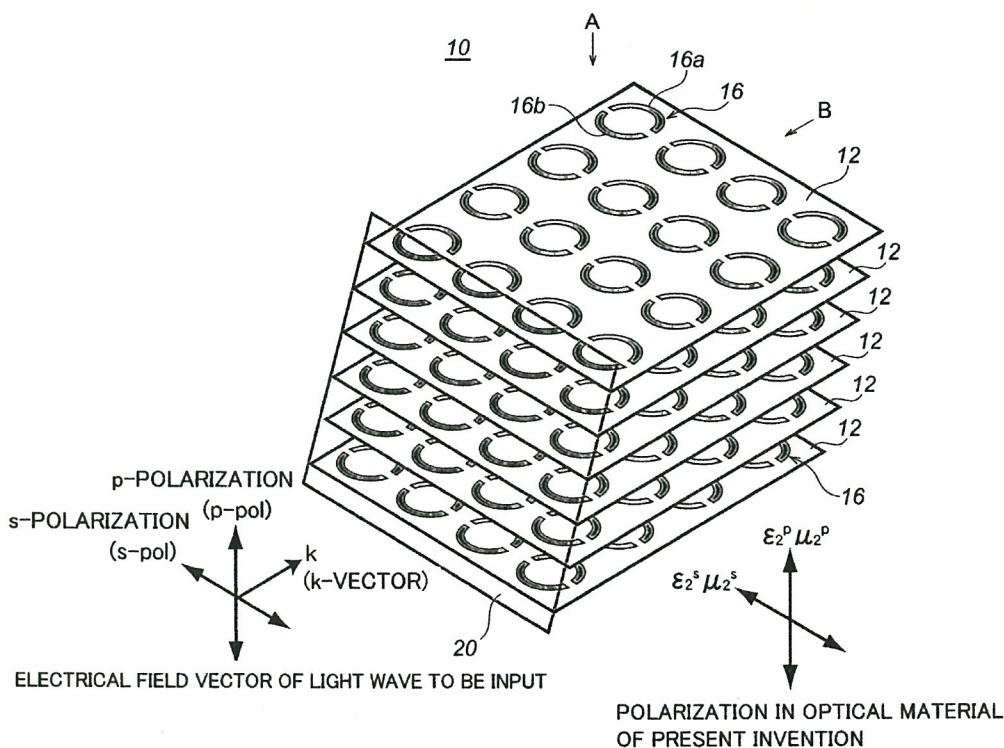
*Primary Examiner*—Arnel C Lavarias

(74) *Attorney, Agent, or Firm*—Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

In order to make a reflection coefficient in boundary surface between materials to be zero and permeate 100% of a light independent of a polarization direction, an optical device made of an optical material composed of a metamaterial prepared by arranging a plurality of at least either of electrical resonators or magnetic resonators each being smaller than a wavelength of a light wave in only a predetermined plane, and at least either of the electrical resonators and the magnetic resonators arranged functioning with respect to s-polarization, wherein at least either of the dielectric constant or the magnetic permeability is controlled in response to the function to induce a Brewster phenomenon in the s-polarization.

**4 Claims, 14 Drawing Sheets**



The  
United  
States  
of  
America



**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 for the term set forth below, subject to the payment of maintenance fees as provided by law.*

*If this application was filed prior to June 8, 1995, the term of this patent is the longer of seventeen years from the date of grant of this patent or twenty years from the earliest effective U.S. filing date of the application, subject to any statutory extension.*

*If this application was filed on or after June 8, 1995, the term of this patent is twenty years from the U.S. filing date, subject to any statutory extension. If the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121 or 365(c), the term of the patent is twenty years from the date on which the earliest application was filed, subject to any statutory extensions.*

*John Doll*

Acting Director of the United States Patent and Trademark Office

〈新規程〉

## 特許登録通知連絡書

平成 21 年 8 月 27 日

河田ナノフォトニクス研究室  
田中拓男 殿

知的財産戦略センター  
知的財産戦略グループ  
知財創出・活用チーム  
担当：原田  
TEL 048-467-9262  
Mail:eiko.harada@riken.jp

この度、下記の特許・実用新案登録出願が登録となりましたので、特許・実用新案登録証（写）を送付いたします。

特許番号 7532397  
設定登録日 2009/05/12

SEQ-NO	20820	出願国	US
出願番号	11/455092	出願日	2006/06/19
公開番号	US2007-014006-A1	公開日	2007/01/18

発明者 田中拓男、河田聡

出願人 理化学研究所

名称 光学材料、それを用いた光学素子およびその作製方法

要約 【課題】偏光方向に依存せずに物質界面での反射率をゼロとし、光を100%透過させる。

(添付書類)

特許・実用新案登録証（写）