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D E C I S I O N
of 10 November 1998

Case Number: T 0610/96 - 3.5.2

Application Number: 92103874.1

Publication Number: 0503499

IPC: H01F 10/12

Language of the proceedings: EN

Title of invention:
Magnetoresistive materials

Patentee:
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.

Opponent:
Siemens AG

Headword:
-

Relevant legal provisions:
EPC Art. 54(3), 56, 123(2)

Keyword:
"Novelty (after amendment - yes)"
"Inventive step (after amendment - yes)"
"Amendments extending beyond the original disclosure (no)"

Decisions cited:
T 0012/81, T 0017/85, T 0026/85, T 0279/89

Catchword:

Case Number: T 0610/96 - 3.5.2

D E C I S I O N
of the Technical Board of Appeal 3.5.2
of 10 November 1998

Appellant: (Opponent)
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Respondent: (Proprietor of the patent)
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Decision under appeal: **Decision of the Opposition Division of the European Patent Office posted 14 June 1996 rejecting the opposition filed against European patent No. 0 503 499 pursuant to Article 102(2) EPC.**

Composition of the Board:

Chairman: W. J. L. Wheeler
Members: F. Edlinger
B. J. Schachenmann

Summary of facts and submissions

I. The appeal is against the decision of the opposition division to reject the appellant's opposition against European patent No. 0 503 499.

II. Opposition was filed against the patent as a whole and based on Article 100(a) EPC. In the course of the opposition proceedings, the appellant relied on the following documents:

D1: PHYSICAL REVIEW B; Vol. 40, No. 8, 1989; pages 5837-5840; LAMELAS F.J. *et al*; "Coherent fcc stacking in epitaxial Co/Cu superlattices"

D2: ZEITSCHRIFT FÜR PHYSIK B - CONDENSED MATTER 78; 1990; pages 475-477; PESCIA D. *et al*; "Magnetic coupling between Co layers separated by Cu"

D3: THIN SOLID FILMS; 193/194; 1990; pages 877-885; LACROIX C. *et al*; "Interlayer coupling in $[3d\ \text{ferromagnetic/non-magnetic}]_n$ multilayers"

D4: PHYSICAL REVIEW B; Vol. 39, No. 16, 1989; pages 12003-12012; VOHL M. *et al*; "Effect of interlayer exchange coupling on spin-wave spectra in magnetic double layers: Theory and experiment"

D5: JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN; Vol. 59, No. 9, 1990; pages 3061-3064; SHINJO T. *et al*; "Large Magnetoresistance of Field-Induced Giant Ferrimagnetic Multilayers"

D6: PROGRESS OF THEORETICAL PHYSICS SUPPLEMENT; No. 101, 1990; pages 529-535; SHINJO T. *et al*; "Magnetoresistance of Multilayers"

D7: IEEE TRANSLATION JOURNAL ON MAGNETICS IN JAPAN; Vol. 5, No. 12, 1990; pages 1127-1133; TANAKA T. *et al*; "Magnetoresistance and Hall Effects for Fe-Ni-M Alloy Thin Films"

D8: US-A-4 476 454

D9: PHYSICAL REVIEW B; Vol. 43, No. 1, January 1991; pages 1297-1300; DIENY B. *et al.*; "Giant magnetoresistance in soft ferromagnetic multilayers"

D10: EP-A-0 506 433

D11: DE-C-3 820 475

D12: EP-A-0 346 817

D13: BOZORTH R.M.; "Ferromagnetism"; 1956; D. VAN NOSTRAND COMPANY, INC.; Princeton, New Jersey; pages 160-171.

In the notice of opposition, claims 1 to 6 were opposed on the ground that their subject-matter lacked an inventive step within the meaning of Article 56 EPC in view of the prior art disclosed in documents D1 to D9. Claims 5 and 6 were also opposed on the ground that their subject-matter lacked novelty with respect to the disclosure of document D10 belonging to the state of the art according to Article 54(3) EPC. Documents D11 to D13 were introduced by the opponent in preparation for the oral proceedings and admitted by the opposition division.

III. With the statement setting out the grounds of appeal the appellant filed a further document

D14: EP-A-0 498 640

belonging to the state of the art according to Article 54(3) EPC and raised a new objection of lack of novelty against claims 1 to 6.

