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Datasheet for the decision of 13 October 2016

Case Number: T 1101/12 - 3.4.03

Application Number: 06124375.4

Publication Number: 1850373

IPC: H01L21/20, H01L21/02

Language of the proceedings: EN

Title of invention:
Method of forming highly orientated silicon film, method of manufacturing three-dimensional semiconductor device, and three-dimensional semiconductor device

Applicant:
Samsung Electronics Co., Ltd.

Headword:

Relevant legal provisions:
EPC 1973 Art. 56, 84
EPC Art. 123(2)

Keyword:
Inventive step - after amendment - (yes)
Claims - clarity after amendment (yes)
Amendments - added subject-matter (no)

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It can be changed at any time and without notice.

Decisions cited:

Catchword:

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Case Number: T 1101/12 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 13 October 2016

Appellant: Samsung Electronics Co., Ltd.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted on 15 December 2011 refusing European patent application No. 06124375.4 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman G. Eliasson
Members: T. M. Häusser
T. Bokor

Summary of Facts and Submissions

I. The appeal concerns the decision of the examining division refusing the European patent application No. 06 124 375 for added subject-matter (Article 123(2) EPC).

II. In the decision, additional comments were made in relation to lack of clarity of the claims and lack of inventive step in view of the following documents:

D1: Kang H C et al, Synthesis of epitaxial γ-Al_2O_3 thin films by thermal oxidation of AlN/ sapphire(0001) thin films, Appl. Phys. A 77, 627-632 (2003),

D2: Ishida M et al, Double SOI Structures and Device Applications with Heteroepitaxial Al_2O_3 and Si, Jpn. J. Appl. Phys. 34, 831-835 (1995),

D5: Ishida M et al, Epitaxially Stacked Structures of Si/Al_2O_3/Si for Sensor Materials, Sensors and Actuators A21-A23, 267-270 (1990),

D6: Ko B-C et al, SMaterial and SAW properties of AlN thin film deposited by reactive RF magnetron sputtering method on various substrates, International Symposium on Electrical & Electronics Engineering (2005), Vietnam, Track 1 Electronics & Telecommunications - Section A, pages 1-4.

III. With the letter dated 18 April 2016, the appellant (applicant) requested as sole request the setting aside of the decision under appeal and the grant of a patent on the basis of the following documents:

Description: pages 1-4, 9 filed with letter dated 18 April 2016 and pages 5-8 as originally filed,

Claims: 1-3 as filed with letter dated 18 April 2016,

Drawings: Figs. 1-5, Sheets 1/3-3/3, as originally filed.

IV. The wording of independent claim 1 is as follows:

"1. A method of manufacturing a three-dimensional semiconductor device, comprising:

forming an interlayer insulating layer (111) on a silicon substrate (100) on which silicon substrate a first electronic device is formed;

forming a highly oriented AlN film (112) oriented in a specific direction on the first interlayer insulating layer (111);

forming a highly oriented Al_2O_3 layer (113) on an upper surface of the highly oriented AlN film (112) by oxidizing only the upper surface of the highly oriented AlN film (112);

growing a highly oriented silicon film (114) on the highly oriented Al_2O_3 layer (113); and

forming a second electronic device on the highly oriented silicon film (114)."

V. The appellant argued essentially as follows:

(a) Amendments

The basis of claim 1 was original claim 15 in combination with original claim 1 and page 4, lines 1-8, page 6, line 27, and page 8, lines 8-10 of the original description.

(b) Clarity

By omitting from the amended claims the crystalline orientations, the objection as to lack of clarity mentioned in the decision had been overcome. Moreover, by omitting "is repeated" in claim 3 it is clarified that the steps of claim 3 are only carried out once.

