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SEARCH REPORT

Application Number

LH 31
LT 2021565

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	MARKO I P ET AL: "Physical properties and optimization of GaBiAs/(Al)GaAs based near-infrared laser diodes grown by MOVPE with up to 4.4% Bi", JOURNAL OF PHYSICS D: APPLIED PHYSICS, INSTITUTE OF PHYSICS PUBLISHING, BRISTOL, GB, vol. 47, no. 34, 1 August 2014 (2014-08-01), page 345103, XP020268634, ISSN: 0022-3727, DOI: 10.1088/0022-3727/47/34/345103 [retrieved on 2014-08-01] * sections 1-3; figure 1; table 1 * -----	1,3	INV. H01L33/06 H01L33/30
X	LIU JUANJUAN ET AL: "Electrically injected GaAsBi/GaAs single quantum well laser diodes", AIP ADVANCES, AMERICAN INSTITUTE OF PHYSICS, 2 HUNTINGTON QUADRANGLE, MELVILLE, NY 11747, vol. 7, no. 11, 3 November 2017 (2017-11-03), XP012223394, DOI: 10.1063/1.4985231 [retrieved on 2017-11-03] * section "EXPERIMENT"; figure 1 * ----- -/--	1,3	TECHNICAL FIELDS SEARCHED (IPC) H01L H01S

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	3 June 2022	Franssen, Gijs

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

1

EPO FORM 1503 11.08 (P04C80)

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DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	BUTKUTE RENATA ET AL: "Photoluminescence at up to 2.4[mu]m wavelengths from GaInAsBi/AlInAs quantum w", JOURNAL OF CRYSTAL GROWTH, ELSEVIER, AMSTERDAM, NL, vol. 391, 21 January 2014 (2014-01-21), pages 116-120, XP028651808, ISSN: 0022-0248, DOI: 10.1016/J.JCRYSGRO.2014.01.009 * section 2; figure 3b *	1,2	
Y	CN 103 401 144 A (SUZHOU INST NANO TECH & NANO B) 20 November 2013 (2013-11-20) * paragraph [0033] - paragraph [0039]; figure 1 *	1,2	
A	US 2008/089375 A1 (KANSKAR MANOJ [US] ET AL) 17 April 2008 (2008-04-17) * paragraph [0063] - paragraph [0064]; figure 5 *	1,3	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	3 June 2022	Franssen, Gijs

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1

EPO FORM 1503 11.08 (P04C80)

ANNEX TO THE SEARCH REPORT ON LITHUANIAN PATENT APPLICATION NO.

LH 31
LT 2021565

This annex lists the patent family members relating to the patent documents cited in the above-mentioned search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

03-06-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 103401144 A	20-11-2013	NONE	
US 2008089375 A1	17-04-2008	DK 1800374 T3	25-06-2018
		EP 1800374 A1	27-06-2007
		EP 2375514 A1	12-10-2011
		ES 2675150 T3	09-07-2018
		TR 201808671 T4	23-07-2018
		US 2008089375 A1	17-04-2008
		WO 2006044314 A1	27-04-2006

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WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
LH31	25.10.2021		LT2021565

International Patent Classification (IPC)
INV. H01L33/06 H01L33/30

Applicant
Valstybinis mokslini tyrim institutas Fizini ir technologijos moksl centras

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of the opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the application
- ☐ Box No. VIII Certain observations on the application

	Examiner
	Franssen, Gijs

Application number

WRITTEN OPINION

LT2021565

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	2
	No:	Claims	1, 3
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-3
Industrial applicability (IA)	Yes:	Claims	1-3
	No:	Claims	

2. Citations and explanations

see separate sheet

1 **Re Item V**

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1.1 Reference is made to the following documents:

D1 MARKO I P ET AL: "Physical properties and optimization of GaBiAs/(Al)GaAs based near-infrared laser diodes grown by MOVPE with up to 4.4% Bi",
JOURNAL OF PHYSICS D: APPLIED PHYSICS, INSTITUTE OF PHYSICS PUBLISHING, BRISTOL, GB,
vol. 47, no. 34, 1 August 2014 (2014-08-01), page 345103, XP020268634,
ISSN: 0022-3727, DOI: 10.1088/0022-3727/47/34/345103

D2 LIU JUANJUAN ET AL: "Electrically injected GaAsBi/GaAs single quantum well laser diodes",
AIP ADVANCES, AMERICAN INSTITUTE OF PHYSICS, 2 HUNTINGTON QUADRANGLE, MELVILLE, NY 11747,
vol. 7, no. 11, 3 November 2017 (2017-11-03), XP012223394,
DOI: 10.1063/1.4985231

D3 BUTKUTE RENATA ET AL: "Photoluminescence at up to 2.4[mu]m wavelengths from GaInAsBi/AlInAs quantum w",
JOURNAL OF CRYSTAL GROWTH, ELSEVIER, AMSTERDAM, NL,
vol. 391, 21 January 2014 (2014-01-21), pages 116-120, XP028651808,
ISSN: 0022-0248, DOI: 10.1016/J.JCRYSGRO.2014.01.009

D4 CN 103 401 144 A (SUZHOU INST NANO TECH & NANO B) 20 November 2013

D5 US 2008/089375 A1 (KANSKAR MANOJ [US] ET AL) 17 April 2008

2 **Independent claim 1**

2.1 **Novelty**

2.1.1 The present application does not meet the criteria of patentability because the subject matter of independent claim 1 is not new.

2.1.2 With respect to independent claim 1, document D1 discloses (sections 1-3; figure 1; table 1):

a semiconductor light source (see **Sample D**) comprising:
- a semiconductor substrate (see "GaAs n+ Substrate" in **fig. 1**),
- a light emitting multilayer structure grown on the semiconductor substrate (see layers on top of "GaAs n+ Substrate" in **fig. 1**), wherein multilayer structure comprises:
a) a quantum well layer (see "$GaAs_{0.978}Bi_{0.022}$" in **fig. 1**) made from a first semiconductor material,
b) two overgrowth layers (see **Sample D** with "AlGaAs barriers" comprising 0% Al in **Table 1**) located on both sides of the quantum well layer respectively and made from a second semiconductor material,
c) two barrier layers (see "$Al_{0.4}Ga_{0.6}As$ cladding layers" in **lines 4-5** of section 2, and **fig. 1**) respectively located on the overgrowth layers and made from a third semiconductor material,
wherein
the quantum well layers from the first semiconductor material contain bismuth atoms (see **lines 1-2** of section 2, and "$GaAs_{0.978}Bi_{0.022}$" in **fig. 1**);
an energy bandgap ε_{g2} of the overgrowth layers made from the second material is larger than an energy bandgap ε_{g1} of the first material (implicit for a $GaAs_{0.978}Bi_{0.022}$/GaAs quantum well), and a conduction band offset ΔE_{c12} at the interface with the first material is lower than valence band offset ΔE_{v12} (see ΔE_c vs. ΔE_v for **Sample D** in **Table 1**);
an energy bandgap of two barrier layers from the third material is larger than in the second material (implicit for GaAs/$Al_{0.4}Ga_{0.6}As$ junction), and a conduction band offset ΔE_{c23} at the interface with the second material is larger than valence band offset ΔE_{v23} (implicit for a GaAs/$Al_{0.4}Ga_{0.6}As$ junction, see e.g. **fig. 5; §63-64** of document D5).

Therefore, the subject matter of independent claim 1 is not new.

2.1.3 Notwithstanding the above, with respect to independent claim 1, document D2 discloses a semiconductor light source comprising a "GaAsBi" quantum well layer, two "GaAs" overgrowth layers, and two "AlGaAs" barrier layers, see **fig. 1** thereof. Said materials implicitly comprise the claimed relative energy bandgaps and band offsets.

