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DECISION
of 14 December 2000

Case Number: T 0946/95 - 3.4.3

Application Number: 91107938.2

Publication Number: 0461414

IPC: H01L 21/90

Language of the proceedings: EN

Title of invention:
Method of cutting interconnection pattern with laser and apparatus thereof

Applicant:
Hitachi, Ltd.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 52(1), 56

Keyword:
"Inventive step (no - absence of synergy between different features)"

Decisions cited:
-

Catchword:
-

Case Number: T 0946/95 - 3.4.3

DECISION
of the Technical Board of Appeal 3.4.3
of 14 December 2000

Appellant:

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Decision under appeal:

Decision of the Examining Division of the European Patent Office posted 23 May 1995 refusing European patent application No. 91 107 938.2 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: R. K. Shukla
Members: E. Wolff
M. J. Vogel

Summary of Facts and Submissions

I. The appeal lies against the decision of the examining division, dated 23 May 1995, to refuse European patent application No. 91 107 938.2 for lack of an inventive step, having regard to the disclosure in the following prior documents:

D1: IEEE Journal of Solid-State Circuits, vol. SC-16, No. 5, October 1981, pages 506 to 514: "Laser programmable redundancy and yield improvement in a 64K DRAM", R.T. Smith et al.

D3: Annals of the CIRP, vol. 28/1, 1979, pages 113 to 115,

D4: VLSI Technology, S.M. Sze, McGraw-Hill, 1984, pages 250 to 253.

The following prior art document was cited by the examining division during examination proceedings:

D2: EP-A-0 281 086

II. The notice of appeal was filed on 24 July 1995, requesting that the decision of the examining division be set aside. The appeal fee was paid on the same day. The statement setting out the grounds of appeal was filed on 2 October 1995.

Oral proceedings took place on 14 December 2000. During the oral proceedings the appellant filed a new request for the grant of a patent based on the following documents:

Claims: 1 to 5 filed during the oral proceedings on 14 December 2000;

Description: pages 1 to 6 filed on 23 November 2000;
pages 7 to 11 filed on 2 October 1995;

Drawings: sheets 1/3 to 3/3 as originally filed on 16 May 1991.

This new request replaced all previous requests.

III. Claim 1 of the request reads as follows:

"1. Method of cutting an interconnection pattern formed on a semiconductor substrate by a laser beam (2), comprising the steps of

- aligning said laser beam (2) with the portion to be cut of the interconnection pattern (34b) and

- cutting said interconnection pattern (34b) by illuminating and evaporating said portion of the interconnection pattern (34b) with the laser beam (2),

characterized in that

- the laser beam (2) has a pulse duration of 1 ns or less which is smaller than the pulse duration at which the removal occurs and has an energy density of 10^6 to 10^9 W/cm^2, and

- the laser beam (2) is shaped by a transmission type liquid crystal mask (4) into a desired form corresponding to the width of the portion (35) to be cut of the interconnection pattern (34b),

- so that all the laser energy is received by the portion (35) to be cut of the interconnection pattern (34b) and the illumination of the laser pulse is completed before a change on the interconnection pattern (34b) due to the heat phenomenon occurs."

Independent claim 3 of the request relates to an apparatus for cutting an interconnection pattern.

IV. The arguments put forward by the appellant can be summarized as follows:

(i) The invention aims to provide a method of laser-cutting interconnections on semiconductor devices which does not damage material alongside or underneath the connection to be cut.

(ii) The claimed method is based on two main ideas.

The first of these ideas is to apply only the laser energy required to cut the connection. This prevents the laser damaging the material underneath the connection to be cut. The claimed invention puts this idea into practice by employing short pulses of 1 nanosecond or less in duration. Such a short pulse has the effect that the connection begins to heat up only after the pulse has ended. This represents a new mechanism for preventing damaging the material underneath the connection, and this new mechanism is not suggested by the prior art.

The second idea is that all the energy is directed towards melting and vaporising the connection. The claimed invention puts this idea is into practice by employing a mask which confines the laser beam to the area of the connection to be cut. The material outside the connection does not receive any laser radiation capable of damaging it. The mask is a liquid crystal mask and can be configured electronically to match the area or areas where connections are to be cut.

(iii) Of the cited documents, document D1 is taken to represent the closest prior art since it relates to laser programmable redundancy in DRAMs and describes a method of laser-cutting links to replace defective elements in such devices.

