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D E C I S I O N
of 9 September 1998

Case Number: T 0592/95 - 3.4.1

Application Number: 89202084.3

Publication Number: 0349095

IPC: H01L 21/607

Language of the proceedings: EN

Title of invention:
Method of making a metal wire for use in integrated circuits

Applicant:
Hitachi, Ltd.

Opponent:
-

Headword:
Metal wire with a ball/HITACHI

Relevant legal provisions:
EPC Art. 84, 56

Keyword:
"Clarity - yes"
"Product-by-process feature in a product claim"

Decisions cited:
T 0148/87, T 0487/89

Catchword:
-

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 0592/95 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 9 September 1998

Appellant: Hitachi, Ltd.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 1 March 1995 refusing European patent application No. 89 202 084.3 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: G. Davies
Members: R. K. Shukla
G. Assi

Summary of Facts and Submissions

I. European patent application No. 89 202 084.3 relates to a metal wire having a ball at a tip thereof for use in integrated circuits. This application was refused in a decision of the examining division, dated 1 March 1995, on the ground that it did not meet the requirement of Article 84 EPC, since independent claims 1 and 5 forming the basis of the main request filed at the oral proceedings held on 5 July 1994 were not clear. In particular, it was held in the decision under appeal that, the subject-matter of claim 1 belonged to the category of a "product" claim and contained a feature, i.e "the wire having been annealed at a temperature higher than the recrystallisation temperature of the metal material", which was clear only as a part of a process of making the wire and thus rendered the category of claim 1 as a whole unclear. According to the decision, there was a lack of clarity, since a given wire annealed at a temperature above the recrystallisation temperature does not necessarily exhibit a grain size which is distinguishable from a nonannealed wire or a wire annealed at another temperature. In support of the above, the examining division cited excerpts from the following standard text book,

D3: Physical Metallurgy Principles, R.E. Reed-Hill, Van Nostrand Reinhold Co., 1964, pages 179, 194, 195 and 197, Section 7.16 and Figure 7.20.

With regard to method claim 5, it was held in the decision under appeal that, it did not contain all features essential to the performance of the invention.

Moreover, according to the decision under appeal, the subject-matter of claim 1, in so far as it could be understood, did not involve an inventive step having regard to the following prior art documents :

D1: Patent Abstracts of Japan, vol. 6, No. 72 (E-105) [950], 7 May 1982; & JP-A-57 012 531, and

D2: EP-A-0 043 692.

With regard to the auxiliary request filed at the oral proceedings, the decision under appeal contained a statement to the effect that since the applicants in their response, dated 21 November 1994, to the official communication pursuant to Rule 51(4) EPC had expressed their wish to obtain an appealable decision on their main request, the text of the auxiliary request as communicated under Rule 51(4) EPC was not approved by the applicants and was accordingly disregarded under Article 113(2) EPC.

II. The applicants lodged an appeal on 25 April 1995 paying the appeal fee on the same day, and filed with the statement of the grounds of appeal on 4 July 1995, a main request, an auxiliary request and a request for oral proceedings in the event that the main request was to be refused. The applicants also requested that the appeal fee be refunded, on the ground that a procedural violation had been committed by the examining division in failing to give a reasoned written decision after the oral proceedings indicating that the auxiliary request was allowable and giving reasons for the refusal of the main request.

III. In a communication annexed to the summons to the oral proceedings, the Board informed the applicants of its preliminary views that the subject-matter of claim 1 according to the main request was not clear and did not appear to involve an inventive step, that there was no procedural mistake committed by the examining division in the issue of a Rule 51(4) EPC communication in respect of the auxiliary request submitted at the oral proceedings on 5 July 1994, and that the examining division was justified in disregarding the auxiliary request in the decision under appeal under Article 113(2) EPC.

IV. In response, the applicants submitted, *inter alia*, the following documents and requested that they be introduced into the proceedings:

D1': English translation of opening paragraphs of D1 (i.e. JP-A-57 012 531)

D6: Fundamentals of Engineering Materials; P. Thornton and V. Colangelo; Prentice-Hall, Inc; pages 470 to 472 and 162 to 163.

