PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G02B 6/12	A1	(11) International Publication Number: WO 00/07049 (43) International Publication Date: 10 February 2000 (10.02.00)

(21) International Application Number: PCT/EP99/04040

(22) International Filing Date: 9 June 1999 (09.06.99)

(30) Priority Data:
98202496.0 24 July 1998 (24.07.98) EP

(71) Applicant *(for all designated States except US)*: AKZO NOBEL N.V. [NL/NL]; Velperweg 76, NL–6824 BM Arnhem (NL).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: HOEKSTRA, Tsjerk, Hans [NL/NL]; Meidoornlaan 151, NL–6951 LZ Dieren (NL).

(74) Agent: SCHALKWIJK, Pieter, Cornelis; Akzo Nobel N.V., Intellectual Property Dept. (Dept. AIP), P.O. Box 9300, NL–6800 SB Arnhem (NL).

(81) Designated States: CA, JP, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: OPTICAL WAVEGUIDE COMPONENT

(57) Abstract

The invention pertains to an optical waveguide component comprising a substrate, a core–matching refractive index lower cladding layer, a core layer, a core–matching refractive index upper cladding layer, a low refractive index upper cladding, wherein the core–matching refractive index lower cladding layer is deposited directly onto the substrate and has a thickness sufficient to avoid substantial capture and/or absorption by the substrate of a guided mode in the core layer, whereas slab modes, quasi–guided modes and/scattered light leak to the substrate. The components according to the invention allow high switching speeds and high confinement of a guided mode on the one hand and, on the other hand, absorption by the substrate of stray–light and radiation modes, which, in turn, leads to improved optical devices, such as optical switches with improved isolation.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

Optical waveguide component.

The invention pertains to an optical waveguide component comprising a substrate, a core-matching refractive index lower cladding layer, a core layer, a core-matching refractive index upper cladding layer, and a low refractive index top cladding.

Such a component is known from, e.g., International patent application WO 97/01782. This publication concerns optical components having an at least penta-layered polymer structure on a substrate comprising: a) a low refractive index bottom cladding layer, b) a core-matching refractive index lower cladding layer, c) a core layer, d) a core-matching refractive index upper cladding layer, and e) a low refractive index top cladding layer.

With this specific layer structure optimum confinement in the direction of the thickness of the stack of layers (also denoted as transverse direction) can be obtained, which results in less loss of light and an improved switching efficiency. However, present and future applications of optical devices require crosstalk to be as low as possible.

Accordingly, it is an object of the present invention to further reduce crosstalk. This is achieved, in the components described in the first paragraph, by leaving out the low refractive index bottom cladding layer and employing a single core-matching refractive index lower cladding layer which has a thickness sufficient to avoid substantial capture and/or absorption by the substrate of a guided mode in the core layer, whereas slab modes, quasi-guided modes and/scattered light leak to the substrate.

It was found that, in the said penta-layered components, slab modes, quasi-guided modes and/or scattered light (sometimes also referred to as radiation modes and stray light respectively) become trapped between the lower and upper cladding layers, with the core layer and the core-matching refractive index cladding layers serving as a (composite) core. By leaving out the bottom cladding layer, making sure that the slab modes, quasi-guided modes and/scattered light leak to the substrate, and selecting the thickness of the core-matching refractive index lower cladding layer such that substantial absorption of a guided mode by the substrate is avoided, crosstalk and other detrimental phenomena are significantly reduced. Once captured or absorbed by the substrate, the said modes cannot have any interaction with the guide mode(s) in the core layer and a decrease of the optical performance is avoided. E.g., for an 1x2 optical switch, avoiding interaction between a guided mode in the core layer and slab modes, quasi-guided modes and/scattered light will result in a considerably improved isolation (defined as the ratio of the optical power in an output in the on-state and the optical power in an output in the off-state).

Capture and/or absorption of the guided mode should preferably be smaller than 0.01 dB/cm, more preferably smaller than 0.001 dB/cm.

Leaking of slab modes, quasi-guided modes and/or scattered light to the substrate can be achieved by using a substrate that has a refractive index higher than that of the core-matching refractive index lower cladding layer and/or that functions as an absorber of the said undesirable modes. Any material that absorbs and dissipates light in the optical frequencies used in the structure in question will do. Examples of suitable materials are metals such as titanium, silver, gold, or nickel or non-transparent dielectric polymers containing a dye. It is noted that the substrate may comprise one or more (usually very thin) top layers or coatings, e.g., to promote adhesion to the core-matching refractive index lower cladding layer.

The components according to the invention allow high switching speeds and high confinement of a guided mode, require less power for switching and, due to the capture or absorption by the substrate of slab modes, quasi-guided modes and/or scattered light, exhibit less crosstalk.

It is noted that EP 642 052 discloses a polymeric thermo-optical device comprising a polymeric core layer sandwiched between two cladding layers having a refractive index lower than that of the guiding layer. A heating element is placed against one of the cladding layers and this layer has a lower refractive index than the other cladding layer. In a particularly preferred embodiment, the lower cladding layer is made up of two sublayers to provide optical isolation from the substrate. Thus, the gist of EP 642 052 runs counter to that of the present invention.

