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(54) Title: POLARIZATION-MODULATING OPTICAL ELEMENT

(57) Abstract: A polarization-modulating optical element (1) consisting of an optically active crystal material has a thickness profile where the thickness, as measured in the direction of the optical axis, varies over the area of the optical element. The polarization-modulating optical element (1) has the effect that the plane of oscillation of a first linearly polarized light ray and the plane of oscillation of a second linearly polarized light ray are rotated, respectively, by a first angle of rotation and a second angle of rotation, with the first angle of rotation and the second angle of rotation being different from each other.
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO,
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GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— of inventorship (Rule 4.17(iv)) for US only

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INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G03F7/20 G02B27/28 G02B5/30

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 G03F G02F

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)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>GB 856 621 A (NATIONAL RESEARCH DEVELOPMENT CORPORATION)</td>
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<td>US 3 630 598 A (WILLIAM S. LITTLE JR)</td>
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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

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"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

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Date of the actual completion of the international search

9 August 2005

Date of mailing of the international search report

2005

Name and mailing address of the ISA

European Patent Office, P.B. 5618 Patentlaan 2 NL - 2280 HV Rijswijk, Tel: (+31-70) 540-2040, Txs: 31 651 epo ni, Fax: (+31-70) 340-4016

Authorized officer

Michel, A

Form PCT/ISA/10 (second sheet) (January 2004)
INTERNATIONAL SEARCH REPORT

Box II  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.; because they relate to subject matter not required to be searched by this Authority, namely:

2. [ ] Claims Nos.; because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.; because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a):

Box III  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this International application, as follows:

see additional sheet

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [X] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

   1–55

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[X] No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (January 2004)
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-31

Claim 1 relates to a polarization-modulating optical element comprising an optically active crystal having an optical axis (claims 2-31 are dependent thereupon).
The problem to be solved is how to rotate the oscillation plane of the electrical field vector of linearly polarized light by an angle proportional to the distance travelled in said crystal.
The special characteristic is the thickness profile being variable along said optical axis.

2. claims: 32-55

Claim 32 relates to a polarization-modulating optical element comprising an optically active crystal (claims 33-55 are dependent thereupon).
The problem to be solved is how to produce an arbitrarily selected distribution of the oscillation planes of the electrical field vector of linearly polarized light traversing said crystal.
The special characteristic is the two different angles at which two different linearly polarized light rays are rotated.

3. claim: 56

Claim 56 relates to a method for manufacturing a micro-structured semiconductor component.
The problem to be solved is how to increase the achievable resolution by enabling immersion microlithography technique.
The special method step is using a projection system where a polarization modulating optical element comprising an optically active crystal is arranged in its illumination system.

4. claims: 57-64

Claim 57 relates to an optical system having an optical axis and a polarization modulating element comprising an optically active material (claims 58-64 are dependent thereupon).
The problem to be solved is how to... produce a tangential polarization distribution.
The special characteristic is the effective thickness profile being variable in a direction non parallel to said optical axis.
5. Claims: 65-74

Claim 65 relates to an optical system having an optical axis and a polarization modulating element (claims 66-74 are dependent thereupon).
The problem to be solved is how to thermally control the change of polarization.
The special characteristics are the:
- effective thickness profile being constant along the optical axis of a solid and/or liquid optically active material therein;
- polarization control system having a heating or cooling device.

6. Claims: 75-80

Claim 75 relates to an optical system having an optical axis and two polarization modulating elements (claims 76-80 are dependent thereupon).
The problem to be solved is how to athermalise the system.
The special characteristics are the:
- two polarization modulating elements having optically active materials with specific rotations of opposite signs; and
- effective thickness profile of one polarization modulating element being variable in a direction non parallel to the optical axis of a solid and/or liquid optically active material therein; and/or
- effective thickness profile of one polarization modulating element being constant in a direction non parallel to the optical axis of a solid and/or liquid optically active material therein.

7. Claim: 81

Claim 81 relates to a method for manufacturing micro-structured semiconductor components.
The problem to be solved is how to control the change of polarization by Faraday effect.
The special method step is using a projection system comprising a polarization modulating optical element having optically active or inactive material subjected to a magnetic field.
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