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D E C I S I O N
of 6 February 2004

Case Number: T 1163/01 - 3.4.3

Application Number: 97310536.4

Publication Number: 0851473

IPC: H01L 21/3205

Language of the proceedings: EN

Title of invention:
Method of making a layer with high dielectric K, gate and capacitor insulator layer and device

Applicant:
LUCENT TECHNOLOGIES INC.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 84, 56

Keyword:
"Clarity (denied) - process features in a device claim"
"Inventive step (denied)"

Decisions cited:
-

Catchword:
-

Case Number: T 1163/01 **-** 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 6 February 2004

Appellant:	LUCENT TECHNOLOGIES INC. 600 Mountain Avenue Murray Hill, New Jersey 07974-0636 (US)
Representative:	Williams, David John Page White & Farrer 54 Doughty Street London WC1N 2LS (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted 3 May 2001 refusing European application No. 97310536.4 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman:	R. K. Shukla
Members:	V. L. P. Frank
	J. P. B. Seitz

Summary of Facts and Submissions

I. The appeal lies from the decision of the Examining Division dated 3 May 2001 refusing the European patent application No. 97 310 536.4. The grounds for the refusal were *inter alia* that the independent device claim lacked clarity contrary to the requirement of Article 84 EPC and that the subject-matter of the independent method claim did not involve an inventive step within the meaning of Article 56 EPC.

The following document was cited in the decision in respect of the issue of inventive step:

D3: EP-A-0 575 650

II. The appellant (applicant) lodged an appeal against the above decision on 3 July 2001, paying the appeal fee the same day. The statement setting out the grounds of appeal was filed on 13 September 2001.

III. The appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of claims 1 to 8 according to the request filed with the letter of 5 December 2000 on which the decision of the Examining Division was based.

The wording of the independent claims is as follows (emphasis added by the Board):

"1. A method of making an integrated circuit fabrication having an oxidizable layer (2) with a surface with a grown oxide layer (3 or 14), including the step of:

depositing a high-k dielectric layer (4 or 15) on the grown oxide layer;
depositing an oxide layer (5 or 16) on the high-k dielectric layer;
forming a conductive layer (6 or 17) over the oxide layer;
characterized by:
the step of densifying the deposited oxide layer (5 or 16); and
the step of forming the grown oxide layer (3 or 14) by thermal oxidation."

"5. An integrated circuit having a oxidizable layer (2) with a surface;
characterized in that:
a high-k dielectric (4 or 15) on a **thermally grown oxide** layer (3 or 14);
a **deposited densified oxide** layer (5 or 16) on the high-k layer; and
a contact layer (6 or 17) in contact with the **deposited oxide** layer (5 or 16)."

IV. In response to a communication of the Board under Article 11(1) RPBA accompanying the summons to oral proceedings the appellant submitted a declaration made by Mr Isik C. Kiziyalli, one of the inventors of the application in suit, and document

D4: 'Silicon Processing for the VLSI Era', Volume I: 'Process Technology' by S. Wolf and R. N. Tauber, Lattice Press, 1 September 1986, pages 182 to 195 and 198 to 211.

V. At the oral proceedings before the Board held on 6 February 2004 the appellant was not represented as announced in his letter dated 29 January 2004.

VI. In the decision under appeal the Examining Division argued that the independent device claim 5 was not clear as required by Article 84 EPC, since although directed to an integrated circuit device it specified that one oxide layer is thermally grown and the other deposited. However, it is not possible in a finished circuit to ascertain how the oxide layers were formed. Moreover, the specification in claim 5 that the deposited layer is densified is not clear, since it cannot be ascertained whether the deposited oxide layer has been densified or whether it had already such density on deposition.

The Examining Division argued further that the method according to claim 1 differed from the method disclosed in document D3 only in that the oxide layer in contact with the substrate was thermally grown instead of being formed via a CVD process. However, growing an oxide layer by thermal oxidation was a simpler process than a CVD process. The skilled person would, therefore, select the thermal oxidation process when the circumstances allowed it without an inventive step being involved.

VII. The arguments of the appellant in favour of inventive step can be summarized as follows:

– The declaration of Mr Kiziyalli and the disclosure of document D4 provide evidence that the physical properties of a deposited oxide layer and a thermally grown oxide layer are different irrespective of the process conditions employed during the thermal growth process. They also show that a deposited densified layer can be differentiated from a deposited oxide layer without any densification.

– The use of a thermally grown oxide layer adjacent to the substrate is not an arbitrary choice, since in paragraph 6 of the declaration of Mr Kiziyalli the technical effects achieved by the use of a thermally grown oxide layer are clearly established. It is submitted, moreover, that document D3 leads away from the present invention, since it is the aim of this document to provide a low temperature oxide deposition process. A thermal growth of the oxide layer would result in significant redistribution of the dopants in the underlying transistors, since high temperatures are necessarily involved in such a process. A person skilled in the art would, for these reasons, not be motivated to replace the low temperature deposition process disclosed in document D3 with a method involving thermal growth of the oxide layer as in the application in suit.

Reasons for the Decision

1. The appeal is admissible.

2. *Clarity - Claim 5*

2.1 In its decision the Examining Division argued that the process features *'thermally grown'* oxide layer and *'deposited'* oxide layer used in the device claim 5 rendered the latter unclear, since it was not possible to distinguish between these two types of oxides layers. Moreover, the expression *'deposited densified oxide layer'* in the claim was found to be lacking clarity, since it could not be ascertained in the finished device whether it had already this density on deposition (see point 2 of the 'Grounds for the Decision').

2.2 The appellant has submitted the Declaration of Mr Kiziyalli, an expert in the field and one of the inventors of the application in suit, and document D4 to show that a *thermally grown* oxide layer has different physical properties from a *deposited* oxide layer irrespective of the process conditions employed in the thermal growth process. These documents provide, according to the appellant's submissions, evidence that a deposited *densified* oxide layer can be differentiated from a deposited oxide layer in an integrated circuit.

2.3 In his declaration, Mr Kiziyalli affirmed that:

(i) CVD (chemical vapour deposition) silicon dioxide is an amorphous structure of SiO_x, where x is not 2. Depending on the deposition conditions, the

CVD silicon dioxide may have lower density and different stoichiometry from thermal silicon dioxide, causing difference in their respective mechanical and electrical film properties (such as index of refraction, etch rates, stress, dielectric constant and electric field breakdown strength). While deposition at high temperatures or the use of a separate high temperature post-deposition anneal step (referred to as densification), attempts to make the properties of the CVD silicon dioxide film approach those of the thermally grown oxide layer, the properties of the two different layers never align with one another and therefore always remain different (cf. point 6 of the declaration).

(ii) The thermally grown oxide layer exhibits more uniform thickness and composition, lower particulate and chemical contamination, better adhesion to the substrate, better integrity for higher dielectric breakdown and lower pinhole density. Additionally, the thermally grown oxide layer exhibits lower interface trap states than the CVD deposited counterpart (ibid).

(iii) Mechanical density measurements could be employed to differentiate a deposited layer from a densified deposited layer. Similarly, an exposed edge of each of the different layers could be subjected to selective etch, which would decorate each of the layers differently. This difference could be observed by SEM or TEM devices. Thus, the difference in etch rate of the different layers would further differentiate the two dissimilar layers. On the electrical foot, one could perform gate oxide current leakage tests on the different layers to differentiate them. Other mechanical, chemical and electrical tests might also be used (cf. point 8 of the declaration).

2.4 The Board notes that the declaration by Mr Kiziyalli relates exclusively to Si oxide layers. Similarly, document D4 is concerned with the processing of silicon for integrated circuits. Claim 5 is, however, not limited to a silicon oxide layer, but refers to an oxide layer in general. The description of the application in suit, moreover, specifies that 'while silicon is described as the material type for the substrate and other layers, it is understood that other materials may be used, such as GaAs, InP, etc.' (cf. column 4, lines 6 to 8 of the published application). There is, therefore, no doubt that several different materials fall within the scope of claim 5 as long as they form an oxide and are suitable for forming integrated circuits. The evidence provided by the appellant, in the Board's view, thus does not clearly establish that any thermally grown oxide layer and not only thermally grown silicon oxide layers, can be distinguished from a deposited oxide layer.

2.5 Moreover, in case of silicon oxide, the submitted evidence does not show conclusively that a thermally grown silicon oxide layer can be distinguished from a deposited silicon oxide layer under all circumstances. The declaration of Mr Kiziyalli states that electrical and mechanical measurements can be employed to distinguish both kinds of layers. The declaration, however, does not specify how this can be achieved. In the declaration neither results of different tests for thermally grown and deposited silicon oxide layers allowing the distinction to be made nor an indication of the tests that should be made depending on the possible deposition techniques of the oxide layer are provided. A general reference to document D4, which consists of 28 pages, without providing any specific reference to the text locations or tables on which the author of the declaration relies, does not allow any conclusions to be drawn regarding the properties of the thermally grown silicon oxide layer distinguishing it from the deposited silicon oxide layer.