IV. In reply thereto, the respondent did not object to the introduction of document D14, but filed a new document

D15: JAPANESE JOURNAL OF APPLIED PHYSICS; Vol. 31, April 1992; pages 484-486; SAKAKIMA H. *et al*; "Low-Field Giant Magnetoresistance in [Ni-Fe-Co/Cu/Co/Cu] Superlattices"

to demonstrate the improved characteristics of the materials of the contested patent.

V. Oral proceedings were held on 10 November 1998, during which the respondent further amended the main request which had been filed with the letter dated 8 October 1998.

Claims 1 to 5 of the main request are all presented in independent form and are worded as follows:

Claim 1: "A magnetoresistive material comprising first magnetic thin film layers mainly composed of Co with a thickness of 10 to 100Å, and second magnetic thin film layers mainly composed of $Ni_XFe_YCo_Z$ in which X, Y and Z are $0.6 \le X \le 0.9$, $0 \le Y \le 0.3$, and $0.01 \le Z \le 0.3$, respectively, with a thickness of 10 to 100Å, both of the first and second layers being alternately laminated through a non-magnetic metallic thin film layer sandwiched therebetween, said non-magnetic layer mainly composed of Cu with a thickness of 10 to 35Å."

Claim 2 is the same as claim 1 except that it specifies "... $0 \le Y \le 0.25$, and $0.01 \le Z \le 0.25$,..." and "... Cu with a thickness of 10 to 25Å."

Claim 3: "A magnetoresistive material comprising first magnetic thin film layers mainly composed of Co with a thickness of 10 to 100Å, and second magnetic thin film layers mainly composed of Ni-Co containing not less than 50 atomic% of Ni, with a thickness of 10 to 100Å, both of said first and second layers being alternately laminated through a non-magnetic metallic thin film layer sandwiched therebetween, said non-magnetic layer mainly composed of Cu with a thickness of 10 to 35Å, said second magnetic thin film layers containing less than 90 atomic% of Ni."

Claim 4 is the same as claim 3 except that it specifies "...Cu with a thickness of 10 to 25Å, ..."

Claim 5: "A magnetoresistive material comprising magnetic metallic thin film layers mainly composed of $Ni_XFe_YCo_Z$ with a thickness of 10 to 100Å, and non-magnetic metallic thin film layers mainly composed of Cu with a thickness of 10 to 25Å, both of the two kinds of layers being alternately laminated, wherein X, Y and Z are, by atomic composition ratios, $0.6 \le X \le 0.9$, $0 \le Y \le 0.3$, and $0.01 \le Z \le 0.3$."

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

The respondent requested as main request that the patent be maintained in amended form with:

- description, pages 2 to 7, filed at the oral proceedings;
- claims 1 to 5 filed at the oral proceedings;
- drawings as in the patent specification.

First and second auxiliary requests were as filed with the letter dated 8 October 1998.

VII. The appellant (opponent) essentially argued as follows:

(i) The subject-matter of claim 5 was not novel in view of the content of the earlier European application D10.
The content of D10 had to be construed in the light of the general knowledge of the skilled person, which was reflected in the standard textbook D13. In particular the ternary phase diagram, figure 5-84, showed that the overwhelming majority of Ni-Fe-Co-alloys were soft magnetic materials ($H_c < 13$ Oe). Document D10 disclosed soft magnetic materials reaching high magnetoresistance ratios (eg example 5: 7.8%). Other embodiments with higher nickel contents showed even higher values (eg example 10). The skilled person would thus expect other soft magnetic materials to provide the same effect, and would be led to test such materials with promising giant magnetoresistance-effect (gmr-effect), since there was no established theory explaining this effect at the priority date of the contested patent. Table I in document D3 proved these test activities in the field.

The limits of the range of Cu-layer thickness specified in claim 5 had to be considered as arbitrary because they did not correspond to any peak in the diagrams of figures 2 to 5 of the contested patent. The person skilled in the art would inevitably have come to the teaching of claim 5 when practising what was inherently disclosed in document D10.

(ii) Regarding novelty of the subject-matter of claims 1 to 5 in view of the content of the earlier European application D14, the appellant presented similar arguments. D14 (in particular claim 7 and column 6, lines 38 to 41) mentioned that material compositions as in the contested patent would yield a gmr-effect. Although D14 did not mention concrete compositions for the Ni-Fe-Co-alloys, the person skilled in the art, who was a highly specialised scientist and aware of publications such as D11 to D13, would be led to use material compositions that were known to him. Thus, document D14 inherently gave the same technical teaching as claims 1 to 5 of the contested patent.

