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D E C I S I O N
of 4 October 2004

Case Number: T 1059/02 - 3.4.3

Application Number: 97105449.9

Publication Number: 0810646

IPC: H01L 29/737

Language of the proceedings: EN

Title of invention:

Method of fabricating very high gain heterojunction bipolar transistors

Applicant:

Northrop Grumman Corporation

Opponent:

-

Headword:

-

Relevant legal provisions:

EPC Art. 54, 56

Keyword:

"Novelty (yes)"

"Inventive step (yes): no clear disclosure in the prior art"

Decisions cited:

-

Catchword:

-



Case Number: T 1059/02 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 4 October 2004

Appellant:

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Representative:

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Decision under appeal:

Decision of the Examining Division of the
European Patent Office posted 10 April 2002
refusing European application No. 97105449.9
pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: R. K. Shukla
Members: V. L. P. Frank
M. B. Günzel

Summary of Facts and Submissions

I. The appeal lies from the decision of the Examining Division dated 10 April 2002 refusing the European patent application No. 97 105 449.9. The grounds for the refusal were that the subject-matter of claim 1 according to the main, first and second auxiliary requests lacked novelty, that the subject-matter of claim 1 according to the fourth and sixth auxiliary requests lacked an inventive step and that claim 1 according to the third and fifth auxiliary requests did not comply with the requirements of Article 123(2) EPC.

The following prior art documents were cited inter alia in the decision under appeal:

D2: Electronics Letters, vol. 22, No. 15, 17 July 1986, pp. 781-783

D3: EP-A-0 592 765

II. The appellant (applicant) lodged an appeal against the above decision on 6 June 2002, paying the appeal fee the same day. The statement setting out the grounds of appeal was filed on 9 August 2002 together with a main and an auxiliary request.

III. During the oral proceedings before the Board which took place on 4 October 2004, the appellant replaced his previous requests by a new main request, requesting the grant of a patent with the following patent application documents:

- Claims:** No. 1 to 9, filed during the oral proceedings
- Description:** pages 3, 3a and 7, filed during the oral proceedings
page 5, filed with the letter dated 4 September 2001
pages 1, 2, 4 and 6, as originally filed
- Drawings:** figures 1 to 11, as originally filed.

The wording of the only independent claim is as follows:

"1. A method for fabricating a heterojunction bipolar transistor (HBT) comprising:

- a) forming a structure with a vertically integrated profile having a substrate layer (34), a collector layer (38), a base layer (40) arranged on top of said collector layer (38) and an emitter layer (50) arranged on top of said base layer (40);
- b) forming an emitter mesa (42) and a thin layer (58) adjacent said emitter mesa (42) from said emitter layer (50); and
- c) depositing one or more base contact metals on said thin layer (58);

characterised in that a collector contact layer (36) is arranged on top of said substrate layer (34) and underneath the collector layer (38) and further characterised by the step of

- d) annealing said base contact metals to cause diffusion of a base contact metal through said thin layer (58) to enable reaction of said base contact

metal with said base layer (40) resulting in ohmic base metal contacts (46, 48)."

IV. The argumentation of the Examining Division which is relevant to the present decision can be summarized as follows:

- (a) Document D3, which is the closest state of the art, discloses a method for fabricating a heterojunction bipolar transistor (HBT) on a substrate. Although document D3 does not disclose a collector contact layer, the lower part of the collector layer corresponds to the collector contact layer specified in claim 1 and its upper part to the proper collector layer. The HBT according to claim 1 of the main request was therefore not new over the structure disclosed in document D3.

- (b) Document D2, moreover, discloses three alternative methods for establishing contacts to the base layer of an HBT, namely:
 - (i) selective etching of the emitter mesa down to the base layer and providing base metal contacts on the so exposed surface,
 - (ii) local Zn diffusion through the emitter layer from a vapour diffusion source, and
 - (iii) local Zn diffusion through the emitter layer from AuZnAu base contacts used as a solid diffusion source.

It would, however, have been obvious to the skilled person to choose alternative (iii) for forming the base metal contacts in order to reduce

the number of processing steps involved in the fabrication of the base metal contacts according to document D3, which involves the deposition of a ZnO layer, a Zn diffusion step, the removal of the remaining ZnO layer and the formation of the base metal contacts on the doped base regions. The combination of the teachings of documents D2 and D3 did not involve, for this reason, an inventive step.

V. The appellant argued essentially as follows:

According to document D3, the object of introducing Zn as a p-type dopant into the base layer is not for forming the base contacts, but for reducing the overall resistance of the base layer. This document, moreover, does not disclose the reasons for forming the thin emitter portions adjacent to the emitter base. Probably they are formed for isolating the SiN sidewalls from the base layer, since in most of the embodiments disclosed in this document the remaining thin emitter portions are left only under the sidewalls and are removed to expose the surface of the base layer prior to the formation of the base metal contacts.

Document D2, moreover, does not disclose that the AuZnAu layer which is the source of Zn forms the base metal contacts. Apparently the lower Au layer is used for adhesion on the emitter and the upper Au layer for preventing the evaporation of the Zn into the atmosphere. The formation of the proper base metal contacts is not dealt with in this document. Furthermore, the statement that "Devices fabricated using the selective etching techniques required no heat

treatment other than for contact formation" suggests that the devices obtained by the other two alternative methods disclosed in this document require further heat treatments for the formation of metal contacts besides the Zn diffusion step.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments*

Claim 1 is based on claims 1 (in particular step (j)) and 14 as filed originally. Moreover, the expressions "base metal contact" and "base ohmic contacts" have been respectively replaced by "base contact metals" and "ohmic base metal contacts" in order to clarify that the former expression refers to a metal and the later to a contact.