V. At the oral proceedings held on 9 September 1998, the applicants submitted a main request and several auxiliary requests, the main request being as follows:

Claims 1 to 14, and pages 1 to 3, 3a and 4 to 12 as filed at the oral proceedings; and the drawings as originally filed.

The request for the refund of the appeal fee, because of an alleged procedural violation was withdrawn at the beginning of the oral proceedings.

Claim 1 and independent claim 5 of the main request read as follows:

Claim 1

"A metal wire having a ball (7) at a tip thereof for use in integrated circuits, the wire (1) having a diameter of 20 to 100 μm and being an Al wire or a Cu wire and the wire (1) having been annealed at a temperature higher than the recrystallization temperature of the metal material and having a maximum elongation of not more than 60 % at room temperature (20°C), said ball (7) of said metal wire (1) being spherical in shape, having a hardness substantially equal to that of said metal wire (1), and being symmetrical with respect to the axis of said wire, said wire having substantially no local constriction at its tip adjacent to the ball."

Claim 5

"A method of manufacture of a metal wire (1) having a ball (7) at a tip thereof for use in integrated circuits, wherein the ball is formed by melting the tip of a metal wire (1) by means of arc discharge, hydrogen flame, plasma arc or laser beam, said metal wire being an Al wire or a Cu wire, having a diameter of 20 to 100 µm and having been annealed prior to the ball formation at a temperature higher than the recrystallisation temperature of the metal material, wherein the maximum elongation of the wire after annealing is not more than 60% at room temperature (20°), the ball is spherical in shape, has a hardness substantially equal to that of the metal wire and is symmetrical with respect to the axis of the wire, said wire having substantially no local constriction at its tip adjacent to the ball."

VI. The applicants made essentially the following submissions:

Clarity (Article 84 EPC)

Claim 1 clearly relates to a product so that the category of the claim is clear. Also, according to the established case law of the boards of appeal, there may be circumstances, such as in the present case, where it is appropriate to combine product and process features. Mr J. Onuki's statement filed with the letter of 13 August 1993 and photographs A, B, C and D and the accompanying explanation filed with the letter dated 15 January 1993 on a related divisional application No. EP 89202085.0 (Appeal case No. T 340/95), show that there is a clear and discernible difference in the crystal grain size, shape and grain distribution between a ball formed on a wire which had been annealed at a temperature above the recrystallisation temperature, and a ball formed on a wire which had not been so annealed.

Inventive step

There is no suggestion in either D1 or D2 of a product in the form of a wire having a ball at the tip thereof, the wire having been annealed at a temperature higher than the recrystallisation temperature of the metal material, the ball being spherical and having a hardness substantially equal to that of the metal wire. The essential concept of document D1 is annealing after bonding, which is useful for resistance to stress during encapsulation and is unrelated to bonding properties. The method of bonding is irrelevant in this document, so that the document is not concerned with the problems of a uniform ball formation and constriction of the wire adjacent to the ball in a ball bonding method, addressed by the present invention.

Document D2 makes no mention of pre-annealing, and implies that the ball and the metal wire have a different hardness prior to bonding. It is hindsight to suggest that a skilled man would be prompted to anneal a wire, prior to ball bonding from the teaching of these two documents.

Reasons for the Decision

1. The appeal is admissible.

2. The Board is satisfied that there are no objections to the amendments to the claims and the description, under Article 123(2) EPC.

3. *Clarity*

Claim 1 clearly concerns a metal wire, i.e a product, and includes a process step of annealing the wire at a temperature higher than the recrystallization temperature of the metal. The Board agrees with the applicants that the inclusion of the process feature of annealing the wire does not render the category of claim 1 unclear. Moreover, according to the case law of the boards of appeal, it is permissible under Article 84 EPC to combine product and process features in a product claim, where the product cannot be satisfactorily defined other than by reference to the process by which it is formed (see, e.g. T 487/89, dated 17 July 1991; T 148/87, dated 24 November 1989).