(iii) Concerning inventive step, the appellant considered that it was important to view the contribution of the contested patent from the historical development in this technical field. The contested decision only dealt in detail with document D4 and did not take account of the general knowledge reflected by the other documents.

The gmr-effect was first discovered with ferromagnetic layers consisting of monolayers (see D1 to D3). Then it was observed that the effect could be improved with binary alloy layers (see D4; D11; D12, in particular claim 5). Also ternary Ni-Fe-Co-systems had been envisaged in the art (D7).

Starting from this situation with a poor understanding of the underlying effect, the person skilled in the art would look for other soft magnetic material alloys and consult ternary phase diagrams according to standard practice (eg D13, figure 5-84) because Permalloy® (mentioned in D4, D11 and D12) was considered as representative of a class of soft magnetic materials. This route had already been suggested in D11 (claim 5).

Also combinations of soft and hard magnetic materials were envisaged in the prior art (D11, claim 2). Furthermore, since RKKY-oscillations were known to show high resistance change only at certain low values of Cu-layer thickness, the border values of the claimed thickness ranges not corresponding to peak values (figures 2 to 5 of the contested patent) were arbitrary and not based on an effect supported by the disclosure of the contested patent which failed to recognise a peak at around 10Å.

The subject-matter of the contested patent had to be seen as a particular choice of alloys independently of the improved effect invoked by the patentee with the support of a document (D15) which was not available at the priority date when the effect was not understood. Further investigations before and after the priority date had shown that the gmr-effect was due to spin-dependent scattering effects, not to ferromagnetic coupling. The effect was later also observed with uncoupled systems (eg D9) and depended on the number of layers (D14, figure 4). The effect should therefore not be taken into account when judging inventive step.

Nevertheless, document D6 (figure 3) showed that a large gmr-effect was obtained when the magnetization of a soft component layer (Ni-Fe) on one side of a Cu-layer was rotated in a magnetic field too weak to rotate the magnetization of a hard component layer (Co) on the other side of the Cu-layer, resulting in an antiparallel alignment state. The same effect was obtained according to the contested patent. Since this effect was obtained with soft magnetic materials, the person skilled in the art would be prompted by D6, figure 3, to look for such materials and would find, in the standard textbook D13 (figure 5-84), ternary alloys with a low Co content.

(iv) The appellant also objected to the amendment of lines 36 and 37 of page 2 of the patent specification because it implied that the materials of the present invention might be obtained by methods other than "by using a sputtering apparatus" and thus infringed Article 123(2) EPC.

VIII. The respondent (patentee) essentially argued as follows:

(i) Concerning novelty of claim 5, it was not permissible to combine specific elements of general knowledge disclosed in other documents with the content of a prior application under Article 54(3) EPC. The person skilled in the art had not seriously contemplated working within the selected sub-ranges of the contested patent in view of the disclosure of D10. Many degrees of freedom were open (composition and thickness of the different layers), and the selection of two parameters (Ni-content and thickness of the Cu-layer) constituted a narrow and purposive selection with significantly improved gmr-effect because it provided the effect with a low magnetic field and maintained the resistance change even with large magnetic fields. Moreover, the passage in D10, column 3, lines 6 to 11, preferring Fe-Co-alloys to Fe-Ni-alloys, constituted a reasoned statement dissuading the person skilled in the art from practising the teaching of the prior art in the selected ranges specified in the claims.

(ii) Essentially the same considerations also applied to the content of D14. Although Ni-Co-alloys were generally referred to therein, D14 did not disclose any numerical values of compositional ranges and the examples only mentioned magnetic monolayers.

(iii) Concerning inventive step, the respondent argued that the prior art falling under Artic e 54(2) EPC disclosed either materials showing monotonically decreasing magnetoresistance (as Fe/Cr, D6, figure 2) requiring a large magnetic field for noticeable resistance change, or systems with magnetically hard and soft layers having a noteworthy resistance change in a low magnetic field which disappeared in high magnetic fields (as in D6, figure 3), or uncoupled ferromagnetic systems (D9, figure 1) where the effect also disappeared in high magnetic fields. While D9 proposed Ni-Co-layers, the described effect was different in that an additional Fe-Mn-layer constrained the magnetic orientation of one of the Ni-Co-layers.

The contested patent disclosed systems with a high gmr-effect at low magnetic fields which maintained the effect when the magnetic field was increased. The prior art proved that the activities went in many different directions concerning the materials, thickness of the layers and their combinations, but none of the prior solutions had such high values of resistance change in low magnetic fields.

