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# D E C I S I O N
**of 7 May 2004**

**Case Number:** T 1289/01 - 3.5.2

**Application Number:** 90904934.8

**Publication Number:** 0473782

**IPC:** H01F 27/24

**Language of the proceedings:** EN

**Title of invention:**
Magnetic core

**Patentee:**
Kabushiki Kaisha Toshiba

**Opponent:**
Vacuumschmelze GmbH & Co. KG

**Headword:**
-

**Relevant legal provisions:**
EPC Art. 56

**Keyword:**
"Inventive step (yes)"

**Decisions cited:**
-

**Catchword:**
-

Case Number: T 1289/01 - 3.5.2

# DECISION
of the Technical Board of Appeal 3.5.2
of 7 May 2004

| | |
|---|---|
| **Appellant:** (Opponent) | Vacuumschmelze GmbH & Co. KG<br>Bereich Verträge und Patente<br>Grüner Weg 37<br>Postfach 2253<br>D-63412 Hanau (DE) |
| **Representative:** | Patentanwälte<br>Westphal, Mussgnug & Partner<br>Mozartstrasse 8<br>D-80336 München (DE) |
| **Appellant:** (Proprietor of the patent) | Kabushiki Kaisha Toshiba<br>72, Horikawa-cho,<br>Saiwai-ku<br>Kawasaki-shi,<br>Kanagawa-ken 210-8572 (JP) |
| **Representative:** | Liesegang, Roland, Dr.-Ing.<br>Forrester & Boehmert<br>Pettenkoferstrasse 20-22<br>D-80336 München (DE) |
| **Decision under appeal:** | **Interlocutory decision of the Opposition Division of the European Patent Office posted 22 November 2001 concerning maintenance of European patent No. 0473782 in amended form.** |

**Composition of the Board:**

**Chairman:** W. J. L. Wheeler
**Members:** M. Ruggiu
E. Lachacinski
W. D. Weiß
B. J. Schachenmann

## Summary of Facts and Submissions

I. Both the proprietor of the patent and the opponent filed appeals against the interlocutory decision of the opposition division concerning maintenance of European patent No. 0 473 782 in amended form.

II. The following documents of the state of the art played a role in the appeal proceedings:

E2: JP-A-64-84602;

E3: M. Matsuura *et al.* "Effects of Ambient Gases on Surface Profile and Related Properties of Amorphous Alloy Ribbons Fabricated by Melt-Spinning" published in Japanese Journal of Applied Physics, vol. 19, No. 9, September 1980, pages 1781 to 1787;

E5: EP-A-0 271 657; and

E8: EP-B-0 072 574.

The opponent had already provided a translation into English of document E2 in the first instance proceedings. This translation will be referred to as E2a. Document E8 was cited for the first time in the opponent's letter dated 6 April 2004.

III. The patentee further referred to the results of comparative tests filed with a letter of 23 December 1994 during the examination proceedings. A copy of these comparative tests was annexed to the letter of 26 March 2002 of the patentee. The parties also referred to a declaration by one of the inventors, Mr T. Sawa, a copy of which had been filed with a letter of 8 October 1996 during the examination procedure.

IV. Oral proceedings before the board took place on 7 May 2004.

The appellant patentee requested that the decision under appeal be set aside and that the patent be maintained unamended (main request) or in amended form according to one of the auxiliary requests 1 to 9 filed with letter from 31 March 2004.

The appellant opponent requested that the decision under appeal be set aside and that the patent be revoked.

V. Claims 1 and 8 of the patent in suit as granted read as follows:

"1 A magnetic core formed by winding or laminating an alloy ribbon, the magnetic core having a saturation magnetic characteristic of no more than 550 G and having a squareness ratio of Br/B1, wherein Br is remanent magnetic flux density and B1 is magnetic flux density at a magnetic field of 1 Oe, of at least 96 % at a frequency of 100 kHz,
the saturation magnetic characteristic being expressed by the difference between a magnetic flux density and a residual flux density, said magnetic flux density being obtained by applying a magnetic field of 16 Oe to a magnetic core having a outer diameter of 15 mm and an inner diameter of 10 mm and a height of 4.5 mm, with

10 turns using a measurement frequency of 100 kHz, wherein:
the alloy ribbon comprising a Co-based amorphous alloy having a Curie temperature in the range of 160 - 300°C or Fe-based alloy,
a first surface of said alloy ribbon has a surface roughness wherein the area occupied by concavities formed on the first surface is no more than 30 % of the total area of said first surface,
a second surface of said alloy ribbon has a surface roughness value in the longitudinal direction of said alloy ribbon that satisfies the following equation:

$$Rf \leq 0.3$$

wherein Rf is a parameter characterizing a roughness as determined by the following equation:

$$Rf = Rz/T$$

wherein Rz represents the average roughness of ten points at a standard length of 2.5 mm, and T represents the average plate thickness in µm."