In a preferred embodiment, the component is a thermo-optical component and/or the thickness of the core-matching refractive index lower cladding layer is (preferably at least 30 percent) greater than the thickness of the stack containing the core layer, the core-matching refractive index upper cladding layer, and the low refractive index upper cladding. Thus, the core layer is asymmetrically buried in the layer stack, close to the heater element and far from the heatsink, i.e. the substrate.

As will be clear from the above explanations, it is advantageous to select the refractive index of the substrate to be higher than the refractive index of the core-matching refractive index lower cladding layer. Silicon substrates are preferably used, because silicon exhibits a very high refractive index and silicon substrates are readily available on the market and of homogeneous thickness. Furthermore, they are frequently used in integrated circuit techniques and apparatus.

Within the framework of the present invention, components wherein the layers are made of optical polymeric materials are preferred. Active optical components, such as 1xN switches, switch matrices, and MZIs, can be, e.g., so-called thermo-optical (TO) components, which are preferred, or electro-optical components (EO). Both thermo-optical and electro-optical components are known.

The working of thermo-optical components is based on the phenomenon of the optical waveguide material employed exhibiting a temperature dependent refractive index. On top of the upper cladding layer heating elements are provided (usually metal strips) to heat the polymeric cladding and core materials, in order to change the refractive index for switching.

The working of electro-optical devices is based on the phenomenon of the non-linear optically active material employed exhibiting an electric field dependent refractive index. On top of the upper cladding layer electrodes are provided to apply an electric field to the non-linear optically active material to change the refractive index for switching.

Of course, the invention also applies to passive components, like splitters and combiners.

Devices according to the invention can be used with advantage in optical communications networks of various kinds. Generally, the optical components either will be directly combined with optical components such as light sources (laser diodes) or detectors, or they will be coupled to input and output optical fibres, usually glass fibres.

Polymer optical devices are commonly optical fibre-compatible and based on embedded or embedded ridge-type channel waveguides. The resulting structure comprises a high refractive index core polymer (usually of rectangular or square cross-section) embedded in a lower refractive index cladding material.

Suitable materials for and configurations of the cladding and the core layers are disclosed, int. al., in M.B.J. Diemeer et al., "Polymeric phased array wavelength multiplexer operating around 1550 nm," *Electronics Letters*, Vol. 32 (1996), pp. 1132-1133; and T.A. Tumolillo et al., "Solid State Optical

Space Switches for Network Cross-Connect and Protection Applications," *IEEE Communications Magazine* (1997), pp 124-130; and International Patent Application WO 97/01782.

Within the framework of the present invention the term "core-matching refractive index" means that the refractive index is matched to that of the core so as to obtain the required contrast.

Figure 1 shows a polymeric five- or penta-layered structure on a silicon substrate in accordance with the prior art. Figure 2 shows a polymeric four-layered structure on a silicon substrate in accordance with the present invention (in both structures N_0 eguals 1.513). Both devices were operated using light having a wavelength of 1550 nm and, in comparison with the one according to Figure 1, the scattered light in the device according to the present invention was considerably reduced.

Claims

1. An optical waveguide component comprising a substrate, a core-matching refractive index lower cladding layer, a core layer, a core-matching refractive index upper cladding layer, and a low refractive index top cladding, characterised in that the core-matching refractive index lower cladding layer is deposited directly onto the substrate and has a thickness sufficient to avoid substantial capture and/or absorption by the substrate of a guided mode in the core layer, whereas slab modes, quasi-guided modes and/or scattered light leak to the substrate.

2. The optical waveguide component according to claim 1 wherein the component is a thermo-optical component.

3. The optical waveguide component according to claim 1 or 2 wherein the thickness of the core-matching refractive index lower cladding layer is greater than the thickness of the stack containing the core layer, the core-matching refractive index upper cladding layer, and the low refractive index upper cladding.

4. The optical waveguide component according to claim 3 wherein the thickness of the core-matching refractive index lower cladding layer is at least 30 percent greater than the thickness of the said stack.

5. The optical waveguide component according to any one of the preceding claims wherein the layers are made of polymeric materials.

6. The optical waveguide component according to any one of the preceding claims wherein the component comprises a switch.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/04040

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 01782 A (AKZO NOBEL) 16 January 1997 (1997-01-16) cited in the application abstract; claims 1-7	1,2,5,6
A	EP 0 642 052 A (AKZO NOBEL) 8 March 1995 (1995-03-08) cited in the application abstract; figure 1	1,2,5,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 July 1999	03/08/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Malic, K

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 99/04040

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9701782 A	16-01-1997	CA 2222145 A	16-01-1997
		EP 0835469 A	15-04-1998
		US 5861976 A	19-01-1999
EP 0642052 A	08-03-1995	AU 7141794 A	30-03-1995
		CA 2130605 A	25-02-1995
		CN 1115865 A	31-01-1996
		JP 7084226 A	31-03-1995