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Bezeichnung der Erfindung: Plasma etching system
Title of invention:
Titre de l'invention :

Klassifikation / Classification / Classement : H01J 37/32

ENTSCHEIDUNG / DECISION

vom / of / du 12 October 1990

Anmelder / Applicant / Demandeur : International Business Machines Corporation

Patentinhaber / Proprietor of the patent /
Titulaire du brevet :

Einsprechender / Opponent / Opposant :

Stichwort / Headword / Référence :

EPÜ / EPC / CBE Art. 56

Schlagwort / Keyword / Mot clé : "Inventive step (no)"

Leitsatz / Headnote / Sommaire

Case Number : T 757/89 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 12 October 1990

Appellant : International Business Machines Corporation
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Representative : Bailey, Geoffrey Alan
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Decision under appeal : Decision of Examining Division 047 of the European Patent Office dated 6 July 1989 refusing European patent application No. 85 111 747.3 pursuant to Article 97(1) EPC

Composition of the Board :

Chairman : K. Lederer
Members : Y. van Henden
G.D. Paterson

Summary of Facts and Submissions

I. European patent application No. 85 111 747.3 (publication No. 0 180 020) was refused by decision of the Examining Division.

II. The decision was based on claims submitted on 14 April 1989 and numbered 1-4. The reason for the refusal was that, in view of the prior art disclosed in document

D1: US-A-4 298 419,

the subject-matter of independent Claims 1 and 4 lacked novelty, whereas that of Claims 2 and 3 could not be considered as involving an inventive step.

III. The Appellant lodged an appeal against this decision.

IV. In a communication pursuant to Article 11(2) of the Rules of Procedure of the Boards of Appeal, the rapporteur referred to (D1) and the further documents

D2: K. Suzuki et al. "Radio-frequency biased microwave plasma etching technique: a method to increase SiO_2 etch rate", "Journal of vacuum science and technology B", Vol. 3, No. 4 (July-August 1985), American Vacuum Society, Woodbury, New York, US (referred to in the grounds of appeal)

and

D3: US-A-4 401 054

and expressed the provisional view that confirmation of the impugned decision was likely.

V. Oral proceedings were held at the end of which the Appellant requested that the decision under appeal be set

aside and that a patent be granted on the basis of four claims presented at the oral proceedings.

VI. Claim 1 according to the Appellant's request reads:

"1. Apparatus for the chemical etching of a material surface with a plasma, comprising:

a reaction chamber (26);

means for maintaining a flow of gas through the reaction chamber (26) and against the material surface to be etched, comprising a source of gas (32), a gas confining tube (24) and evacuating means (40,42,44);

means (14) for exciting said flowing gas with microwave energy to form a flowing plasma extending substantially throughout the reaction chamber comprising a microwave generator, a waveguide and a microwave cavity (10);

characterised by an electrode for supporting the material to be etched, the electrode (30) being connected to a radio frequency power source for producing a plasma exciting radio frequency electric field;

wherein the microwave energy and the radio frequency electric field both continuously excite formation of the flowing plasma as it flows against the material surface to be etched whereby the radio frequency excitation produces a more chemically reactive flowing plasma which enhances the etching rate of the flowing plasma and makes the etching effect of the flowing plasma more anisotropic."

Claims 2 and 3 are dependent on Claim 1, whereas the independent Claim 4 covers the etching method to be carried out by an apparatus according to Claim 1.

VII. The Appellant submitted essentially the following arguments.

The apparatus known from (D1) is a magnetically enhanced etcher in which the gas pressure is as low as 0.133 Pa (1 mTorr) and microwave induced plasma is confined by mirror coils (4). The purpose of applying a radio frequency bias to the sample is there to overcome charge build up that would repel ions. It is, therefore, obvious that the technique disclosed in (D1) would not improve the etch rate of conductors.

It is furthermore contested that, in said apparatus, which is of the electron cyclotron resonance (ECR) type, microwave excitation would extend to the sample surface to be etched. There is indeed no reason to question the statement that microwaves are absorbed by the etching gases reserved in the discharge room (3) - cf. column 3 of (D1), lines 6 to 15. Moreover, in ECR machines, the magnetic field strength and microwave frequency have to match for resonance to occur. This condition is not realised outside the discharge room as the magnetic field weakens, so that excitation to plasma will cease. It is consequently thought that (D1) does not disclose the most relevant state of the art to start from when examining for inventive step in the present case.