"8. Use of a magnetic core as a component in which excellent high frequency magnetic characteristics is required, such as saturable reactors, remiconductor [sic] circuit reactors, high frequency switching power sources, residual current transformers, current sensors and noise filters, wherein
the magnetic core is formed by winding or laminating an alloy ribbon and has a saturation magnetic characteristic of no more than 550 G and having a squareness ratio of Br/Bl, wherein Br is remanent magnetic flux density and Bl is magnetic flux density at a magnetic field of 1 Oe, of at least 96 % at a frequency of 100 kHz,
the saturation magnetic characteristic being expressed

by the difference between a magnetic flux density and a residual flux density, said magnetic flux density being obtained by applying a magnetic field of 16 Oe to a magnetic core having a outer diameter of 15 mm and an inner diameter of 10 mm and a height of 4.5 mm, with 10 turns using a measurement frequency of 100 kHz, wherein:
the alloy ribbon comprising a Co-based amorphous alloy having a Curie temperature in the range of 160 to 300°C or Fe-based ultramicrocrystalline alloy,
a first surface of said alloy ribbon has a surface roughness wherein the area occupied by concavities formed on the first surface is no more than 30 % of the total area of said first surface,
a second surface of said alloy ribbon has a surface roughness value in the longitudinal direction of said alloy ribbon that satisfies the following equation:

$$Rf \leq 0.3$$

wherein Rf is a parameter characterizing a roughness as determined by the following equation:

$$Rf = Rz/T$$

wherein Rz represents the average roughness (μm) of ten points at a standard length of 2.5 mm, and T represents the average plate thickness in μm."

Claims 2 to 7 of the patent are dependent on claim 1.

