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**Datasheet for the decision
of 30 October 2025**

Case Number: T 1743/23 - 3.4.03

Application Number: 17000294.3

Publication Number: 3211657

IPC: H01L21/02

Language of the proceedings: EN

Title of invention:

METHOD FOR MANUFACTURING DIAMOND SUBSTRATE, DIAMOND SUBSTRATE,
AND FREESTANDING DIAMOND SUBSTRATE

Applicant:

Shin-Etsu Chemical Co., Ltd.
National Institute of Advanced Industrial Science
and Technology
National University Corporation Kanazawa
University

Relevant legal provisions:

EPC Art. 56

Keyword:

Inventive step - (no)



Beschwerdekammern

Boards of Appeal

Chambres de recours

Boards of Appeal of the
European Patent Office
Richard-Reitzner-Allee 8
85540 Haar
GERMANY
Tel. +49 (0)89 2399-0

Case Number: T 1743/23 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 30 October 2025

Appellant:
(Applicant 1)

Shin-Etsu Chemical Co., Ltd.
4-1, Marunouchi 1-chome
Chiyoda-ku
Tokyo 100-0005 (JP)

Appellant:
(Applicant 2)

National Institute of Advanced Industrial Science
and Technology
3-1 Kasumigaseki 1-chome
Chiyoda-ku
Tokyo (JP)

Appellant:
(Applicant 3)

National University Corporation Kanazawa
University
Nu 7, Kakuma-machi
Kanazawa-shi,
Ishikawa 920-1164 (JP)

Representative:

Wibbelmann, Jobst
Wuesthoff & Wuesthoff
Patentanwälte und Rechtsanwalt PartG mbB
Schweigerstrasse 2
81541 München (DE)

Decision under appeal:

**Decision of the Examining Division of the
European Patent Office posted on 25 May 2023
refusing European patent application No.
17000294.3 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman M. Stenger
Members: M. Ley
 E. Mille

Summary of Facts and Submissions

- I. The appeal is against the decision of the examining division refusing European patent application No. 17 000 294 pursuant to Article 97(2) EPC on the ground that there was a lack of inventive step (Article 56 EPC) in view of documents D8 (WO 2015/197632 A1) and D9 (US 2011/081531 A1).
- II. The appellant requests that the decision be set aside and a European patent be granted on the basis of the set of the claims underlying the impugned decision, as a main request, or on the basis of the claims according to the auxiliary requests I or II, filed with the statement setting out the grounds of appeal.

The appellant also submitted the following documents:

- D10 K. Suzuki et al., "Epitaxial Growth of diamond on iridium surfaces", 1998
- D11 S. Yugo et al., "Generation of diamond nuclei by electric field plasma chemical vapor deposition", App. Phys. Lett., vol. 58, 10, 1991

- III. Claim 1 according to all requests has the following wording (board's feature labelling):

A method for manufacturing a diamond substrate, comprising:

(a) a first step of preparing patterned diamond by growing diamond on a surface of a foundation, (a1) the surface being composed of a different kind of material

other than diamond, and (a2) processing the grown diamond to have a patterned shape, (a3) wherein a bottom portion of a pattern gap of the patterned diamond is composed of a different kind of material other than diamond or at least a part of the bottom portion of the pattern gap is pierced through by removing a part of the foundation,

(b) a second step of growing diamond from the patterned diamond prepared in the first step to form the diamond in the pattern gap of the patterned diamond prepared in the first step,

(c) a third step of removing the patterned diamond prepared in the first step to form a patterned diamond composed of the diamond formed in the second step, and

(d) a fourth step of growing diamond from the patterned diamond formed in the third step to form the diamond in a pattern gap of the patterned diamond formed in the third step.

- IV. The appellant mainly argued that the skilled person would not combine documents D8 and D9 without knowledge from the application, as these documents refer to different technologies, see point 3. below.

Reasons for the Decision

1. The invention relates to a method for manufacturing a diamond substrate with a reduced dislocation defect density, see paragraphs [0015] or [0019] of the application, when compared to conventional methods, see paragraphs [0006] to [0015]. These conventional methods

provide a diamond substrate having an etch-pit density by hydrogen plasma treatment, which is a measure of a dislocation defect density, of e.g. approximately 10^5 cm^{-2} , see paragraph [0008], or of 10^8 cm^{-2} , see paragraph [0012].