(iv) As to the duration of the pulses, in the method described in document D1 a single 50 ns laser pulse is used to cut a connection (page 508, right-hand column, penultimate paragraph). This pulse duration is much longer than duration of the pulses employed in the invention as claimed. There is no indication in document D1 that the duration of a laser pulse may be shorter than the time taken to remove all the material from the severed connection.

Document D3 describes the removal of thin layers of aluminium with long pulses having a duration of 500 ns, and short pulses having a duration between 100 ns and 12 ns. There is no suggestion in document D3 that the pulses could be as short as one nanosecond or less. Nor is there any suggestion in document D3 that the pulse could be of a duration so short that the pulse ends before any heating of the connection occurs.

(v) Concerning the area irradiated by the laser, Figures 5 and 6 of document D1 show the laser beam extending well beyond the width of the connection to be cut. The width of the connection shown in Figure 6 is 3 Fm. The effective laser spot diameter, defined by Figure 5 as being the diameter within which the power density exceeds a certain threshold value, is about 7 to 8 Fm. Document D1 explains that there is a trade-off between nominal spot size and targeting accuracy (page 507, right-hand column). The disclosure in document D1 leads the reader to conclude that the laser spot not only is wider, but must be wider than the connection to be cut. As described, targeting errors of several micrometres may be compensated for (page 509, right-hand column) by a wicking effect (page 509, left-hand column) which concentrates the thermal energy in heavily doped polysilicon forming the connections.

Document D2 relates to printing and hence to a different technical field. The contents of document D2 cannot therefore be relevant to the invention as claimed, in which the laser radiation is confined by a mask to a selected area of the connection to be cut.

Reasons for the Decision

1. The appeal is admissible.

2. Independent claims 1 and 3 have been amended in relation to claims 1 and 10, respectively, as filed. As the subject-matter of claim 1 is not allowable for the reasons which follow, these amendments are not discussed in detail here. The Board has, however, examined these amendments and is satisfied that they comply with the requirement of Article 123(2) EPC.

The only issue to be decided is whether the invention as claimed involves an inventive step.

3. *Inventive step*

3.1 Document D1 discloses that interconnection patterns can be cut by a method which, in common with the invention as claimed, comprises aligning a laser beam with the portion to be cut, and cutting the interconnection pattern by illuminating the portion to be cut with a laser. This makes document D1 the nearest prior art among the cited documents.

3.1.1 Document D1 relates specifically to the use of laser programming to improve yields for 64K DRAMs. The DRAMs described are formed according to 3.5 Fm design rules (page 507, right-hand column, third paragraph). The DRAMS are reprogrammed to replace defective elements by cutting appropriate links with a laser (see page 506, right-hand column, last two paragraphs).

3.1.2 Effective laser spot diameters (ELSD) of both 7-8 Fm and 5 .5Fm are referred to with reference to Figure 5 and Figure 7 respectively (see also page 509, left-hand column, last two lines to right-hand column, end of the paragraph). The beam is expanded and collimated, attenuated as required, and focussed to a small waist on the wafer surface. (page 508, right-hand column, section B, paragraph 1).

3.1.3 It is also foreseen that future laser programming systems should be capable of providing, among others, a range of effective spot sizes and improved targeting accuracy (page 507, right-hand column, penultimate paragraph). For the specific case of 256K DRAMs the effective laser spot size would need to be reduced to 4-5 Fm "because of tighter design rules, including feature width shrinkage and smaller row line pitch" (page 513, Section C)

3.1.4 A single laser pulse is used to cut a link, and the duration of the single pulse is 50 ns. The short duration of the pulse is said to be required to "explode the target with no damage to adjacent and underlying structures. (page 508, right-hand column, section B, paragraph 1).

3.1.5 A CCTV camera is used, together with a minicomputer, to provide both automatic wafer and target die alignment, with the final lens of the laser optics being used as the viewing lens of a CCTV monitoring system (page 508, left-hand column to right-hand column, end of paragraph 1).

3.2 The invention as claimed thus differs from the disclosure in document D1 on account of the following two features:

(a) The laser beam according to the invention has "a pulse duration of 1 ns or less which is smaller than the pulse duration at which the removal occurs and has an energy density of 10^6 to 10^9 W/cm^2 ..." (cf. first paragraph of the characterizing clause of claim 1) "... so that the illumination of the laser pulse is completed before a change on the interconnection pattern (34b) due to the heat phenomenon occurs" (cf. third paragraph, second feature of the characterizing clause of claim 1).