The Board is therefore satisfied that the requirements of Article 84 and 123(2) EPC are fulfilled.

Furthermore, the description has been amended to concord with the amended claims.

3. *Novelty*

3.1 The Examining Division argued that the single collector layer of the heterojunction bipolar transistor (HBT) disclosed in document D3 could be considered to be formed by a lower and an upper part which correspond, respectively, to the collector contact layer 36 and the

proper collector layer 38 of the HBT according to claim 1 of the application in suit.

3.2 The Board however considers that it is not derivable from document D3 that the collector layer 2 of the embodiments described with reference to Figures 1 to 4 of this document comprises two distinct identifiable layers, ie a collector contact layer and a collector layer as required by the wording of claim 1 of the application in suit. Furthermore, nothing in the disclosure of this document suggests that there is eg an abrupt variation in impurity concentration or an impurity concentration gradient in the layer 2 suggesting that the collector layer is subdivided in two sub-layers.

3.3 Document D2 discloses a HBT having a mesa structure. However, there is no formation of a thin layer of emitter material adjacent to the emitter mesa through which a base contact metal is diffused as in the process of claim 1.

3.4 For the foregoing reasons the Board considers that the fabrication method according to claim 1 is new.

4. *Inventive step*

4.1 Document D3 discloses a method for forming a HBT in which a ZnO film 8 is deposited onto the whole surface of the device once the emitter layer 4 has been etched into a mesa. A thin emitter layer 41 remains at both sides of the emitter mesa, covering the otherwise exposed base layer 3 (cf. Figure 1b). The device is then annealed to diffuse the Zn of the ZnO layer into

the underlying base layer. This increases the impurity concentration in the diffused regions 9 of the base layer and improves, in consequence, the conductivity of the base layer. The remaining ZnO layer is afterwards removed and TiMoAu metal contacts 11 are formed onto the diffused regions to provide an ohmic contact to the base layer. Although in several embodiments the thin emitter layer 41 is removed prior to the formation of the base metal contacts 11, it is also disclosed in this document that the layer 41 may remain in place, since its conductivity has been converted into p-type due to the Zn diffusion and does not, therefore, hinder the formation of ohmic contacts to the base. This second alternative avoids a second base etching step which would be necessary for removing the thin emitter layer 41 as done in the other embodiments (cf. column 1, line 14 to column 2, line 13; column 9, lines 40 to 47; Figure 1).

- 4.2 The fabrication method according to claim 1 differs from the method disclosed in document D3 essentially in that the metals deposited and later diffused into the base layer form simultaneously the ohmic contact to the base region (cf. column 4, lines 40 to 47 of the published application).

This reduces the number of processing steps required with respect to the method disclosed in document D3, as in this document the ohmic metal contacts to the base region are formed after the Zn diffusion and the subsequent removal of the ZnO layer.

- 4.3 The Examining Division argued that document D2 discloses three ways of contacting the base region of a

HBT, namely by (cf. page 782, left-hand column, 3rd and 4th paragraph; Figure 1):

- (a) selectively etching the emitter layer to expose the underlying base layer and providing metal contacts on the so exposed surface,
- (b) local Zn diffusion from a vapour source through the whole thickness of the emitter layer, and
- (c) local Zn diffusion from a AuZnAu solid source provided on top of the emitter layer.

In their view, the skilled person would have chosen method (c) for providing the ohmic base metal contacts to the HBT disclosed in document D3, since this method avoids the ZnO etching step and the formation of the metal contacts in a separate step from the diffusion process. It, therefore, reduces the number of processing steps required for manufacturing the HBT.

- 4.4 The Board, however, concurs with the appellant that although there is a clear disclosure that the AuZnAu layer acts as a source of diffusion of Zn, a p-type impurity, the document does not disclose that the AuZnAu layer forms the base metal contacts after the diffusion of Zn. The statement, "Briefly, the diffusion of Zn to contact the base relies on ..." on page 782, left hand column, 3rd paragraph, also does not unambiguously disclose that the AuZnAu layer is used as the ohmic base metal contact.

Moreover, as the appellant pointed out, the statement in document D2 that "Devices fabricated using the

selective etching techniques required no heat treatment other than for contact formation" suggests that, in contrast to the selective etching method (i.e. technique (a) as identified under point 4.3), in techniques (b) and (c) a further heat treatment for contact formation was required after the Zn diffusion step (cf. page 782, left-hand column, end of 4th paragraph). In other words, it would appear that in method (c), ie the diffusion of Zn from a solid AuZnAu layer, a further step of contact formation is required after the diffusion of Zn.

- 4.5 The Board, for the above mentioned reasons, concludes that there is no clear disclosure in document D2 that the doping of the regions of the base layer and the forming of the ohmic metal contacts on these regions is done in a single heat treatment step. To interpret document D2 in the sense that the Zn diffusion into the base layer and the ohmic metal contacts are performed in the same step tantamounts to an *ex post facto* interpretation of this document.

As there remain doubts on the real disclosure of document D2, it cannot be concluded that the method according to claim 1 is obvious with regard to documents D2 and D3.

It is therefore the Board's judgement that the application in suit fulfils the requirements of the 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 with the following documents:

Claims: No. 1 to 9, filed during the oral proceedings

Description: pages 3, 3a and 7, filed during the oral proceedings
page 5, filed with the letter dated 4 September 2001
pages 1, 2, 4 and 6, as originally filed

Drawings: figures 1 to 11, as originally filed.

The Registrar:

The Chairman:

P. Cremona

R. K. Shukla