The method according to the present invention generally has the following steps as shown in Figures 1 and 3 (see reproduction below) of the application:

- a first step of preparing patterned diamond by growing diamond on a surface of a foundation, see Figures 1(A) and 3(A)
- a second step of growing diamond from the patterned diamond prepared in the first step to form the diamond in the pattern gap of the patterned diamond prepared in the first step, see Figures 1(B) and 3(B)
- a third step of removing the patterned diamond prepared in the first step to form a patterned diamond composed of the diamond formed in the second step, see Figures 1(C) and 3(C)
- a fourth step of growing diamond from the patterned diamond formed in the third step to form the diamond in a pattern gap of the patterned diamond formed in the third step, see Figure 1(D) and 3(D).

According to the application, the foundation or growth substrate in this process can be diamond (see e.g. Figure 1) or a material different from diamond (see e.g. Figure 3), see also paragraphs [0022] to [0025], [0065] to [0071], [0074] and [0075] of the application.

According to paragraphs [0077], [0078] or [0095] the pattern of Figures 1(A) or 3(A) can be of any shape.

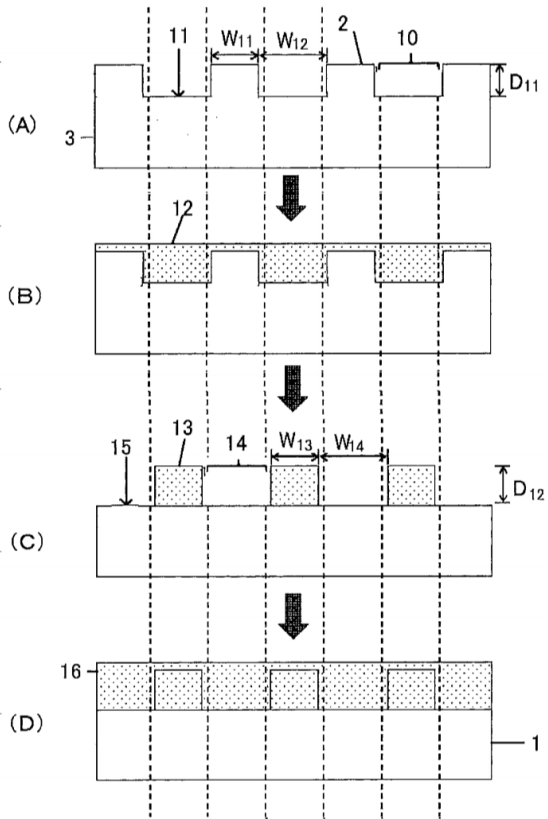


Figure 1

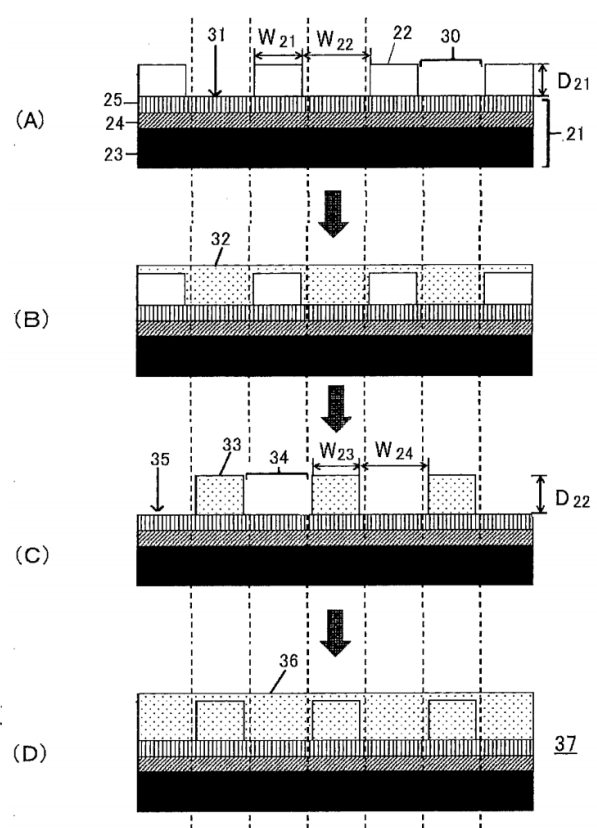


Figure 3

Claim 1 according to all requests is limited by virtue of features (a1) and (a3) to the case of a foundation or substrate made of a material different from diamond. In a further variation (not shown in the Figures), a part of the bottom portion of the pattern gap is pierced through by removing a part of the foundation (whose surface is composed of a different kind of material other than diamond), see feature (a3), second alternative.