In the present case, therefore, it needs to be considered what particular property or parameter of the metal wire the process step of annealing seeks to define in the claim, and whether it is defined clearly so as to comply with the requirement of Article 84 EPC.

In this connection, referring to the "Comments" of Mr J. Onuki, the hand-drawn figures, and the copies of the photomicrographs C and D (see item VI above), it follows that the annealing step in the claim is intended to define the grain size and shape of the crystals and their distribution (see Section B, paragraph 3 of the "Comments"). The question which needs to be answered is, therefore, whether a copper or aluminium wire having a ball at the tip thereof, a diameter as specified in claim 1 and having been annealed at a temperature above the recrystallisation temperature of the material of the wire can be distinguished from such a wire which has not been so annealed, by examination of the crystal grain size, shape and the grain distribution.

In the decision under appeal, the objection of lack of clarity was based on generally known facts, as disclosed in document D3 (page 194 to 195, Section 7.16, first paragraph and page 197, Figure 7.20) i.e. that, the recrystallised grain size immediately at the end of recrystallisation is dependent upon prior cold work and material impurity, and that the subsequent grain growth is dependent upon post recrystallisation annealing conditions. Consequently, it was reasoned in the decision, it followed that a given wire annealed at a temperature above the recrystallisation temperature does not necessarily exhibit a grain size which is distinguishable from a nonannealed material or a material annealed at another temperature.

In connection with the above, as was submitted by the applicants, according to the above-cited text location in Section 7.16, the recrystallised grain size at the end of recrystallisation is in fact the crystal size **before** grain growth proper has had a chance to occur. In the application in suit, annealing is carried out at

a temperature **higher** than the recrystallisation temperature, and thus concerns the final and third stage of annealing, i.e. grain growth, and not the second stage of annealing, i.e. recrystallisation. The graph of Figure 7.18 thus shows a relationship between elongation (prior cold-work) and the grain size at the end of recrystallisation, and not at the end of the grain growth. Moreover, as can be seen from the photocopies (C) and (D) of scanning electron photomicrographs, and the hand-drawn figures, of a copper wire with a ball at the tip thereof before annealing and after annealing at a temperature above the recrystallisation temperature (see item VI above), in the annealed wire the crystal grains are much larger having approximately the size of the wire diameter and are equiaxial, in comparison with the crystal grains in the non-annealed wire, which are fine and elongated along the axis of the wire. The above observation that the crystal grains are equiaxial in the wire annealed at a temperature above the recrystallisation temperature, is consistent with the definition of the recrystallisation temperature given in Document D6 on page 162, section "Recrystallisation", i.e. that, the recrystallisation temperature is the lowest temperature at which stress-free equiaxial grains appear in the microstructure of a cold-worked metal. Furthermore, an examination of the photomicrograph (C) (of the non-annealed wire) reveals that there is a boundary region between a small grain size area in the non-annealed wire portion and a large grain size area in and adjacent to the ball portion caused by annealing during the formation of the ball. Such a boundary region is not present in the photomicrograph (D), since both the annealed wire portion and the ball at the tip thereof have relatively large crystal grains.

Moreover, an aluminium or copper wire having a diameter in the claimed range of 20 μm to 100 μm implies that the wire is highly work-hardened in the as-drawn state, and as can be seen from the graph of Figure 7.18 of document D3, the grain size does not vary appreciably with the amount of deformation for high values of deformation prior to annealing.

For the foregoing reasons, the Board agrees with the applicants that, despite the variation in the degree of deformation of a wire in the as-drawn state on account of the diameter range claimed, it would be possible to distinguish a copper or aluminium wire with a ball at the tip thereof annealed at a temperature higher than the recrystallisation temperature from a non-annealed wire with a ball by an examination of the microstructure of the wire using, e.g. a scanning electron microscope. Consequently, in the Board's judgement, claim 1 clearly defines the subject-matter for which protection is sought in accordance with the requirement of Article 84 EPC.