Therefore, also for this reason the subject matter of independent claim 1 is not new.

2.2 **Inventive step**

2.2.1 Notwithstanding the above, the present application does also not meet the criteria of patentability because alternatively the subject matter of claim 1 does not involve an inventive step in view of further document D3 and D4.

2.2.2 With respect to independent claim 1, document D3 discloses (section 2; figure 3b):

a semiconductor light source (see **fig. 3b**) comprising:
- a semiconductor substrate (see "InP:Fe substrate" in **fig. 3b**),
- a light emitting multilayer structure grown on the semiconductor substrate (see layers on top of "InP:Fe substrate" in **fig. 3b**), wherein multilayer structure comprises:
a) a quantum well layer (see "$Ga_{0.47}In_{0.53}As_{1-x}Bi_x$" with x = 0.037 above **fig. 1** on **p. 117**; and "GaInAsBi QW" in **fig. 3b**) made from a first semiconductor material,
~~b) two overgrowth layers located on both sides of the quantum well layer respectively and made from a second semiconductor material,~~
c) two barrier layers (see "$Al_{0.48}In_{0.52}As$" below **fig. 2** on **p. 117**; and "AlInAs" in **fig. 3b**) respectively located on the overgrowth layers and made from a third semiconductor material,
wherein
the quantum well layers from the first semiconductor material contain bismuth atoms (see "$Ga_{0.47}In_{0.53}As_{1-x}Bi_x$" with x = 0.037 above **fig. 1** on **p. 117**; and "GaInAsBi QW" in **fig. 3b**);
~~an energy bandgap ε_{g2} of the overgrowth layers made from the second material is larger than an energy bandgap ε_{g1} of the first material, and a conduction band offset ΔE_{c12} at the interface with the first material is lower than valence band offset ΔE_{v12};~~
~~an energy bandgap of two barrier layers from the third material is larger than in the second material, and a conduction band offset ΔE_{c23} at the interface with the second material is larger than valence band offset ΔE_{v23}.~~

N.B. Missing features are indicated by ~~strike-through~~.

2.2.3 The subject matter of claim 1 differs from the disclosure of D3 by:

two overgrowth layers located on both sides of the quantum well layer respectively and made from a second semiconductor material, wherein

an energy bandgap ε_{g2} of the overgrowth layers made from the second material is larger than an energy bandgap ε_{g1} of the first material, and a conduction band offset ΔE_{c12} at the interface with the first material is lower than valence band offset ΔE_{v12};
an energy bandgap of two barrier layers from the third material is larger than in the second material, and a conduction band offset ΔE_{c23} at the interface with the second material is larger than valence band offset ΔE_{v23}.

2.2.4 However, an active area comprising at least two overgrowth layers located on both sides of the quantum well layer is well-known in the art, see e.g. graded layers **501, 503** on either side of an $In_{0.008}Ga_{0.992}As_{0.972}Bi_{0.028}$ quantum well layer **502** in **fig. 1; §37** of document D4. Said graded layers comprise also GaInAs, see y = 0 in **§37** of D4.

As disclosed in **§35** of D4, the quantum well structure of **fig. 1** of D4 is particularly suitable for generating light in the wavelength band 2-6 µm. As such, the person skilled in the art would not require any inventive skill to replace the quantum well area of **fig. 3b** of document D3 with the quantum well area of **fig. 1** of document D4. The disclosed materials would then necessarily and implicitly comprise the relative energy bandgaps and band offsets according to claim 1.

Therefore, according to this alternative reasoning the subject matter of independent claim 1 does not involve an inventive step.

2.3 **Dependent claims 2 and 3**

2.3.1 The reasoning of section 2.2 above applies to the particular materials according to claim 2.

Therefore, the subject matter of dependent claim 2 does not involve an inventive step.

2.3.2 The reasoning of sections 2.1.2 and 2.1.3 above applies to the particular materials according to claim 3.

Therefore, the subject matter of dependent claim 3 is not new.

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