(c) Inventive step

Document D1 related to a Si on insulator (SOI) device. There was no suggestion of manufacturing a first electronic device on a Si substrate and a further device on an upper Si layer. Document D6 related to a thin film SAW device with AlN and Al_2O_3 deposited on silicon. Again, there was no suggestion of manufacturing multiple electronic devices including a first electronic device on a silicon substrate and a second device formed on a highly oriented silicon film on the AlN and Al_2O_3 layers as claimed. Further, in D6 the Al_2O_3 thin film was formed by RF deposition and not by oxidation of the surface of the AlN. Neither D1 nor D6 was concerned with the same general problem as the invention of manufacturing multilayer semiconductor devices.

The best starting point for assessing inventive step might be document D2 or document D5 since these taught a Si - insulator - Si structure. With this starting point the novel features were the provision of an electronic device on the Si substrate, the formation of an AlN film as well as the formation of the Al_2O_3 film by thermal oxidation. Documents D1 and D6 would not lead the skilled person to the claimed invention from this starting point.

Reasons for the Decision

1. Amendments

1.1 In the decision under appeal the examining division held that the feature of forming a highly oriented AlN film "on an insulating substrate" in former claim 1 had not been disclosed in the application as filed. Moreover, former claims 13 and 15 also lacked a basis because a growth method involving both an insulating and a silicon substrate had not been mentioned in the application as filed (see section 2 of the Reasons of the decision).

1.2 In present claim 1 it is specified that the highly oriented AlN film is formed on an "interlayer insulating layer", which is in turn formed "on a silicon substrate (100) on which silicon substrate a first electronic device is formed". The examining division's objections have therefore been overcome by way of amendment.

Indeed, claim 1 is based on claims 1, 2 and 15 as originally filed and on the description and drawings as originally filed (paragraph bridging pages 2 and 3; page 4, lines 4-5; page 6, lines 26-27; Figures 3B and 5).

Dependent claims 2 and 3 are based on original claims 16 and 17, respectively. The description has been brought into conformity with the amended claims and supplemented with an indication of the relevant content of the prior art without extending beyond the content of the application as filed.

Accordingly, the board is satisfied that the amendments comply with the requirements of Article 123(2) EPC.

2. Clarity

The decision under appeal contains additional comments concerning lack of clarity of former claims 1 and 4. In particular, the examining division expressed the opinion that former claim 1 lacked an essential feature leading to the claimed <001> direction of the Al_2O_3 layer orientation. Furthermore, this claimed orientation as well as the orientation of the AlN film as specified in former claim 4 (<002> direction) were ambiguous (see section A of the Additional Comments of the decision).

These objections are no longer relevant, since in the present claims no reference is made to the crystal orientations of the Al_2O_3 layer or the AlN film. The claims are considered to meet the requirements of Article 84 EPC 1973.

3. Inventive step

3.1 Closest state of the art

3.1.1 In the decision under appeal the examining division expressed the view that the subject-matter of former claims 1 and 13, if amended to satisfy the requirements of Article 123(2) EPC, would lack inventive step over the combination of documents D1 and D6 (see section B of the Additional Comments of the decision). Former claim 13 corresponds largely to present claim 1.

3.1.2 Document D1 is concerned with the synthesis of epitaxial γ-Al_2O_3 thin films by thermal oxidation of AlN films deposited on single-crystal sapphire substrates and document D6 relates to the deposition of an AlN

film for surface acoustic wave (SAW) filter applications on various substrates such as sapphire, silicon, Si_3N_4/Si and Al_2O_3/Si. Neither of these documents is thus conceived for the same purpose as the claimed invention, namely for providing a method of manufacturing a three-dimensional semiconductor device with an electronic device on a silicon layer.

On the other hand, both documents D2 and D5 are concerned with this purpose. Moreover, document D5 has the most relevant technical features in common with the claimed invention, as detailed below. This document is therefore regarded as the closest state of the art.

3.2 Distinguishing features

Document D5 discloses (see D5, page 267, right-hand column, second paragraph; page 269, left-hand column, first paragraph) a method of manufacturing epitaxially stacked structures of $Si/Al_2O_3/Si$ for sensor applications. The Al_2O_3 films are grown epitaxially on a Si substrates by chemical vapour deposition or gas-source molecular beam epitaxy and then silicon epitaxial films are grown on the Al_2O_3/Si substrates. On the resulting $Si/Al_2O_3/Si$ structures, field effect transistors are fabricated in order to characterize the epitaxial $Si/Al_2O_3/Si$ structures.