2. The examining division focused on the first alternative according to feature (a3), as shown in Figure 3 of the application, and decided that the subject-matter of claims 1 and 14 of the then only request lacked an inventive step in view of document D8 in combination with document D9 or in view of document D9 in combination with document D8.

3. The appellant argued that, although both D8 and D9 referred to a method of manufacturing a diamond substrate, they were not equally valid springboards. D8 concerned homoepitaxial growth of diamond substrates on diamond material, see abstract. As heteroepitaxial growth was not disclosed in D8, D9 was to be taken as the closest prior art.

Document D9 described the heteroepitaxial growth of diamond on a different material other than diamond. D9 also disclosed in paragraph [0008], that "it is difficult to grow in size, while the HPHT single crystal diamond having high crystallinity can be obtained. In addition, a price of the diamond becomes extremely high when its size becomes big and consequently, it is difficult to put it into practical use as the substrate for the devices".

D9 disclosed (see e.g. Figure 2) a method for manufacturing a diamond substrate, comprising a first step of preparing diamond by growing diamond (14) on a surface of a foundation ([0045], silicon (13), MgO (11), rhodium or iridium (12)), the surface being composed of a different kind of material, other than diamond (14).

D9 did not disclose the four methods steps of claim 1.

The technical effect was an improved defect density and lowered stress, see the application, paragraphs [0021], [0066], [0141], [0164], [0149], [0171]. The objective technical problem was to provide a method for manufacturing a diamond substrate having reduced defect concentration and lower stress.

The examining division was incorrect when concluding that the skilled person would realize that the homoepitaxial growth method of D8 could be applied to the heteroepitaxial diamond growth of D9.

While homoepitaxial growth had "very small lattice mismatch" between the substrate and the epitaxial growth layer, heteroepitaxial growth generally "had a large lattice mismatch" between the two components. Both methods were "technologically fundamentally different with respect to the requirements during the growth process". The assumption that the disclosure of document D9 – specifically referring to heteroepitaxial methods – and a teaching of document D8 – specifically referring to and teaching homoepitaxial methods – would be combined or even considered by the skilled person as compatible was purely based on hindsight in view of the present application. In the appellant's view, the skilled person would not combine the methods of both documents. It would be contrary to its knowledge and its common sense to do this combination without any particular reason.

While paragraphs [0010] to [0012] of D9 discussed heteroepitaxial growth as a strict alternative to homoepitaxial growth, D9 did not teach to combine features of these methods.

In particular, in claim 1 and Figure 1 of D8, the diamond substrate was first etched to form a pattern shape on the surface. This was only possible when the same material was grown, and was different from document D9 and the method of the present application, which grew diamond on a material other than diamond.

The position of the examining division was based on the extraction and combination of various convenient elements in order to potentially arrive at the subject-matter of present claim 1, irrespective of the fundamentally different methods, requiring fundamentally different procedures, employed in documents D8 and D9.

The appellant submitted with the statement setting out the grounds of appeal documents D10 and D11 to emphasize the difficulty of heteroepitaxial growth of diamond as well as the necessity of a special method for adapting to the difficulties when diamond was heteroepitaxially grown on Si substrates. D10 disclosed that "the epitaxial growth of diamonds can result in increased surface area, diamond grain erosion, tilt, and growth of unwanted carbide layers". D11 disclosed that the "[g]eneration of diamond nuclei has been realized on a silicon mirror surface in plasma chemical vapor deposition. Prior to the normal diamond growth process, a predeposition process of several minutes duration was introduced in which a high methane fraction in the feed gas was used and in which a negative bias voltage was applied to the substrate. This resulted in an enormous enhancement of the generation of diamond nuclei", i.e. D11 emphasized the necessity of a specially adapted method for heteroepitaxial growth of diamond on Si substrates.