VI. The opponent essentially argued as follows:

Document E2 concerned the same Co-based alloys as the patent in suit. Thus, the Curie temperature of these alloys was necessarily that specified in claim 1 of the patent in suit, i.e. in the range of 160 to 300°C. E2 specified a roughness value for the second surface of the ribbon (the free side not in contact with the cooling roll during melt-spinning of the alloy) of Rf = 0.15 and thus Rf ≤ 0.3 and a squareness ratio of 99.4% at 50 kHz. As appeared from table 1 of document E8, the squareness ratio increased or at least remained the same with an increase in the frequency, so that E2 implicitly disclosed a squareness ratio of at least 96% at a frequency of 100 kHz. The only two features of claim 1 that were not disclosed in document E2 were, firstly, that the magnetic core had a saturation magnetic characteristic of no more than 550 G and, secondly, that the first surface of the alloy ribbon had a surface roughness wherein the area occupied by concavities formed on the first surface was no more than 30% of the total area of said first surface. As concerned this second feature, document E2 discussed (in the middle of page 5 of the translation E2a) the surface characteristics of the first surface (the side of the ribbon in contact with the cooling roll during melt-spinning of the alloy) which depended especially on the incorporation of air bubbles. This passage of E2 made the skilled person aware that the surface characteristics and thereby the magnetic properties of the roll side of the ribbon were strongly influenced by, i.e. qualitatively correlated to the presence of air bubbles. The next sentence in E2a, according to which no clear relation was noted with magnetic properties in comparison with the free side, merely indicated that no quantitative relation had been found between the roughness of the roll side and the magnetic properties of the alloy ribbon. It was not plausible that the skilled person, who knew from E2 that the surface characteristics of the second surface (the free side) was important for the magnetic properties of the alloy ribbon, would not give attention to the surface characteristics of the first surface (the roll side), especially because it was apparent that both surfaces were equally important when the alloy ribbon was wound or laminated to form a magnetic core. Thus, the problem solved by the invention defined in claim 1 of the patent in suit was to improve the alloy ribbon of E2, in particular to improve its surface characteristics and find a quantitative relation between the surface characteristics of the roll side and the magnetic properties of the ribbon. The skilled person looking for a solution to this problem would consider document E3 because E3 pertained to the same art as E2. The alloy discussed in E3 was Fe-based. It was however apparent to the skilled person that this Fe-based alloy was only used as an example and that the teaching of E3 was independent of the particular alloy used. Figure 3 of E3 showed that ribbons melt-spun in vacuum had a better roughness on the free side. It was therefore obvious to resort to the teaching of E3 to obtain an alloy ribbon having a second surface with a roughness $Rf \leq 0.3$. Ribbons melt-spun in vacuum, which had a better roughness on the free side, also had fewer concavities on the roll side and the same correlation between these parameters was apparent from the declaration of Mr Sawa. Furthermore, E2 suggested (on page 5 of E2a) that the reason for the improvement of the magnetic properties at high frequency that was observed for alloy ribbons having a roughness $Rf \leq 0.3$ was due to a reduction in the shape anisotropy caused by surface roughness. E3 provided a similar reason (reduction of induced anisotropy) at page 1786, right hand column, for the improvement in the magnetic properties of ribbons fabricated in He or vacuum. The skilled person would have realised that E2 and E3 were related and he would have combined their teachings. Since, as appeared from E3, ribbons melt-spun in vacuum had practically no concavities on the roll side, the combination would have provided ribbons in which the area occupied by concavities formed on the first surface was no more than 30% of the total area of the first surface. The other feature of claim 1 not disclosed in E2, i.e. the saturation magnetic characteristic, was an unusual, arbitrary parameter for characterising a magnetic core. Furthermore, the feature that the saturation magnetic characteristic was no more than 550 G was not present in the claims as originally filed. This feature was not independent from the other features of claim 1 of the patent in suit; it was necessarily obtained in a core having the other features of the claim. Thus, the obvious combination of E2 and E3 led the skilled person to the subject-matter of claim 1 of the patent in suit, which therefore did not involve an inventive step. Document E5, in particular claim 12 thereof, disclosed nanocrystalline Fe-based alloys that were equivalent to Co-based alloys. It was therefore obvious to apply the teaching of E2, which referred to Co-based alloys, to the Fe-based alloys of E5.

VII. The arguments of the patentee can be summarised as follows:

The magnetic core specified in claim 1 of the patent in suit differed from the cores disclosed in document E2 in the squareness ratio at 100 kHz, the magnetic saturation characteristic and the percent area occupation of the first surface by concavities. E2 disclosed a Co-based alloy ribbon having a squareness ratio Br/Bl at 50 kHz of 99.4% with a surface roughness value of Rf = 0.15 in the longitudinal direction of the free side (the "second" surface of the ribbon). However, E2 did not disclose the squareness ratio Br/Bl at 100 kHz. In the letter of 7 October 2002, the opponent had asserted that it was generally known that the squareness ratio decreased with higher frequencies. In the letter of 6 April 2004, the opponent contradicted that assertion and alleged that the squareness ratio increased with the frequency. However, the magnetic behaviour of an alloy ribbon as disclosed in E2 was highly complex at high frequency and there was no systematic relation between the squareness ratios at 50 kHz and 100 kHz. In E2, the alloy had such a composition that the saturation flux density was ≤ 7 kG. E2 was silent regarding the saturation magnetic characteristic specified in claim 1 of the patent in suit. As was apparent from the patent in suit, the saturation magnetic characteristic was an independent parameter that could be adjusted. E2 was exclusively interested in the roughness of the free side of the ribbon, which was set to Rf ≤ 0.3. As regards the occupation of the roll side by concavities, E2 indicated that no clear relationship was noted with magnetic properties in relation to the free side and thereby did not disclose any correlation between the roughness of the free side of the ribbon and the occupation by concavities on the roll side. Furthermore, E2 did not disclose a method that inevitably yielded the surface roughness of the first surface as defined in claim 1. Thus, E2 did not make it obvious to have no more than 30% of the area of a first surface of the ribbon occupied by concavities. Document E3 only concerned ribbons made of a $Fe_{78}Si_{10}B_{12}$ alloy. Starting from E2 as closest prior art, the objective problem solved by the invention of the patent in suit was to improve the squareness ratio at high frequencies around 100 kHz and simultaneously achieve a small saturation inductance of the magnetic core. The skilled person would not combine E2, which concerned Co-based alloys, with E3, which related to a specific Fe-based alloy. E3 only disclosed DC magnetic properties, in particular the DC squareness ratio, of cores made from amorphous $Fe_{78}Si_{10}B_{12}$ ribbons. As was apparent from the results of the tests filed with the letter of 23 December 1994, there was no relation between the DC characteristics and AC characteristics at high frequency. Thus, the skilled person would not consider E3 for improving high frequency magnetic properties of the cores disclosed in E2. E3 had been published in 1980 and referred to previous publications dated around 1978, so that about ten years had elapsed between E3 and the invention of the patent in suit. It was therefore apparent that the skilled person did not think in the direction of E3 at the time the invention was made. This was confirmed by the passage bridging pages 2 and 3 of the declaration of Mr Sawa. E3 gave no indication of a range for the percent area occupation by concavities that would provide acceptable magnetic properties of the alloy ribbon at high frequency. Figure 3 of E3 showed that the free side of a ribbon produced in vacuum had more irregularities than that of a ribbon produced in a He-atmosphere, while Figure 4 of E3 showed that the roll side of a ribbon produced in He-atmosphere had more concavities than that of a ribbon produced in vacuum. Thus, E3 did not disclose a correlation between the roughness of the free side and the occupation by concavities on the roll side of the alloy ribbon.