The apparatus of the invention falls in the class of downstream etchers, i.e. microwave etchers with no magnetic enhancement. These etchers operate at relatively high pressure, to wit 13.3 Pa (100 mTorr), whereby a much greater concentration of reactive particles is produced.

The isotropic nature of downstream etchers results, however, in a substantial undercutting, so that it is desirable to improve the anisotropy.

The solution discovered by the Appellant is to modify an existing downstream etcher by application of a radio frequency bias to the sample in order to subject the latter to the simultaneous formation of plasma from two sources. Besides the ability to control the edge profile by varying the ratio of the applied power to the two plasma generators, this also provides an unexpected synergy between the two etch processes. This is due to the resulting mixture of plasma being more highly chemically reactive.

Reasons for the Decision

1. The appeal is admissible.

2. **Novelty**

2.1 The first question to be answered concerns the Appellant's objections regarding the technical fields and problems which document (D1) and the present application respectively tackle. Said application is indeed said to relate to "dry chemical etching" - cf. first paragraph of the description - whereas (D1) merely mentions "dry etching". Furthermore, the analysis of ions working as disclosed in (D1) leads the reader to think that only mechanical interactions occur between the ions and the material to be etched.

It is, however, clear that the effects produced in the operating conditions of the device known from (D1) exclusively depend on the choice of etching gases, the

material to be etched and the physical conditions prevailing in the discharge and etching rooms (3,7), in particular the gas pressure and the respective frequencies and intensities of the two excitation modes. Now, it is also clear that document (D2) pertains to the same etching apparatus as (D1). The constructional features, etching gases, materials to be etched, pressures and excitation frequencies are indeed the same in both documents. Therefore, and albeit (D2) was published after the priority date of the present application, its teachings relating to observed and/or predicted effects - for instance the length of particles mean free paths - may, as far as the parameters from which said effects result remain unchanged, be accepted as completing those of (D1). Moreover, said teachings also appear to be more credible than those of (D1), since (D2) is an article published in a scientific review of wide diffusion.

2.2 Document (D2) reveals that the construction of the etching equipment used by its authors was the same as in previous papers, except that an alumina discharge tube was used instead of a quartz tube - see the first paragraph of section II.A. The reason for the change, to wit that the reactive particles needed for etching are consumed at the surface of a quartz tube, is already evidence that a chemical reaction takes place between silica and ions, and it is noteworthy that the samples to be etched in (D1) are substrates on which a silicon dioxide layer has been formed. An additional reason to admit the occurrence of a chemical reaction is perceived in the mention of C_2F_6 as etching gas in both documents and in the known reactivity of fluor with silicon - see also in (D2), first paragraph of page 1026, the reference to reactive particles that etch SiO_2.

2.3 It is not denied that, as explained in (D3) - see column 8, lines 6 to 53 - the efficiency of energy transmission from the microwaves to the electrons is the highest where the induction (B) and the microwave frequency (f) are such that ($2 f = eB/m$), (e) and (m) respectively designating the charge and mass of the electron. With the microwave frequency of 2.45 GHz mentioned in (D3), the optimum value of (B) derived from above formula is 0.0875 T_1, i.e. 875 Gauss. Nevertheless, it is stated in (D3) that the maximum induction is 0.1 T_1 and that the top of the plasma formation chamber (21) is located in the region of maximum induction - see column 8, lines 18 to 30. Such measures obviously aim at mirroring ions that would spiral around the magnetic field lines in the wrong direction, i.e. towards the upper part of the plasma formation chamber (21).

A similar disposition is represented in Figure 1 of (D2) and it may be accepted that, in accordance with the Appellant's submission, in the apparatus of (D1) the conditions of electron cyclotron resonance are met at the lower part of the discharge room (3). It is however stated in (D1) that "mirror magnetic fields are established by coils (4) and a permanent magnet (5)", and that "the active ions move along the mirror magnetic fields" - see column 3, lines 6 to 22. Considering that the permanent magnet (5) is arranged beneath the substrate stage (9), it thus appears that, in the region of the etching room (7) extending between the discharge room (3) and said stage, the divergence of magnetic field lines is not so marked as the Appellant contends and that the conditions of electron cyclotron resonance are at least nearly met. Considering moreover that nothing opposes microwave propagation into the etching room (7) and that microwave energy absorption is never complete, it also appears that the statement in column 3 of (D1), lines 6 to 12 - to wit: "the microwaves

... are guided ... until they are absorbed by the etching gases ... reserved in ... discharge room (3)" - is not absolutely correct and that, there too, the microwave energy continuously excites plasma formation as the plasma flows against the surface to be etched.