In case that document D8 would be considered as suitable starting point, the arguments given applied *mutatis mutandis*. The appellant added that it was possible to obtain a large-area diamond substrate easily and at relatively low cost by heteroepitaxial growth. Hence, when heteroepitaxial growth was applied according to the present invention, a high-quality and large-area diamond substrate could be manufactured (paragraph [0072] of the description).

4. The board is not convinced by the appellant's arguments and agrees with the examining division that an inventive step (Article 56 EPC) of the subject-matter of claim 1 cannot be acknowledged.

4.1 The wording of feature (a3) in claim 1 encompasses two possibilities. As did the examining division, the board will focus on the first one ("*wherein a bottom portion of a pattern gap of the patterned diamond is composed of a different kind of material other than diamond*").

4.2 Both documents D8 and D9 can be considered as suitable starting points for assessing whether the claimed subject-matter involves an inventive step.

In particular, Document D8 deals with a method of growing of diamond on a substrate and includes method steps similar to those claimed. D8 cannot and should not be ruled out as a possible springboard to the invention.

4.3 Starting from D8

The board agrees with the examining division with respect to the disclosure of D8 and the distinguishing features, see points 1 and 2 on page 4 of section II.

of the impugned decision. This is not contested by the appellant.

D8 starts with a diamond substrate as foundation (D8, page 6, lines 19 to 22, "substrat germe 1", "substrat monocristallin en diamant"), while the claimed method uses a foundation with a surface being composed of a material other than diamond.

As pointed out by the examining division on page 4 of the impugned decision, the subject-matter of claim 1 therefore differs from the disclosure of D8 in that the surface of the foundation is a material other than diamond, and that the bottom of the pattern gap of the patterned diamond is also composed of a different kind of material, other than diamond.

The distinguishing features are therefore features (a1) and (a3).

It is noted that the application discloses both these possibilities for the foundation (diamond, see Figure 1 or a material other than diamond, see Figure 3) and does not disclose any particular effect related to the choice of the foundation with respect to the defect density, see e.g. paragraphs [0021] to [0025], [0064] to [0096] and see also example 1 ([0149], etch-pit density of $3 \times 10^6 \text{ cm}^{-2}$, [0151], " 15×10^{-2} ") and example 2 ([0171], etch-pit densities $3 \times 10^6 \text{ cm}^{-2}$, $4 \times 10^6 \text{ cm}^{-2}$, [0173], " 10×10^{-2} ").

The objective technical problem associated to the distinguishing features can be formulated as how to adapt the method of D8 to use an alternative, ideally cheaper, foundation substrate.

Both homoepitaxial and heteroepitaxial growth relate to epitaxy. The prefix "homo" indicates that the material of the substrate and the grown layer are identical, which is not the case for heteroepitaxy. However, also for heteroepitaxial growth, the lattice constants of the substrate and the grown diamond layer must be sufficiently close, otherwise, an epitaxial growth would not be possible. As pointed out in paragraph [0069] of the application, a difference in lattice constants of 10 % is acceptable for an heteroepitaxial growth.

The board is thus convinced that both epitaxial growth methods are not so different that the skilled person would not consider D9 when wishing to solve the objective technical problem.

The board shares the examining division's view that the skilled person would find a solution in D9, which teaches to grow a diamond layer 14 on an Si/MgO/Ir substrate (13, 11, 12), see figures 1 and 2. D9 also addresses the issue of high cost of diamond substrates and of reducing costs by using the substrate disclosed in D9 (see [0008], [0009], [0011], [0014], "at low cost", [0016], [0037], [0057]). Hence, a motivation to consider document D9 when starting from D8 is clearly given in Document D9, and does not result from hindsight knowledge of the application, contrary to the arguments of the appellant.

Wishing to solve the objective technical problem defined above, the skilled person would replace the diamond substrate 1 of D8 by the substrate (13, 11, 12, 14), including the diamond layer 14, shown in figure 2(d) of D9 and perform the process steps known from D8 using this substrate.