Reasons for the decision

1. The appeal is admissible.

Respondent's main request

2. Claims 1, 2 and 5 as granted have not been amended. Claim 6 has been deleted. The amendments to claims 3 and 4 are disclosed in the application as filed (see page 9, lines 8 to 10) and the limitation to narrower Ni-ranges and to a plurality of layers in claim 4 does not extend the protection conferred (Article 123(2) and (3) EPC).

Deleting the feature: "shown below, that are formed by using a sputtering apparatus" in the summary of the invention (page 2, lines 36 to 37) does not introduce fresh subject-matter because the materials as such were initially disclosed (see eg claims 1 to 6 as filed). The particular method of producing the materials was not presented as essential for the characteristics of the claimed materials (see eg page 7, lines 8 to 15).

The further amendments adapting the description to the amended claims do not infringe Article 123 EPC either.

3. Claims 1 to 5 of the contested patent either specify bilayer structures comprising a plurality of magnetic layers of at least a binary alloy of Ni-Co with 60 to 90% Ni and 1 to 30% Co (claim 5), or quadlayer structures comprising a plurality of first magnetic layers (mainly Co) and second magnetic layers (Ni-Co with 50 to 90% Ni; claims 1 to 4, the broadest ranges being defined by claim 3). All of these magnetic layers are alternately laminated with Cu-layers of 10 to 35Å (preferably 10 to 25Å) thickness.

The description explains that the magnetoresistance change in these materials was found to show RKKY-like (Rudermann-Kittel-Kasuya-Yosida) oscillations which have a peak (maximum of $\Delta R/R$) at about 20Å because an antiparallel state is achieved between the two magnetic layers (see eg page 3, lines 20 to 30 and lines 47 to 53; figures 1 to 5 of the patent specification). However, as evidenced by documents published after the priority date, this peak is only the second peak and a first peak exists around 10Å (cf D10, figures 2 and 3; D14, figures 2, 4, 6, 9, 11; and D15, page 485, right-hand column, paragraph 1; page 486, left-hand column, paragraph 1).

Nevertheless, the claimed range for the thickness of the Cu-layer is sufficiently supported by the description. The thickness of the Cu-layer at which peaks occur may vary with the material used, in particular the saturation field of the magnetic layers involved. Since the composition of the alloys to be used in the invention may vary within a large range and since an increased resistance change is also observed either side of the peaks, the range of 10 to 35Å Cu-layer thickness specified in claims 1 and 3 is not unduly broad and it is centred on the observed (second) peak. The same technical teaching is thus to be attributed to the whole of the range.

4. *Novelty*

4.1 Novelty over D10

4.1.1 D10 has a priority date (29 March 1991) after the first (8 March 1991) but before the further priority dates (May, June 1991) of the contested patent.

Claims 1 to 4 are entitled to the first priority date (see JP 43305/91, claims 1-2 and page 4, line 11 - page 5, line 15). Claim 5, however, relates to structures for which priority may only be derived from a later priority application (JP 148475/91).

D10 thus constitutes prior art under Article 54(3) EPC for the Contracting States DE, FR, GB as far as claim 5 is concerned.

4.1.2 D10 addresses the problem of providing magnetoresistive elements having a large resistance change ΔR/R in a practical, low magnetic field (column 1, lines 44 to 48; column 2, lines 34 to 45; claim 1). An anti-parallel state between two magnetic metallic thin-film layers separated by a non-magnetic thin-film layer is achieved when substantially no magnetic field is applied thereto. The thickness of the non-magnetic layer is chosen so that the magnetoresistance ratio is large and the saturated magnetic field has "a relationship optimal to the specific application of the element". A first peak of ΔR/R occurs at about 10Å thickness, a second peak of ΔR/R (with an advantageous lower saturated magnetic field: column 3, line 31 to

35) occurs at around 20Å (column 4, lines 10 to 35; figures 2 and 3). The thickness of the Cu-layer is thus selected, as in the contested patent, around a value providing a peak of the oscillating magnetoresistance change.

The general disclosure concerning the composition of the magnetic layers refers to "at least two magnetic elements selected from a group consisting of Fe, Co and Ni in combination with non-magnetic Cu-layers (claims 1, 2 and 7). The magnetic and non-magnetic layers each may have a thickness of 2 to 100Å (claims 11 and 13).

Fe-Co and Permalloy® are presented as the particularly preferred alloys to obtain a large magnetoresistance change (column 3, lines 2 to 16; claims 5 and 8).