Furthermore, as appeared from the test results submitted, the squareness ratio and saturation magnetic characteristic specified in claim 1 of the patent in suit were only obtained when all the other features of claim 1 were present, in particular both the specified roughness of the first surface and the specified roughness of the second surface of the ribbon. Moreover, E2 was completely silent on alloy ribbons made from Fe-based alloys.

## Reasons for the Decision

1. The appeals are admissible.

2. The novelty of the subject-matter of claim 1 of the patent in suit is not in dispute.

3. The board concurs with the parties in regarding E2 as the closest prior art from which to start the assessment of inventive step.

E2 concerns the problem of improving the magnetic properties at high frequency, especially the squareness ratio, of magnetic cores formed by winding a thin strip, obtained by the melt-spinning process, of an amorphous ferromagnetic alloy. The solution suggested in E2 rests on the two basic features of:

(i) using a Co-based amorphous alloy for the ribbon (which alloy has a composition falling under the scope of claim 1 of the patent in suit), and

(ii) having a roughness of the free side of the ribbon in the longitudinal direction of $Rf \leq 0.3$ (a condition identical to the one specified in claim 1 of the patent in suit for the surface roughness value of the second surface of the ribbon).

E2 mentions as background art a core made from an Fe-Ni alloy (see page 2, penultimate paragraph of E2a). Consequently, it appears that E2 deliberately teaches a combination (and not a mere aggregation) of features (i) and (ii) and suggests that the validity of feature (ii) is limited to the choice of the particular alloy specified in feature (i).

4. As regards the other surface of the ribbon (the side of the ribbon in contact with the cooling roll), E2 simply mentions the following (see page 5, lines 20 to 25 of E2a):

"In passing, when the strip is made in a normal atmosphere, the surface characteristics of the roll surface depend especially on the incorporation of air bubbles; however, no clear relationship is noted with magnetic properties in comparison with the free side."

Thus, it is known from E2 that the roll surface (the first surface) of the alloy ribbon is affected by concavities. According to E2 however, in comparison with the surface roughness of the free side (the second surface of the ribbon), these concavities do not have a clear relationship with the magnetic properties of the ribbon. In particular, E2 does not teach that the area occupied by concavities formed on the first surface should be no more than 30% of the total area of said first surface.

5. According to page 3, lines 42 to 54, of the printed specification of the patent in suit, the problem of the present invention is to provide a magnetic core obtained by using an alloy ribbon having a large squareness ratio at high frequency and a small saturation inductance. According to the cited passage of the patent in suit, this problem is met by claim 1. This appears plausible in view of the results of the tests presented in the patent in suit, in the letter of 23 December 1994 and the declaration by Mr T. Sawa.