As pointed out by the examining division, the skilled person would thereby arrive at the subject-matter of claim 1 without exercising an inventive step.

4.4 Starting from D9

The board also agrees with the examining division with respect to the disclosure of D9 and the corresponding distinguishing features of claim 1, see points 1 and 2 on pages 5 and 6 of section II. of the impugned decision. This is not contested by the appellant.

As pointed out by the examining division on pages 5 and 6 of the impugned decision, the subject-matter of claim 1 therefore differs from the disclosure of D9 in

- a first step of growing diamond to have a patterned shape, wherein a bottom portion of a pattern gap of the patterned diamond is composed of a different kind of material,
- a second step of growing diamond from the patterned diamond prepared in the first step to form the diamond in the pattern gap of the patterned diamond prepared in the first step,
- a third step of removing the patterned diamond prepared in the first step to form a patterned diamond composed of the diamond formed in the second step, and
- a fourth step of growing diamond from the patterned diamond formed in the third step to form the diamond in a pattern gap of the patterned diamond formed in the third step.

The appellant argued that lower stress would be obtained by the claimed method, referring to paragraphs allegedly mentioning lowered stress, namely paragraphs [0021], [0066], [0141], [0164], [0149], [0171] of the

application. However, these paragraphs merely mention the reduced defect density, but are silent about any effect on stress.

The application mentions stress in the context of heteroepitaxial growth of diamond substrates, see paragraphs [0016] to [0018]. However, the application does not disclose that this issue would be resolved by the distinguishing features over D9 as identified above.

Paragraphs [0036], [0049], [0053], [0089], [0105], [0109], [0114], [0117], [0142], [0143], [0150], [0151] of the application concern a reduction in stress obtained by "voids". However, such "voids" are not included in claim 1.

In a similar manner, paragraphs [0030] to [0032], [0083], [0084] of the application also explain that internal stress may be relaxed by "at least a part of a bottom portion of the pattern gap being prepared [in the first step] below the foundation surface", but not by the distinguishing features considered by the examining division. Further, paragraphs [0041] to [0043], [0101], [0118] of the application concern a reduction in stress obtained by features ("at least a part of a bottom portion of the pattern gap being prepared [in the third step] below the foundation surface") which are not part of claim 1.

In other words, the board is not convinced that the distinguishing features will necessarily have a positive impact on stress. Instead, according to the application, this effect may be achieved by features not present in claim 1.

Hence, starting from D9, the objective technical problem can be formulated as how to improve the crystalline quality of the diamond material 14 of D9. Insofar, the board agrees with the examining division.

D8 provides a way of reducing the dislocation density in diamond material, see figures 2 to 11, page 3, lines 14 to 17 lines 20 to 23 in view of page 1, lines 18 to 26. Hence, a motivation to consider document D8 when starting from D9 and trying to solve the objective technical problem as defined above is clearly given in Document D8, and does not result from hindsight knowledge of the application, contrary to the argument of the appellant. The skilled person would consider to apply the method known from D8 to the diamond layer 14 on the substrate material 13, 11, 12 known from D9. As pointed out by the examining division, the skilled person would thereby arrive at the subject-matter of claim 1 without exercising an inventive step.

- 4.5 The skilled person is aware of techniques of growing diamond layers on diamond substrates using homoepitaxy or growing diamond layers on substrates other than diamond using heteroepitaxy, in accordance with D10 and D11 submitted by the appellant.

The skilled person would also know that a change of the substrate might need adaptations. However, the board is convinced that the skilled person using its common general knowledge is in a position of make these adaptations e.g. when changing the growth substrate used in D8.

In that context, the board notes that the present application is completely silent about any such adaptations to be made with respect to the growth

substrate. As pointed out above, according to the application, the claimed process can be used on both types of substrates (see Figures 1 and 3 of the present application) without any particular problems using known growth methods, see e.g. paragraphs [0074] to [0076].

- 4.6 Hence, in view of these considerations, the subject-matter of claim 1 of all requests does not involve an inventive step (Article 56 EPC).
5. As no allowable request is on file, the appeal must fail.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar:

The Chairman:



S. Sánchez Chiquero

M. Stenger

Decision electronically authenticated