BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS | BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE | CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

Internal distribution code:
(A) [ ] Publication in OJ
(B) [ ] To Chairmen and Members
(C) [X] To Chairmen
(D) [ ] No distribution

D E C I S I O N
of 15 October 2002

Case Number: T 1058/01 - 3.4.2

Application Number: 96119636.7

Publication Number: 0778488

IPC: G02F 1/37, G02F 1/35

Language of the proceedings: EN

Title of invention:
Optical wavelength conversion element, method of manufacturing the same and optical wavelength conversion module

Applicant:
Fuji Photo Film Co., Ltd.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - yes (after limitation to method)"

Decisions cited:
-

Catchword:
-

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 1058/01 - 3.4.2

D E C I S I O N
of the Technical Board of Appeal 3.4.2
of 15 October 2002

Appellant: Fuji Photo Film Co., Ltd.
210 Nakanuma
Minamiashigara-shi
Kanagawa-kun (JP)

Representative: Klunker, Schmitt-Nilson, Hirsch
Winzererstrasse 106
D-80797 München (DE)

Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 26 April 2001 refusing European patent application No. 96 119 636.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: E. Turrini
Members: M. P. Stock
B. J. Schachenmann

Summary of Facts and Submissions

I. The present appeal is against the decision of the examining division to refuse European patent application 96 119 636.7 published as EP-A-0 778 488 for lack of novelty. Reference was made to the following document:

D1: EP-A-0 592 226

The examining division held that the subject-matter of claim 1 as originally filed (main request) was known from D1. In particular Figures 14 and 17 of D1 showed that the orientation of the spontaneous polarisation P_s of the substrate 42 is at an angle (90°-θ) to the surface of the substrate in a plane normal to the direction in which the fundamental wave is guided by the waveguide 44.

Moreover, the examining division was of the opinion that the subject-matter of versions of claim 1 according to a first and a second auxiliary request was implicitly disclosed by the original claim 1 and therefore also not new.

II. In his statement setting out the grounds of appeal the appellant requested that the decision be set aside and a patent be granted on the basis of an amended set of claims.

The arguments of the appellant can be summarised as follows:

Figures 14 and 15 of D1 do not disclose the feature added to all independent claims that the orientation of polarisation of the domain reversals is parallel to the orientation of spontaneous polarisation. It is true

that the inverted polarisation of layer 43 is directed opposite to the spontaneous polarisation P_s and in the direction of the -C-crystal axis. However, it does not follow from this that the extending direction of the polarisation reversals in D1 is parallel to the spontaneous polarisation. On the contrary the extending direction D_E of each inverted-polarisation layer 43 is inclined at an angle of 90°-θ to the -C-crystal axis and therefore not parallel to P_s or the direction inverted thereto. Therefore the subject-matter of claim 1 is new. This subject-matter also involves an inventive step since with the methods for forming inverted-polarisation kernels described in D1, from which the polarisation-inverted domains (domain reversals) grow, the direction of these kernels is intentionally made non-parallel to the spontaneous polarisation. This is, however, in contrast to the teaching of the invention.

III. In an annex to the summons to oral proceedings requested by the appellant, the board of appeal made the following comments:

In D1, see Figures 14 and 15 with the associated description, there is described an optical wavelength conversion element (41) comprising an optical waveguide (44) which is formed on a ferroelectric crystal substrate (42) having a nonlinear optical effect and extends along one surface of the substrate, and domain reversals (43) which are periodically formed in the optical waveguide and arranged in a direction, the orientation of the spontaneous polarisation of the substrate being reversed in the domain reversals and the optical wavelength conversion element being for converting the wavelength of a fundamental wave travelling in the direction in which the domain reversals are arranged under the guidance of the optical waveguide, wherein the improvement comprises

the orientation of the spontaneous polarisation (P_s) of the substrate being at an angle (90-θ°) larger than 0° and smaller than 90° to said one surface of the substrate in a plane (see Figure 15) normal to the direction in which the fundamental wave is guided, while the orientation of polarisation (inverted polarisation, see column 25, lines 44 to 47) of the domain reversals (inverted polarisation layers 43) is parallel (directed in the -C-crystal axis direction) to the orientation of spontaneous polarisation (P_s which is directed in the +C-crystal axis direction).

Therefore it would appear that the subject-matter of claim 1 filed with the statement setting out the grounds of appeal is not new.

Moreover, the board commented on inventive step, making reference to D2 cited by the examining division in the examining procedure:

D2: US-A-5 415 743

IV. In the oral proceedings which took place on 15 October 2002 the appellant requested that the decision under appeal be set aside and a patent be granted on the basis of claims 1 to 5 filed during the oral proceedings.

Claim 1 which is the only independent claim reads as follows:

"1. A method of manufacturing an optical wavelength conversion element comprising the steps of

forming a substrate by cutting a single domain ferroelectric crystal having a nonlinear optical effect

along a plane at an angle θ larger than 0° and smaller than 90° to the orientation of spontaneous polarization of the ferroelectric crystal,

forming periodic domain reversals on the substrate by applying an electric field in a predetermined pattern to the substrate from outside the substrate, and

forming on the substrate an optical waveguide which includes the domain reversals and extends along a surface of the substrate parallel to the cut surface."

V. In support of an inventive step of the subject-matter of claim 1 the appellant submitted the following:

In D1, the domain reversals are formed by a proton exchange method. Thereby an internal electric field is created which is perpendicular to the surface due to charge separation, and an inverted polarisation kernel is formed. According to D1 a growth of domain reversals from the inverted polarisation kernel into the substrate can only be expected if the internal electric field created has a component E_c in the direction of the spontaneous polarisation P_s. Therefore the substrate is cut to ensure that the spontaneous polarisation is inclined to the surface. It is thus evident that the inclined orientation of the spontaneous polarisation is bound to the proton exchange method creating an internal electric field. Contrary to that in D2, the domain reversals grow along the orientation of an external electric field and no inclined orientation of the spontaneous polarisation is needed. The present invention, however, is based on the recognition that, if the substrate is cut along a surface which is inclined to the spontaneous polarisation P_s, the growth of the domain reversals under an external electric field mainly follows the orientation of P_s and not the electric field. This was not obvious from D1 and D2.