4. *Inventive step*

4.1 Background of the invention

The invention as described and claimed in the application in suit concerns an aluminium or copper wire having a ball at a tip thereof, for use in integrated circuits, and a method of making such a wire. As discussed in the application in suit, a conventional aluminium wire supplied on a reel in its as-drawn state is highly work-hardened and is bent. As a result, when a ball is formed at its end, the ball is asymmetrical or eccentric with respect to the wire. Moreover, when the ball is formed, not only the ball but the wire portion adjacent to the ball is heated and

subjected to annealing, so that the wire portion adjacent to the ball is softened and is locally constricted. The eccentricity of the ball, according to the application in suit, may cause the bonding portion to project from a bonding pad causing a short circuit. Also, the local constriction and softening of the wire adjacent to the ball may lead to the breakage of the wire or to bending thereof when it is bonded between a semiconductor element and a lead frame, which may lead to a short circuit between the wire and the semiconductor element (see pages 1 to 3 of the application as filed).

The invention as claimed in claims 1 and 5 aims to provide a wire having a ball at its tip which enables a reliable connection to be formed in an integrated circuit, with which there is a low risk of breakage of the wire (see page 3, last full paragraph, of the application as filed).

4.2 Claim 1

According to claim 1, aluminium or copper wire is in the annealed state, the annealing having been carried out at a temperature above the recrystallisation temperature of aluminium or copper. This annealing softens the wire throughout, whereby the wire has substantially the same hardness as the ball. Moreover, the wire has substantially no local constriction at its tip adjacent to the ball. Consequently, the risk of breakage of the wire at the constriction, when it is bonded between an integrated circuit and a lead frame is reduced, and the wire due to the uniform hardness throughout its length forms a smooth loop without a sharp bend or kink adjacent to the ball.

Document D1' discloses ultrasonic bonding of a fine (25 μm diameter), hard aluminium wire to an IC substrate and **subsequent** annealing of the wire by heating it to at least the recrystallisation temperature of aluminium, so as to reduce the hardness of the wire. As a result, the aluminium wire is able to absorb external force generated, e.g. during the resin encapsulation of the IC device, and thus the risk of the breakage of the wire is reduced. The type of bonding, i.e. the ball bonding or wedge bonding, is not relevant for the teaching of the document, and consequently, there is no mention of the problem of the formation of a constriction in the wire adjacent to a ball nor any discussion of the advantages in having the same hardness for the wire and the ball.

Document D2 concerns the formation of a ball on a metal wire for bonding in an IC device (see pages 1 and 2). There is however no mention of the problem of breakage of the wire nor any discussion of advantages of annealing of the wire prior to bonding.

In view of the above, the Board agrees with the applicants that documents D1' and D2 do not suggest annealing of the wire with a view to avoiding formation of a constriction in the wire adjacent to the ball, and thereby reducing the risk of the breakage of the wire, or to enabling the wire to form a smooth loop without a sharp bend adjacent to the ball when bonded between a semiconductor element and a lead frame.

For the foregoing reasons, in the Board's judgement, the subject-matter of claim 1 involves an inventive step within the meaning of Article 56 EPC.

4.3 Claim 5

Independent claim 5 concerns a method of manufacture of a metal wire of aluminium or copper having a ball at a tip thereof, the wire and the ball having the features as set out in claim 1. Claim 5 additionally specifies that the wire is annealed at a temperature higher than the recrystallisation temperature of the metal material **prior** to the formation of the ball. The above considerations in respect of the inventive step of claim 1, therefore apply to claim 5 as well, and the claim, accordingly, involves an inventive step within the meaning of Article 56 EPC.

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 the first instance with the order to grant a patent on the basis of the following documents according to the main request:

Claims 1 to 14, and pages 1 to 3, 3a and 4 to 12 as filed at the oral proceedings; and the drawings as originally filed.

The Registrar: The Chairman:

M. Beer G. Davies