Using the wording of claim 1 document D1 discloses therefore a method of manufacturing a three-dimensional semiconductor device, comprising:

forming an interlayer insulating layer (Al_2O_3 film) on a silicon substrate;

growing a highly oriented silicon film on the highly oriented Al_2O_3 layer (Al_2O_3 film); and

forming a second electronic device (field effect transistor) on the highly oriented silicon film.

The subject-matter of claim 1 differs from the manufacturing method of document D5 in comprising the following features:

(a) a first electronic device being formed on the silicon substrate,

(b) forming a highly oriented AlN film oriented in a specific direction on the first interlayer insulating layer, and

(c) forming a highly oriented Al_2O_3 layer on an upper surface of the highly oriented AlN film by oxidizing only the upper surface of the highly oriented AlN film.

3.3 Objective technical problem

3.3.1 In the decision under appeal the examining division expressed the opinion that the objective technical problem was to obtain a device quality silicon-on-insulator layer (see section B.1.3 of the Additional Comments of the decision).

3.3.2 The board observes that it is foreseen in the closest state of the art document D5 to epitaxially grow the silicon film on the Al_2O_3 film thus achieving a device quality silicon-on-insulator layer. Indeed, as pointed out above, it is envisaged in document D5 to fabricate field effect transistors on the silicon films. Therefore, the problem as formulated by the examining division has already been solved according to the manufacturing method of D5.

3.3.3 The advantage of forming a buffer layer formed of aluminum nitrate (AlN) followed by oxidation to form an

alumina (Al_2O_3) layer is to grow a highly oriented silicon film on any suitable type of insulating layer (see the description of the application, page 5, lines 17-23). The effect of features (b) and (c) is therefore to render the manufacturing process more flexible. Furthermore, feature (a) allows for manufacturing a highly integrated semiconductor device.

The objective technical problem is therefore to achieve high flexibility when manufacturing a highly integrated semiconductor device.

3.4 Obviousness

3.4.1 As pointed out above, the examining division was of the opinion that documents D1 and D6 were prejudicial to inventive step of former claim 13.

However, the board notes that the skilled person would not consider either of these documents when attempting to solve the posed technical problem, since the documents are not concerned with manufacturing electronic devices on silicon.

3.4.2 Moreover, even if the skilled person were to consider documents D1 and D6 he would not be led to the claimed subject-matter.

In particular, the combination of features of documents D5 and D1 could merely lead the skilled person to manufacturing a device having the same structure as that of document D5, where the Al_2O_3 film is fabricated by oxidizing an AlN layer deposited on the silicon substrate, such oxidation being known from document D1. However, the stated combination of features could not lead the skilled person to forming on an insulating

layer an AlN layer, whose upper surface is oxidized to form an Al_2O_3 layer (features (a), (b)) or to forming an electronic device on the silicon substrate (feature (c)).

Moreover, document D6 discloses the manufacture of a structure (AlN/Al_2O_3/Si) having a different arrangement of layers than the structure resulting from the claimed manufacturing method (Si/Al_2O_3/AlN/insulating layer/Si) and hence cannot lead the skilled person to the claimed invention.

3.4.3 In view of the above the board concludes that the subject-matter of claim 1 involves an inventive step. Claims 2 to 3 are dependent on claim 1. Accordingly, the subject-matter of claims 1 to 3 involves an inventive step (Article 52(1) EPC and Article 56 EPC 1973).

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 first instance with the order to grant a patent with the following documents:

   Description: pages 1-4, 9 filed with letter dated 18 April 2016, pages 5-8 as originally filed,

   Claims: 1-3 as filed with letter dated 18 April 2016,

   Drawings: Figs. 1-5, Sheets 1/3-3/3 as originally filed.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated