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Datasheet for the decision of 17 October 2008

Case Number: T 0922/06 - 3.4.03

Application Number: 99933164.8

Publication Number: 1195800

IPC: H01L 21/3205

Language of the proceedings: EN

Title of invention:
Device and method for evaluation reliability of metallic interconnection and recorded medium on which evaluation of reliability of metallic interconnection is recorded

Applicant:
Hirosaki University

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 123(2)

Keyword:
"Added subject-matter (yes)"

Decisions cited:
-

Catchword:
-

Case Number: T 0922/06 - 3.4.03

DECISION
of the Technical Board of Appeal 3.4.03
of 17 October 2008

Appellant:	Hirosaki University 1, Bunkyo-cho Hirosaki-shi Aomori 036-8560 (JP)
Representative:	Hofer, Dorothea Prüfer & Partner GbR Patentanwälte Sohnckestrasse 12 D-81479 München (DE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted 16 January 2006 refusing European application No. 99933164.8 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman:	R. Q. Bekkering
Members:	V. L. P. Frank T. Bokor

Summary of Facts and Submissions

I. This is an appeal from the refusal of European patent application 99 933 164 for containing subject-matter extending beyond the content of the application as filed (Article 123(2) EPC).

II. The appellant applicant requested that the decision under appeal be set aside and that a patent be granted on the basis of claims 1 to 4 filed with the letter of 17 September 2008 (main request), or alternatively on the basis of claims 1 to 3 filed during the oral proceedings (1st auxiliary request).

III. Claim 1 of the main request reads:

> "A method using a suitably programmed computer system for evaluating reliability of a metal interconnect characterized by comprising
> a first step of dividing a metal interconnect into numerical elements;
> a second step for finding electric current density and temperature distribution of a metal interconnect using numerical analysis methods;
> a third step for calculating the atomic flux divergence (AFD_{gen}) of each numerical element using said current density and temperature distributions found and using an identical model of the microstructure of the metal interconnect for each numerical element, as well as material property constants of an interconnect material;
> a fourth step for finding the reduction in volume of each numerical element in each calculation step; and

> a fifth step for finding the change in thickness of each numerical element;
> wherein processing is performed by repeating the second to fifth step until reaching the state that numerical elements whose thickness becomes zero and/or numerical elements having a temperature exceeding the melting point of the material thereof occupy the width of an interconnect in order to estimate interconnect lifetime and failure location."

Claim 1 of the auxiliary request reads as follows (the differences with respect to claim 1 of the main request have been marked by the board):

> "A method using a suitably programmed computer system for evaluating reliability of a metal interconnect characterized by comprising
> a first step of dividing a metal interconnect into numerical elements;
> a second step for finding electric current density and temperature distribution of a metal interconnect using numerical analysis methods;
> a third step for calculating the atomic flux divergence (AFD_{gen}) of each numerical element using said current density and temperature distributions found and using a~~n identical~~ model of the microstructure **including only one triple point composed by three crystal grain boundaries** of the **polycrystalline** metal interconnect for each numerical element, as well as material property constants of an interconnect material;

a fourth step for finding the reduction in volume of each numerical element in each calculation step; and

a fifth step for finding the change in thickness of each numerical element;

a sixth step of converting the pattern of numerical elements such that it includes exclusive elements, wherein the pitch of the exclusive elements corresponds to the average size of the crystal grains and the effective width of the exclusive elements is determined based on SEM observations of straight interconnect lines,

wherein processing is performed by repeating the second to ~~fifth~~ **sixth** step until reaching the state that numerical elements whose thickness becomes zero and/or numerical elements having a temperature exceeding the melting point of the material thereof occupy the width of an interconnect in order to estimate interconnect lifetime and failure location."

IV. The appellant applicant argued essentially as follows:

- Though in figures 4 and 15 of the application the shape and size of the numerical elements may change, the micro structural model used throughout the interconnect is the same irrespective of the position within the metal interconnect.

- Figure 2 shows identical hexagonal grains as micro structural model. The position that the rectangles have with respect to the individual grains, may differ. However, this has nothing to do with the fact that throughout the whole interconnect the grain structure does not change. The micro structural model has nothing to do with the size and shape of the numerical elements.

- The same model of the micro structure is applied to all elements of the interconnect, even to edge elements of the interconnect. It is not necessary to consider a different model of the micro structure for the edge of the interconnect. The inventors found that the simulation of the invention was able to obtain the results described in figures 12 and 13 (polycrystalline interconnects) and figures 24 to 26 (bamboo interconnects). The edges are not so important in the present simulation method, because no current is flowing across the edges.

- Figure 2 shows the micro structural model that is identical for each element. In each element there is a triple point formed by three crystal grain boundaries and it is this model that is used for calculating the atomic flux divergence in an interconnect (AFD_{gen}) as explained on page 17 and in the flow chart of figure 3. This model allows predicting the void distribution and the location of the failures after a given time has passed. In order to further predict the lifetime of the interconnect it is necessary to convert the pattern of void formation into slit-like voids along the crystal boundaries. To this effect exclusive elements for the configuration of slit-like voids are arranged as shown in figure 4 and explained on page 18.

Reasons for the Decision

1. The appeal is admissible.

2. *Main request*

2.1 Claim 1 of this request is directed to a method for evaluating the reliability of a metal interconnect comprising five steps. These steps are repeated until the condition specified in the last paragraph of the claim is fulfilled, ie that the width of the interconnect is occupied by numerical elements having a zero thickness or having a temperature exceeding the melting point of the interconnect material.

In a first step the interconnect is divided into numerical elements. The electric current density and temperature distribution is then evaluated using numerical analysis in the second step. The third step calculates the atomic flux divergence (AFD_{gen}) using an identical model of the microstructure of the metal interconnect for each numerical element, as well as material property constants of the interconnect material. The volume reduction of each numerical element is found in the fourth step using the calculated AFD_{gen} and the volume reduction is transformed in the fifth step to a change in thickness of each numerical element (page 17, lines 2 to 18, page 22, line 10 to page 23, line 3, Figure 3).

The second to fifth steps are repeated until the whole width of the interconnect is occupied by numerical elements with zero thickness or having a temperature exceeding the melting temperature of the material (page 18, line 1 to page 19, line 1, page 23, line 3 to line 11).

2.2 Claim 1 requires that an identical model of the microstructure of the metal interconnect be used for each numerical element. For polycrystalline interconnects this model consists of one triple point formed by three crystal grain boundaries (page 9, lines 5 to 13; Figure 2).

2.3 The description discloses that the procedure based on the repetition of the second to fifth steps allows to predict the void distribution after a certain amount of time has passed, as well as the location of failures in the interconnect. However, in order to predict its lifetime, it is necessary to consider the morphology of voids in a polycrystalline interconnect, ie that slit like voids selectively grow along the crystal grain boundaries extending through the width of the interconnect. Therefore, the pattern of void formation is converted into a pattern of slit-like void formation along the crystal boundaries by arranging exclusive elements for the configuration of slit-like voids in the numerical element mesh of the interconnect (page 18, lines 1 to 15, Figure 4).

2.4 It follows that for polycrystalline interconnects two different kinds of numerical elements are used in the method, one comprising a triple point (which is used through the second to fifth step) and another extending along the crystal grain boundaries (which is used for evaluating the failure condition of the interconnect). The application as filed does not disclose however, that the same model of the microstructure is used for these two kinds of numerical elements contrary to what is now specified in claim 1, namely that *an identical model of the microstructure of the metal interconnect* is used *for each numerical element*.

2.5 The board judges therefore that claim 1 of the main request contains subject-matter which extends beyond the content of the application as filed (Article 123(2) EPC).

3. *Auxiliary request*

3.1 Claim 1 of this request comprises in addition to the features of claim 1 of the main request a sixth step in which the pattern of numerical elements is converted to include exclusive elements. The pitch of the exclusive elements corresponds to the average size of the crystal grains and the effective width of the exclusive elements is determined based on SEM observation of straight interconnect lines.

3.2 The description discloses that it is the pitch of the slits which is determined by the average size of the crystal grains and that it is the width of the slits which is one of the material property constants of the interconnect material (page 18, lines 17 to 19). How the slits relate to the exclusive elements is however not disclosed in the application, in particular it is not disclosed whether slit-like voids occur in every exclusive element and, consequently, if their pitch is the same. Although on page 18 it is stated that the exclusive elements for the configuration of slit-like voids are arranged as shown in Figure 4, it is not possible to discern in this figure which are the exclusive elements and how they are arranged.

It follows that the pitch and the effective width of the exclusive elements as claimed are not directly and unambiguously derivable from the application as filed.

3.3 Moreover, claim 1 specifies *"converting the pattern of numerical elements such that it includes exclusive elements"*. The description however discloses that *"the pattern of void formation is once again converted into a slit-like void formation along the crystal grain boundaries"* and that *"in the generation of element mesh of the interconnect, an exclusive element for the configuration of slit-like voids is arranged as in Fig. 4"* (page 18, lines 10 to 13). The description thus discloses that the whole mesh of numerical elements used for determining the pattern of void formation is converted into a new mesh for determining the slit-like voids which form along the crystal grain boundaries and that by this conversion the exclusive elements are introduced. The conversion disclosed in the description is however not the conversion specified in claim 1 by which the exclusive elements are included into the pre-existing mesh of numerical elements, since the former conversion implies the complete replacement of one mesh by another.

3.4 Furthermore, the application as filed does not disclose that the conversion of the mesh of numerical elements into a mesh comprising the exclusive elements is repeatedly performed until failure of the interconnect, since according to the description only the second to fifth steps are iterated (page 17, lines 2 to 18;

Figure 3). The conversion disclosed in the description is done for predicting the lifetime of the interconnect by evaluating the formation of slit-like voids along the crystal grain boundaries (page 18, lines 1 to 15). It is, however, not directly and unambiguously derivable from the application as filed that this conversion is repeated as specified in the claim.

3.5 The board judges, for these reasons, that claim 1 of the auxiliary request does not fulfil the requirements of Article 123(2) EPC.

Order

For these reasons it is decided that:

The appeal is dismissed.

Registrar	Chair
S. Sánchez Chiquero	R. Q. Bekkering