(b) The invention additionally requires the use of a laser beam "shaped by a transmission type liquid crystal mask into a desired form corresponding to the width of the portion (35) to be cut of the interconnection pattern (34b)" (cf. second paragraph of the characterizing clause of claim 1), "so that ... all the laser energy is received by the portion (35) to be cut of the interconnection pattern (34b)" (cf. third paragraph, first feature of the characterizing clause of claim 1).

3.3.2 The features (a) and (b) referred to in paragraph 3.3.1 both serve to confine the energy of the laser beam to the link to be cut. Their common goal is to avoid damage to the material adjoining the link when the range of laser powers employed is widened (see the objects of the invention on page 2, lines 2 to 9 and 10 to 17 of the application as filed). However, despite their common goal, they are independent of each other because they are adjusted independently. The pulse duration determines the period during which energy is supplied to the irradiated area, irrespective of whether or not the beam has been shaped by a mask. The mask, on the other hand, defines the irradiated area, whatever the duration of the laser pulses.

3.3 The description contains nothing that points to a synergy between pulse duration and beam shaping by a mask. In the absence of any synergy between different features of an invention as claimed, the contribution made by each of those features has to be assessed separately when considering whether that invention involves an inventive step. In the present case the pulse duration and the provision of a mask must be so considered.

3.4 With regard to the pulse duration, document D3 describes a systematic investigation into laser-machining aluminium thin film strips with both long and short duration pulses, including the development of a model of the mechanism by which material is removed from the surface (page 114, section 3 "Machining Mechanism").

3.4.1 Concerning the use of short duration pulses for cutting thin film strips of aluminium, one of the aims of the study is "to get a method of cutting aluminum conductors without damaging the under-layers" (page 115, left-hand column, penultimate paragraph).

3.4.2 The authors of document D3 consider long and short duration pulses. Pulses with a duration of 500 ns are classed as being of long duration (page 113, left-hand column, lines 20 to 22). Short duration pulses, that is pulses of less than 100 ns duration (page 115, right-hand column, paragraph 1) were expected, on the basis of the mechanisms discussed in the study, to make damage-less machining possible (page 115, left-hand column, penultimate paragraph). While a further increase in the laser power density would yet again increase the possibility of damage to the underlying material, reducing the pulse duration would once more "give a larger machining power safety margin for damage less cutting of aluminium conductors" (page 115, right-hand column, paragraph 2), as was demonstrated by experiment using a 12 ns dye-laser.

3.4.3 The Board does not find the argument put forward by the appellant, that document D3 does not teach a reduction in the pulse duration below 12 ns, convincing, since the document refers to a repeated reduction in the pulse duration, first to about 100 ns and then to 12 ns in order to avoid damaging the material underneath the aluminium layer. It is therefore the Board's view that, upon reading document D3, the skilled person would be in possession of the general teaching that the remedy against damaging the underlying material on account of laser power density is to shorten the pulse duration of the laser.

3.4.4 The upper limit of 1 ns as claimed for the range of suitable pulse durations is just an order of magnitude less than the 12 ns explicitly referred to in document D3. The pulse durations of the short pulses referred to in document D3 range over approximately an order of magnitude. They vary from about 100 ns to 12 ns, without 12 ns being presented in any way as constituting a lower limit. A further shortening of the pulse duration to 1 ns or less is therefore well within the range of routine experimentation based on the teaching of document D3.

3.4.5 The power densities claimed for the laser pulses lie between 10^6 and 10^9 W/cm^2. Document D3 refers to a threshold power density for vaporising thin film aluminium, P_{vth}, of $1.1x10^7$ W/cm^2, with the experimentally observed threshold power density being $2x10^7$ W/cm^2 (page 11, section 3.1). These values fall within the range of values claimed in claim 1, and there is nothing in the description of the invention which would lead one to conclude that this range or any part of it lies outside the scope of routine adjustments which the skilled person would contemplate.