2.6 With respect to the possibility of distinguishing a *densified* deposited oxide layer from a deposited oxide layer, Mr Kiziyalli suggests to compare the results of mechanical, chemical and electrical measurements performed on the different layers. The Boards concurs with the appellant that a person skilled in the art is able to distinguish a deposited oxide layer which has been densified from the same deposited oxide layer which has not been subjected to a densification step, by comparing the results obtained on both layers.

This is, however, not the issue under the present circumstances. For the independent device claim to be clear, the feature that the oxide layer has been densified has to be recognizable in the device and, consequently, in the layer itself. The possibility of making a comparison between the properties of a deposited layer and a *densified* deposited layer is not available in the finished integrated circuit of the claim. The appellant has, however, failed to show that a *densified* deposited layer has a specific property or combination of properties that allows it to be distinguished from a deposited layer, as the properties of a deposited layer, and in particular its density, are very different depending on the particular deposition technique employed (cf. D8, page 183, Table 2 and second paragraph, last sentence).

2.7 For these reasons, in the judgment of the Board, claim 5 is not clear contrary to the requirement of Article 84 EPC.

3. The objection of lack of clarity of the independent product claim 5 is in itself sufficient for refusing the application in suit. The Board, however, considers useful a discussion on inventive step of the subject-matter of the independent method claim 1, since this issue was also decided in the decision of the Examining Division.

4. *Inventive step - Claim 1*

4.1 Document D3 discloses a method of forming a capacitor insulating film consisting of a triple layer of a lower CVD silicon dioxide film 20a, a tantalum oxide film 20b and an upper CVD silicon dioxide film 20c. A polysilicon film 18 is provided as the upper contact film of the capacitor. The whole triple layer insulating film is densified by the exposure to ultraviolet light and oxygen or ozone gas (cf. column 22, lines 49 to 53; column 23, lines 26 to 30; column 24, line 46 to column 25, line 2; Figures 9(d) and 10).

It is disclosed in document D3 that the reason for employing a low temperature CVD deposition process for forming the silicon dioxide layers is to avoid temperatures above 450°C which deteriorate the contact characteristics between an Al film and the Si substrate (cf. column 2, lines 16 to 25).

4.2 The method according to claim 1 differs therefore from the method disclosed in document D3 in that the oxide layer in contact with the substrate is formed by thermal oxidation of the substrate.

4.3 According to the application in suit the provision of a thermally grown oxide layer reduces the strain between the high-k dielectric layer and the underlying silicon substrate and provides a good interface with the silicon, reducing undesired surface states in the silicon (cf. column 2, lines 53 to 57 of the published application).

The objective technical problem addressed by the application when considering document D3 as the closest state of the art is, therefore, to improve the electrical and physical properties of the triple layer capacitor disclosed in document D3.

4.4 As explained in Mr Kiziyalli's declaration a thermally grown silicon dioxide layer has improved properties with respect to an oxide layer deposited by a CVD process (cf. point 2.3 (ii) above).

This fact, however, was already known by a person skilled in the art at the priority date of the application in suit. Document D4 is part of the general knowledge of the person skilled in the art of fabricating integrated circuits. It discloses on page 187, last paragraph, that CVD silicon dioxide has a higher density of interface states and poorer interface quality than thermally grown silicon dioxide and is, therefore, mainly used as a temporary structure if used in contact with single crystal silicon.

It follows therefore, that the skilled person would use a thermally grown silicon dioxide layer in contact with the silicon substrate whenever the circumstances allow it, since it improves the overall electrical and mechanical properties of the device. The circumstances disclosed in document D3 do not permit the use of the high temperatures required for growing a silicon dioxide layer, as this would damage the other structures present in the integrated circuit. However, a skilled person would choose a thermally grown oxide layer if no detrimental effects are produced in the integrated circuit by such high temperatures.

The application, however, does not disclose any special measures that allow the use of a thermally grown oxide under the circumstance disclosed in document D3, ie avoiding damage to the underlying components by the high temperature treatment required for growing the oxide layer. The application in suit, furthermore, does not disclose any unexpected effects that are related to the use of a thermally grown oxide layer.

4.5 For these reasons, it is the judgment of the Board that the subject-matter of claim 1 does not involve an inventive step in the sense of Article 56 EPC.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

D. Meyfarth R. K. Shukla