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D E C I S I O N
of 23 August 2001

Case Number: T 1049/96 - 3.4.3

Application Number: 91305737.8

Publication Number: 0469712

IPC: H01L 21/20

Language of the proceedings: EN

Title of invention:
Method for forming semiconductor structures including quantum-well wires

Applicant:
XEROX CORPORATION

Opponent:
-

Headword:
Selective desorption/XEROX

Relevant legal provisions:
EPC Art. 84, 56

Keyword:
"Clarity (yes)"
"Essential features of the invention in the claim (yes)"

Decisions cited:
T 1055/92

Catchword:
-

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 1049/96 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 23 August 2001

Appellant: XEROX CORPORATION
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 23 July 1996 refusing European patent application No. 91 305 737.8 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: G. L. Eliasson
A. C. G. Lindqvist

Summary of Facts and Submissions

I. European patent application No. 91 305 737.8 was refused in a decision of the examining division dated 23 July 1996. The ground for the refusal was that claims 1 and 6 filed with the letter dated 14 February 1995 were not clear, contrary to the requirements of Article 84 and Rule 29(1) and (3) EPC.

II. In the examination proceedings, the following prior art documents were cited:

D1: Patent Abstracts of Japan, vol. 14, No. 178, 10 April 1990 & JP-A-2-031 479;

D2: Applied Physics Letters, vol. 56, 7 May 1990, pages 1828 to 1830; and

D3: Conference Proceedings of the "Laser and Electro-Optics Society Annual Meeting", 17 to 20 October 1989, pages 422 to 423.

III. The reasoning in the decision can be summarized as follows:

(a) The term "selective desorption" in claim 1 is not clear, since it can mean either selective with respect to the composition of the layers or selective with respect to unirradiated areas. In the former case, claim 1 lacks the essential features specifying the parameters of the irradiating beam (wavelength, energy of the irradiating beam), as well as the parameters of the semiconductor (bandgap, optical absorption, temperature). Since different processes of

desorption or evaporation may be involved by the use of an irradiation beam, as broadly defined in claim 1, the above parameters cannot be considered as common features which are obtainable by routine experiments.

In case the "selective" desorption is interpreted as selective with respect to unirradiated areas, it is not specified in claim 1 that the quantum well layer is thicker in the apex of the groove than anywhere else, a feature considered to be essential for such a desorption process.

(b) Furthermore, interpreting the subject matter of claim 6 in the light of the description, it does not involve an inventive step having regard to document D3.

The decision does not deal with novelty and inventive step of the subject matter of claim 1. During the examination proceedings, the examining division had however implied under item 7 of the communication dated 17 October 1994 that a main claim relating to a process of fabrication of a quantum wire may be allowable.

IV. The appellant (applicant) lodged an appeal, paid the appeal fee, and filed a statement of the grounds of appeal together with two sets of claims forming a main and an auxiliary request, respectively, all on 14 September 1996.

V. In response to a communication of the Board, the appellant filed with a letter dated 10 July 2001 new claims 1 to 9 together with an amended page 2 of the description.

The appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the following documents:

Claims: 1 to 9 filed with the letter dated 10 July 2001

Description: pages 1 and 3 to 9 as originally filed
page 2 filed with the letter dated 10 July 2001

Drawings: Sheets 1/4 to 4/4 as originally filed.

In addition, oral proceedings were requested as an auxiliary request.

VI. Claim 1 in accordance with the appellant's request reads as follows:

"1. A method of forming a semiconductor structure (1) on a substrate layer (12), the structure including a longitudinally extending body (38) in which charge carriers are quantum-confined in the two dimensions orthogonal to the axis of the body, whereby the body forms a so-called 'quantum wire', the method comprising the steps of:

epitaxially depositing a layer (22) of semiconductor quantum well material on a substrate layer (12) of semiconductor material having in its surface a channel (14) having sidewalls (16, 18) which converge in depth;
interrupting the deposition process after the deposited layer has reached a chosen depth;

directing a beam of radiation at the deposited layer (22) to evaporate in situ portions (30, 32) of the layer (22) overlying the surface bordering the channel (14) and overlying the upper parts (26, 28) of the sidewalls (16, 18) of the channel (14), down to the interface with the layer beneath is, so as to selectively desorb the deposited material to leave a longitudinally-extending coherent body (38) of deposited semiconductor material in the channel (14); and epitaxially depositing at least one further layer (40) of semiconductor material on top of the resultant structure."