2.4 With regard to the preceding, the Board takes the view that the state of the art disclosed in (D1) is relevant in the present case.

As can readily be perceived when comparing the respective disclosures of (D1) and the application, the etching room (7), microwave generator (1), waveguide (2), discharge room (3), substrate stage (9) and radio frequency power source (10,20) of the known apparatus correspond to the reaction chamber (26), the microwave generator (14), the waveguide, the microwave cavity (10), the electrode (30) and the radio frequency power source (50) of the claimed subject-matter. Likewise, the wall of the discharge room (3) corresponds to the gas confining tube (24) of the present application.

According to (D1), the etching gases are introduced through a leak valve (6) and a gas inlet (17) which opens in the discharge room (3), whereas the etching room (7) is provided with an evacuating outlet (18) at its lower part. It may thus be accepted that a gas source is provided and that the etching gases are continuously introduced into the discharge room (3). Likewise, it may be accepted that means are provided to continuously evacuate the excess gases through the outlet (18), since the pressure is maintained very low. Therefore, considering the respective locations of said outlet and substrate stage (9), in the operating condition of the known device, a flow of gas is maintained through the reaction chamber and against the material surface to be etched.

2.5 As regards the feature of a plasma extending substantially throughout the reaction chamber (26), it is merely stated in the patent application that "the microwave plasma also extends downward into chamber (26) and covers electrode (30) and anything on electrode (30) - see the last two lines of page 5 and the first three lines of page 6. This is also what Figure 1 suggests by means of a stippling which symbolises the ion distribution. Figure 1 of document (D1) suggesting the same, it may thus be accepted that, there too, the plasma extends throughout the etching room (7).

2.6 From statements in (D1), it may furthermore be inferred that the combination of both excitation modes enhances the etching rate - see column 4, lines 15 to 21 and 47 to 52 - and that not only the latter but also the sectional shape of the sample can be controlled by suitably selecting the amplitude of the radio frequency voltage - see column 6, lines 5 to 9. Finally, if the etching rate is enhanced, it may not be denied that the plasma produced in the known device is more chemically reactive than a plasma produced by microwave excitation only.

2.7 In view of the preceding, the only feature of the claimed subject-matter which is not disclosed with absolute certitude in (D1) is that the radio frequency field produced by the electrode (30) and the generator (50) excites plasma formation.

3. **Inventive step**

According to (D1), the gas pressure in the known apparatus is low, to wit 0.133 Pa. Consequences thereof are an ion and electron mean free path of about 50 mm - see (D2) - and a comparatively inefficient dragging of ions by the

gas flow. As a matter of fact, this is the very reason why mirror magnets (4,5) are provided in the apparatus of (D1).

In a device such as described in the present application, however, the pressure is one hundred times higher. Therefore, in accordance with the law of mass action, the ions' neutralisation rate increases in proportion to both the number of collisions affecting ions and that of collisions affecting electrons, so that a smaller fraction of the ions produced by microwave excitation arrives in the vicinity of the substrates to be etched. The need for plasma regeneration in the latter region can thus be felt while performing routine experiments, in particular while investigating whether the apparatus known from (D1) is suitable for plasma etching under increased gas pressure. In Decision T 21/81 (OJ EPO 1983, pages 15-21), it is stated that "if, having regard to the state of the art, something falling within the terms of a claim would have been obvious to a person skilled in the art, because the combined teachings of the prior art documents could be expected to produce an advantageous effect, such claim lacks inventive step, regardless of the fact that an extra effect (possibly unforeseen) is obtained". In the Board's view, in the present case, although there is evidence of synergy between the two etching processes and of an etching enhancement in the case of conducting samples, both such extra effects are simply an extension of the effect which would in any event be expected by the skilled reader of document D1, namely an increased ethcing rate.

The Board, therefore, takes the view that the subject-matter of Claim 1 lacks an inventive step.

4. Claim 1 is therefore not allowable - Article 52(1) EPC in relation with Article 56, and consequently the application must be rejected.

Order

For these reasons, it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

P. Martorana K. Lederer