3.4.6 The appellant put forward the argument (cf. section IV, paragraph (iii) above), that employing short pulses which are 1 nanosecond or less in duration represents a new mechanism for preventing damaging the material underneath the connection. Such a short pulse has, so the argument continues, the effect that the connection begins to heat up only after the pulse has ended. The corresponding feature in the claim, which is that "the illumination of the laser pulse is completed before a change on the interconnection pattern (34b) due to the heat phenomenon occurs" (third paragraph, second feature of the characterizing clause of claim 1) is therefore an additional feature which is neither known from nor suggested by document D3. The Board does not find this argument persuasive. The feature concerned does not constitute another, independent characteristic of the invention; it merely explains the inevitable physical result of shortening the pulses to "a pulse duration of 1 ns or less which is smaller than the pulse duration at which the removal occurs and has an energy density of 10^6 to 10^9 W/cm^2 ..." (first paragraph of the characterizing clause of claim 1) ".

3.4.7 Pulsed lasers with pulse durations as short as a few picoseconds were used at the priority date of the invention in practical semiconductor processing applications such as annealing (as evidenced by document D4, page 252, second paragraph). Against the relevance of document D4, the appellant has argued (statement of grounds, page 4, paragraph 4.1) that the document relates only to annealing, not material ablation techniques, and that the document is therefore not pertinent to the application is suit. The Board does not consider this argument to be persuasive. The relevance of document D4 lies in illustrating that, as a matter of general knowledge at the priority date of the invention, pulsed lasers with pulse durations as short as a few picoseconds were known and had established themselves in practical applications in the field of semiconductor processing. The reported use shows the absence of any technical prejudice, such as on account of lack of reliability, for example, against their practical application in semiconductor manufacturing.

3.4.8 To summarise, document D1 already points towards the use of short pulses as a means of avoiding damage to the underlying structure (page 508, section B paragraph 1). Document D3 explicitly advises shortening the pulse duration if the applied power density poses a risk of causing damage to the underlying layer (page 115, right-hand column, second paragraph). Document D3 discloses power densities which are in the claimed range. At the priority date of the invention, lasers with pulse durations as short as a few picoseconds were known and used in semiconductor manufacturing. In these circumstances, starting from document D1 as the nearest prior art, and given the disclosure in document D3 when applied in the light of the common general knowledge exemplified by document D4, it would in the Board's judgement have been obvious to the skilled person at the priority date of the invention to use lasers with pulse durations as short as 1 ns or less when attempting to solve the problem of widening the laser power output range over which the cutting process could be performed.

3.5 As to the use of a mask, it is known from document D2 that a laser beam can be spatially confined to a desired area, in the case of document D2 an area to be printed, by means of a mask. The mask described consists of an electronically controlled liquid crystal which varies the shape of the beam in accordance with the character to be printed (see document D2, column 1, lines 15 to 19).

3.5.1 The appellant has argued that in document D1 the laser spot not only is wider, but must be wider than the connection to be cut (cf. section IV, paragraph (vii)). The Board does not find this argument persuasive.

Although using an effective spot size which exceeds the width of the connection offers the benefit that some targeting errors can be accommodated (page 509, right-hand column), there is nothing in the description of the cutting process itself which would require the irradiated area to be wider than the connection to be cut. On the contrary, Figure 7 and its associated description on page 509 indicate clearly that with an effective spot diameter of 7-8Fm, together with the phenomenon described as "wicking effect" (page 509, left-hand column), the link is removed over its whole length of 14 Fm.

3.5.2 Given that the function of a transmission mask is to confine the passing light energy to the area defined by the mask, specifying "that ... all the laser energy is received by the portion (35) to be cut of the interconnection pattern (34b)" (cf. third paragraph, first feature of the characterizing clause of claim 1) is merely to state that the mask is shaped such that it prevents laser radiation from reaching the areas it is designed to shield from the radiation.

3.5.3 Starting from document D1, the skilled person addressing the objective problem of implementing better control of the area irradiated by the laser beam, will routinely consider the use of a mask to shield areas which either need not or should not be irradiated. The skilled person is, moreover, taught by document D2 that dynamic control of the exact shape of a laser beam is achievable with the aid of an electronically controlled liquid crystal transmission mask. For these reasons the Board judges it to be obvious to shape the laser beam by a transmission type liquid crystal mask into a desired form corresponding to the width of the portion to be cut of the interconnection pattern.

3.6 It is the Board's judgement, taking into account the stated facts and arguments, that the invention as claimed in claim 1 does not involve an inventive step according to Article 56 EPC.

Order

For these reasons it is decided that:

The appeal is dismissed

The Registrar: The Chairman:

L. Martinuzzi R. K. Shukla