VII. The appellant presented essentially the following arguments in support of his requests:

(a) The term "selectively desorbing" in claim 1 provides a sufficient definition which indicates to a skilled person what is to be achieved, that is, knowing the compositions of the cladding and the quantum-well layers, and the amount of material which has been deposited as the quantum-well layer during the deposition process on the cladding layer, it is possible for a skilled person to determine through routine experiments, the amount of material in the quantum-well layer which has to be removed by desorption to form the coherent body of deposited semiconductor material.

(b) As to the statement in the decision under appeal that it is possible to understand that the desorption is not linked with the composition of the layer, but is selective with respect to the irradiated area, it is submitted that this is

clear from the description of the invention (cf. page 4, lines 26 to 30 and line 37 to page 5, line 6 and Figure 2). Moreover, it is submitted that it is not a necessary condition for the performance of the invention that the quantum-well layer is thicker in the apex of the groove.

Reasons for the Decision

1. The appeal complies with Articles 106 to 108 and Rule 64 EPC and is therefore admissible.

2. *Amendments (Article 123(2) EPC)*

Claim 1 contains the features of claim 1 as filed and has been amended for clarity. The Board is therefore satisfied that the requirements of Article 123(2) EPC are met. It is also noted that in the decision under appeal, the question of added subject~matter was not an issue.

3. *Clarity (Article 84 EPC)*

3.1 In the decision under appeal, it was held that the term "selectively desorbing" in claim 1 was not clear, since it was ambiguous whether the desorption was "selective" with respect to the composition of the layers, or with respect to radiated vs. unradiated areas.

3.1.1 In the Board's view, however, the wording of claim 1 as amended makes it clear that the step of evaporating *in situ* portions of the deposited layer is to be carried out so that a longitudinally-extending coherent body of

deposited material remains in the channel. Thus, contrary to the view held in the decision under appeal, the term "selectively desorbing" in claim 1 neither refers to a selectivity with respect to the composition of the layer, nor with respect to radiated vs. unradiated regions, but means that portions of the deposited layer are removed so that only a *selected portion* of the deposited layer remains in the channel 14, as also described in the application in suit (cf. the application as published, column 2, lines 38 to 44; column 5, lines 41 to 46; Figures 2 and 3).

3.1.2 It should also be pointed out that the radiation-induced evaporation process can also be "selective" with respect to the composition of the layers, as correctly observed by the examining division: For example, a substrate layer made of $Al_xGA_{1-x}As$ is much more difficult to desorb than a deposited layer that is made of GaAs (cf. column 5, lines 3 to 13). The application in suit however discloses that it is possible to carry out the claimed process also when the substrate layer and the deposited layer are made of the same material and only differ in terms of the conductivity types (cf. column 6, lines 12 to 18). Such an evaporation process having both the substrate layer and the deposited layer made of the same material appears, in the Board's opinion, to be feasible, since the very low evaporation rate (0.1 nm/s) involved allows for great precision (cf. column 4, lines 35 to 38).

3.2 In the decision under appeal, it was held that depending on the different interpretations of the term "selective" essential features were missing in claim 1 (cf. item ll(a) above)

3.2.1 In decision T 1055/92 (OJ EPC, 1995, 214), it was held that the function of the claims, according to Article 84 EPC, first sentence, is to define the matter for which protection is sought.

This function, according to T 1055/92, should however be clearly distinguished from the requirement that the European patent application must disclose the invention in such a way that it enables a person skilled in the art to carry out that same invention. In this connection, features which are described as essential in the application for solving the technical problem addressed by the invention must be present in an independent claim in order that the claim is supported by the description as required by Article 84 EPC, second sentence.

3.2.2 In the present case, the invention as disclosed is concerned with finding a method of producing a semiconductor quantum wire structure where the ultra fine patterning of conducting channels or wires or electron waveguides can be achieved in situ without growth interruption by some off-line or non-growth procedure or process (cf. the application as published, column 1, lines 51 to 57). In the invention as described, this is achieved by depositing a quantum-well layer on a substrate layer where the surface of the substrate layer has a channel with sidewalls which converge in depth. After the growth of the deposited quantum- well layer is interrupted, a beam of radiation is directed at the deposited layer to evaporate in situ portions of the deposited layer, so that the deposited material only remains in the channel (cf. column 2, lines 38 to 52). It is also evident that the technique of using a beam of radiation to induce evaporation of a

deposited semiconductor material is known in the art.

3.2.3 Thus, it follows that the contribution to the state of the art made by the present invention lies in the use of the radiation-induced evaporation technique for forming a quantum wire structure without the use of an additional masking step. The crucial feature allowing the formation of a quantum wire is described in the application in suit to be based on the phenomenon that atoms deposited on the sidewalls of the channel in the substrate layer will evaporate more easily at elevated temperatures than those lying at the bottom of the channel (cf. application as published, column 4, lines 42 to 47). Consequently, the channel is in claim 1 defined to have sidewalls 16, 18 which converge in depth, thereby making it possible for the above-mentioned physical process to take place.

3.2.4 As to the specific process parameters, such as wavelength of the radiation, intensity, temperature, and bandgap of the semiconductor, the Board finds that these parameters cannot be regarded as essential features of the invention, since the evaporation of a semiconductor layer induced by a beam of radiation is a technique that is *per se* known in the state of the art, and it is therefore to be expected that the skilled person would be able to determine the proper process parameters through routine experiments.

3.3 Therefore, in the Board's judgement, the requirements of Article 84 EPC are met.

4. *Inventive step (Articles 52(1) and 56 EPC)*

The examining division had indicated under item 7 of

the communication of 17 October 1994 that a claim directed to a method and overcoming the objections under Article 84 EPC would meet the requirements of novelty and inventive step. The Board is also of the view that the subject-matter of claim 1 is not rendered obvious by the cited prior art for the following reasons:

4.1 The application in suit relates to a method of producing a semiconductor quantum wire structure. The technical problem addressed in the application is to find a method where the ultra fine patterning of conducting channels or wires or electron waveguides can be achieved *in situ* without growth interruption by some off-line or non-growth procedure or process (cf. the application as published, column 1, lines 51 to 57).

The present invention solves this problem by depositing a quantum-well layer on a substrate layer where the surface of the substrate layer has a channel with sidewalls which converge in depth. After the growth of the deposited quantum-well layer is interrupted, a beam of radiation is directed at the deposited layer to evaporate in situ portions of the deposited layer, so that the deposited material only remains in the channel (cf. column 2, lines 38 to 52).

4.2 Document D3 which is considered the closest prior art discloses semiconductor quantum wire structure where a V-shaped channel is formed in the substrate layer (cf. Figures). A quantum-well layer (GaAs QW) is deposited on the substrate layer and along the base of the channel. A further layer is subsequently formed on the quantum well layer.

4.3 The method of claim 1 differs from that of document D3 in that the deposited layer of quantum-well material is selectively desorbed so as to leave a longitudinally-extending coherent body of deposited semiconductor material in the channel. In the device of document D3, on the other hand, there is no desorption in the formation of the quantum wire, so that the portions of the quantum-well layer on the sidewalls of the channel and on the surface bordering the channel are not removed but remain as deposited.

4.4 The claimed method has the advantage over that of document D3 that the resulting device has an improved confinement of carriers in the quantum wire. In the latter device, the carrier confinement merely arises due to a crescent shaped quantum-well layer which is thicker at the base of the channel than along the sidewalls of the channel (cf. D3, page 176, first paragraph).

4.5 In the Board's opinion, a skilled person faced with the above technical problem of improving the method of document D3 would not be able to arrive at the method of claim 1 in an obvious manner. Although it is known from e.g. document D2 that GaAs can be desorbed, this document only discloses a method of completely removing the GaAs layer in selected portions having a width of about 3 mm (cf. D2, abstract). Therefore, document D2 does not provide the skilled person with an incentive to use the disclosed radiation-induced desorption for improving the method of document D3.

4.6 For the foregoing reasons, in the Board's judgement, the subject- matter of claim 1 involves an inventive step as defined in Article 56 EPC.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of the first instance with the order to grant a patent on the basis of the documents as specified under item V above.

The Registrar: The Chairman:

L. Martinuzzi R. K. Shukla