6. E3 is a report of 1980 that describes the effects of ambient gases on the surface profiles, magnetic properties and thermal stability of amorphous $Fe_{78}Si_{10}B_{12}$ ribbons fabricated by melt-spinning. According to E3 (see in particular page 1783, right-hand column), the roll side of ribbons fabricated in He and vacuum is flat like the upper side. The uniformity of the thickness of the ribbons fabricated in He and vacuum is excellent. However, the longitudinal cross-section of ribbon fabricated in Ar is significantly different from those fabricated in He and vacuum. There are many large hollows due to gas bubbles in the roll side and occasionally their depths attain almost half of the thickness of the ribbons. Therefore, surface irregularities due to such hollows result in low packing density of wound ribbon cores. The same can be observed in air and N2. E3 also indicates that the ambient gas has a significant effect on the B-H hysteresis curve of amorphous $Fe_{78}Si_{10}B_{12}$ ribbon and reports values for the squareness ratio measured under

DC conditions of 0.73 for a ribbon fabricated in air, 0.86 for a ribbon fabricated in vacuum and 0.88 for a ribbon fabricated in He. As regards the saturation inductance, E3 states that amorphous $Fe_{78}Si_{10}B_{12}$ ribbons fabricated in He and vacuum have nearly the same saturation magnetization ($\sigma$) as ribbons fabricated in air, but the coercive force ($H_c$) is found to be less and the rectangular-ratio ($B_r/B_m$) more in the ribbons fabricated in He and vacuum.

7. Thus, at the filing date of the patent in suit, it had been known for at least ten years from document E3 that the occupation of the roll side of the ribbon by concavities can be reduced by the application of He or vacuum during the melt-spinning process. However, in the view of the board, the sentence on page 5, lines 20 to 25 of E2a (reproduced in paragraph 4 above) dissuades the skilled person from the costly production in He or vacuum because no appropriate positive effect on the magnetic properties is to be expected from the consequent reduction in the occupation of the roll side by concavities.

8. The results of the comparative tests filed with the letter of 23 December 1994 show that, for different ribbons, no systematic relation exists between the value of the DC squareness ratio and the value of the AC squareness ratio at high frequency (100 kHz). The board therefore considers that the skilled person would not regard E3, which only reports DC squareness values, as being relevant for achieving a high squareness ratio at high frequency. This is not inconsistent with document E8, because that document only shows squareness values at high frequencies (20 kHz, 50 kHz

and 100 kHz). Furthermore, in the view of the board, the skilled person is aware that the properties of alloys depend in a complex manner on different parameters, in particular the composition of the alloy. Thus, the board doubts that, without hindsight, the skilled person would resort to a report like E3, which only mentions a specific Fe-based alloy, to solve problems connected with Co-based alloys, such as providing a large squareness ratio at high frequency. For the same reason, the skilled person would be aware that the statement in E3 relating to the saturation inductance ($\sigma$), which is derived from DC measurements on a $Fe_{78}Si_{10}B_{12}$ ribbon, does not necessarily apply to the inductance at high frequencies of a Co-based ribbon.

9. The skilled person knows from E2 that having a roughness of the free side (the second surface) of the ribbon $Rf \leq 0.3$ is important for the magnetic properties at high frequency in the case of a ribbon made of a Co-based alloy. However, claim 1 of the patent in suit imposes a requirement on the roughness of the first surface (the area occupied by concavities formed on the first surface is not more than 30% of the total area of said first surface) which is different from the roughness requirement disclosed in E2 for the second surface ($Rf \leq 0.3$). Furthermore, the requirement specified in claim 1 for the roughness of the first surface is nowhere mentioned in the cited state of the art.

10. Document E5 discloses magnetic cores made of Fe-based alloy ribbons. E5 does not discuss the roughness of the surfaces of the ribbon and thus lies further away from the invention of the patent in suit than E2 or E3.

11. The board concludes therefore that the subject-matter of claim 1 of the patent in suit is to be considered as involving an inventive step in the sense of Article 56 EPC.

The subject-matter of claims 2 to 7 and claim 8, which all impose the above requirement on the roughness of the first surface, is thereby also to be considered as involving an inventive step.

## Order

**For these reasons it is decided that:**

1. The decision under appeal is set aside.

2. The patent is maintained unamended.

The Registrar: The Chairman:

D. Sauter W. J. L. Wheeler