The magnetic layers of example 5 are mainly composed of Ni-Fe-Co containing 40% Ni and have a thickness of 15Å (column 7, line 44 - column 8, line 11), the thickness of the Cu-layer being chosen at 9Å yielding the maximum of ΔR/R. The magnetic layers of example 10 include 80% Ni (but no Co) and have a thickness of 10Å, the thickness of the Cu-layer being 10Å (column 11, lines 22 to 38).

Examples 1 to 4 and 7 to 9 (partly with different non-magnetic layers) cover a Co-range of 25 to 90% and do not contain any Ni. Example 6 has only 25% Ni. Only Permalloy® (examples 10 to 12) is disclosed as an Ni-rich alloy.

4.1.3 Claim 5 of the contested patent specifies magnetic layers with 60 to 90% Ni and 1 to 30% Co alternately laminated with Cu-layers. These ranges, in combination, must be considered as a narrow selection of the generic disclosure of D10 which does not overlap with the sub-ranges preferred in D10 and which further selects a specific non-magnetic layer (Cu) among a group of possible layers (D10, claim 3).

This selection is sufficiently far removed from the specific examples of D10 in the sense that the known examples uncontestedly lie outside it and illustrate different preferred sub-ranges (Fe-Co and Permalloy®).

The material according to claim 5 shows different characteristics of the magnetoresistance change, which is apparently obtained with lower magnetic fields than in the examples of D10 (patent specification: at 300 Oe; page 6, line 7 to 11, and page 7, lines 5 to 9; cf D10, figures 4 to 11 and 13) so that the specific sub-range is not simply an arbitrary part of the generic disclosure of D10, but is of a different nature and therefore novel.

4.1.4 It follows from the foregoing that the criteria for selection inventions set out in unpublished decision T 279/89 (point 4.1) are satisfied in the present case. Moreover, since the technical teaching underlying the respective sub-ranges is different and since the passage of D10 (column 3, lines 6 to 11) may be seen as a statement dissuading the skilled person from applying the concept of D10 in the sub-range of the contested patent, the person skilled in the art would not seriously contemplate applying the teaching of D10 in this range (see decision T 26/85, OJ EPO 1990, 22, point 9).

4.1.5 The board does not agree with the appellant that the general knowledge as reflected by document D13 makes the claimed sub-range available to the person skilled in the art when starting from the teaching of D10. Although it might be obvious to try and find other soft magnetic materials using standard diagrams, this criterion may not be used when judging novelty and comparing subject-matter as claimed with what was made available in a prior disclosure.

The poor knowledge about the gmr-effect at the priority date cannot be accepted as an argument that the teaching of claim 5 is inherent in that of D10 and would be arrived at by experiments when practising this teaching. On the contrary, if experiments had to be carried out to find out the exact teaching of D10 in sub-ranges not mentioned in the document, this indicates that the document did not directly and unambiguously disclose, and thus make available, the range selected in the contested patent.

4.2 Novelty over D14

4.2.1 European application D14 has a priority date (8 February 1991) before the first priority date of the contested patent and thus constitutes prior art under Article 54(3) EPC for all the designated Contracting States.

4.2.2 D14, starting from the basic principle of magnetoresistance oscillations, generally addresses the problem of providing "new structures and/or material combinations" with unexpected advantages (column 1, line 57 - column 2, line 4). To this end, the inventors suggest using bilayer structures (column 2, lines 5 to 15 and lines 38 to 49; column 7, lines 1 to 9; claims 1 and 2) or quadlayer structures (column 2, lines 27 to 37; claims 3 and 10) with Cu or another non-magnetic material as intermediate layers (claims 8 and 11). The thickness of the non-magnetic layers is chosen so that the sensor operates at the first or second magnetoresistance peak (claims 5 and 6; figures 4 and 6). The non-magnetic thin-film layers are thus within the range of those of the contested patent (Cu: 10 to

35Å, in particular 10 to 25Å).

D14 further mentions Co and Ni-Co-alloys in combination with Cu-layers as suitable materials both for bilayer and quadlayer structures (column 6, lines 38 to 45; claims 1, 7, and 10). One specific quadlayer structure disclosed contains Co and Ni-Co-layers separated by Cu-layers (column 6, lines 38 to 45; claims 3, 8, 9, 10).

4.2.3 However, D14 does not indicate any values of atomic percentages for the alloys. All the examples consist of magnetic monolayers, ie layers consisting of only one element. The thickness of the magnetic layers is taught to be "as thin as possible" (column 6, lines 46 to 58), and all the examples using Cu as non-magnetic layers have Co-layer thicknesses of less than or equal to 10Å (figures 2, 4, 6, 8, 13) which is the lower limit of the magnetic layer thickness ranges specified in the claims of the contested patent.