Reasons for the Decision

1. The appeal complies with the provisions mentioned in Articles 106 to 108 and Rules 1(1) and 64 EPC and is therefore admissible.

2. Claims 1 to 5 correspond to claims 8 to 12 as originally filed. Therefore the requirement of Article 123(2) EPC is met.

3. *Novelty*

3.1 The subject-matter of claim 1 differs from what is disclosed in D1 in that the periodic domain reversals are formed on the substrate by applying an electric field in a predetermined pattern to the substrate from outside the substrate. In D1 a proton exchange method is used for this purpose, see eg column 7, lines 46 to 53.

3.2 The subject-matter of claim 1 is distinguished over D2 in that a substrate is formed by cutting a single domain ferroelectric crystal having a nonlinear optical effect along a plane at an angle θ larger than 0° and smaller than 90° to the orientation of the spontaneous polarisation of the ferroelectric crystal. In D2, see Figures 8A and B, 14A and B, and 15, the z-axis which corresponds to the orientation of the spontaneous polarisation is perpendicular to the plane (x-y-plane) along which the crystal is cut.

3.3 The subject-matter of claim 1 is therefore new with respect to document D1 or D2.

4. *Inventive step*

4.1 The closest prior art is represented by document D1, see column 7, lines 7 to 18, since it is concerned like the present application, see EP-A-0 778 488, column 2, lines 37 to 45, with the general problem of quasi phase matched second harmonic generation (QPM-SHG) employing a TE mode waveguide for efficient coupling to commercially available laser diodes also emitting a TE mode.

4.2 A QPM-SHG waveguide supporting a TE mode requires that the spontaneous polarisation is oriented along the surface of substrate in which the waveguide is formed. However, it turns out that for this orientation the depth of the inverted polarisation layers is limited when they are produced by a proton exchange method, see D1, column 6, lines 6 to 33. The solution proposed by D1 employs a substrate which is cut such that the crystal axis (C- or z-axis) which coincides with the orientation of the spontaneous polarisation is inclined to the surface in which the waveguide is formed. According to the explanation offered by D1 it is necessary that the internal electric field created by the proton exchange method has a component (E_c) in the direction of the sponsions polarisation P_s, see Figure 17. By this component an inverted polarisation kernel (47) is formed which thereafter is growing into the substrate by heat treatment, see Figures 18 and 19A.

4.3 According to the present invention QPM-SHG in a TE mode is obtained by the application of a patterned electric field instead of using the proton exchange method. Therefore the problem solved by the present invention addresses the provision of an alternative method. From the explanation given in D1 it was not evident that sufficiently deep domain reversals could be obtained by

the application of a patterned electric field instead of using the proton exchange method on a substrate with the orientation of the spontaneous polarisation being inclined to the surface.

4.4 D2 is also concerned with QPM-SHG. Different methods for the fabrication are described, eg proton exchange followed by the application of an (unpatterned) electric field (see Figures 1A to 1D), and the application of a patterned electric field only (see Figures 8A and 8B). Waveguides supporting a TM mode were thereby formed in substrates having the z-axis coinciding with the orientation of the spontaneous polarisation which is perpendicular to the surface, see Figure 15.

4.5 Hence from D2 the replacement of the proton exchange method by the application of a patterned electric field is only described for a waveguide supporting a TM mode. The fabrication of waveguides for a TE mode is not considered in D2. Matching problems between laser diodes emitting a TE mode and the QPM-SHG waveguide are overcome by using $\lambda/2$ plates (16) for turning the polarisation plane of the laser, see Figures 4 and 15.

4.6 Thus a person skilled in the art did not receive any information from D2 as to the solution that sufficiently deep domain reversals could be obtained by the application of an electric field on a substrate cut such that the orientation of the spontaneous polarisation is inclined to the surface in which the waveguide is formed. Hence, this solution was not obvious to the skilled person.

4.7 If D2 were considered as the closest prior art, the difference of the subject-matter of claim 1 would be related to using a substrate which is cut to have the orientation of the spontaneous polarisation inclined to

the surface, see item 3.2 above. Then the problem to be solved would concern the provision of sufficiently deep domain reversals for supporting a TE mode. Even though D1 discloses such a substrate, it does so only in connection with a proton exchange method which is effective in a substrate having the inclined orientation of the spontaneous polarisation, see point 4.2 above. It was not evident that a substrate cut in such a way would be beneficial with the application of an electric field. Therefore it was not obvious for the skilled person to use such a substrate with the method of applying a patterned electric field described in D2.

4.8 It follows that the subject-matter of claim 1 involves an inventive step within the meaning of Article 56 EPC.

5. Thus the subject-matter of claim 1 meets the requirements of Article 52(1) EPC.

6. Claims 2 to 5 are related to embodiments of the subject-matter of claim 1 and as such also meet the requirements of the EPC.

7. The description will have to be adapted to the claims in accordance with Rule 27(1)(c) EPC. A reference to documents D1 and D2 should be introduced in the description in accordance with Rule 27(1)(b) EPC.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to grant a patent on the basis of the following documents:

   Claims: 1 to 5 filed during the oral proceedings on 15 October 2002;

   Description: to be adapted;

   Drawings: 11 Sheets (Figures 1 to 19) as originally filed.

The Registrar: The Chairman:

P. Martorana E. Turrini