The mere mentioning of these alloys cannot be considered as anticipating the narrower ranges specified in claims 1 to 5 of the contested patent.

Also the effect obtained with the selection of this sub-range, ie a very narrow peak in the curve of resistance change with magnetic field, permitting a large resistance change in low fields and maintaining the obtained change even in high magnetic fields (see the figure filed with the patentee's letter of 20 February 1997), may be seen as an indication that the invention defined by these parameters is different in nature from that of the general disclosure of D14.

4.2.4 The sub-range of 50 to 90% Ni in a binary or ternary Ni-Co alloy, in combination with the values of thickness, has to be seen as narrow when compared with the general disclosure of Ni-Co bilayer or quadlayer structures mentioned in D14. It is also sufficiently far removed from the known range illustrated by means of examples since the known examples do not contain binary or ternary alloys of this kind. Finally, for the reasons set out above, the selected area does not provide an arbitrary specimen from the prior art, but refers to another invention (cf decision T 279/89, point 4.1, *supra*).

Since countless combinations of magnetic and non-magnetic layers with unspecified thickness are offered as possibilities in the general disclosure of D14, the person skilled in the art would not seriously contemplate applying the technical teaching of this document in the range of overlap with the sub-ranges of the contested patent when none of the specific examples of D14 comes close to this range (see decision T 26/85, point 9, *supra*).

4.3 Even taking into account that the disclosure of an earlier European application is not confined to the detailed information given in the examples of how the invention is carried out, but may include ranges where the values lie just outside these examples (see decisions T 12/81, OJ EPO 1982, 296, point 7 and T 17/85, OJ EPO 1986, 406, points 7.3 and 7.4), the ranges specified by the claims of the contested patent are not made available to the person skilled in the art by the disclosure of D10 or D14 because these ranges represent a purposive selection of binary or ternary alloys of specified thickness which, in combination, were not at all contemplated by the authors of D10 or D14.

4.4 None of the other cited documents discloses a material as claimed. This was not disputed by the appellant. The board is therefore satisfied that the subject-matter of claims 1 to 5 of the main request is new in the meaning of Article 54(1) to (3) EPC.

5. *Inventive step*

5.1 The contested decision, under point 8, states that document D4 was accepted by all the parties as reflecting the closest prior art. Also in the oral proceedings before this board the appellant has argued that it would be obvious to replace Permalloy®, a typical representative of a soft magnetic material, by another soft magnetic material.

Document D4 reports on investigations about the dependency of the interlayer exchange constant on the interlayer thickness (see Abstract). The thickness of a Cu-layer sandwiched between two Permalloy®-layers of 290Å thickness is varied between zero and 20Å (page 12010, right-hand column, last paragraph figures 5 and 7). But the document does not give any guidance as to the appropriate interlayer thickness except that it states that the interlayer exchange coupling vanishes for a Cu-layer thickness of 20 to 30Å thereby indicating that the coupling is no longer ferromagnetic (Abstract; page 12005, right-hand column, lines 4 to 7 from the bottom; page 12008, right-hand column, lines 3 to 13 from the bottom). The exchange coupling for 100Å Permalloy®/Co-layers is found to vanish at values of the order of 10Å for Cr as interlayer material (Abstract).

5.2 Documents D5 and D6 refer to superlattices comprising Permalloy®/Co-layers separated by Cu-layers and disclose a large gmr-effect obtained by a field-induced ferrimagnetic state in a field which lies between the saturation fields of the soft (Permalloy®) and the hard (Co) component. The advantage of obtaining this large gmr-effect with very low fields (of the order of 100 Oe) is highlighted as contrasting with the high field needed for Fe/Cr systems where the antiparallel alignment is said to be caused by an interlayer antiferromagnetic coupling (see D5, in particular, figures 1 and 2 and D6, figures 2 and 3 as well as page 534, § 5).

However, these documents disclose different second magnetic layers (Permalloy®) and an interlayer thickness of 50Å which is well outside the claimed ranges.

5.3 Document D3 presents a study and a simplified model of ferromagnetic and antiferromagnetic interlayer coupling in metallic superlattices. Table I lists relevant information from several papers referring, *inter alia*, to the systems of documents D2 and D4 (references 17 and 19). No further details are given about Permalloy®/Cu systems.

5.4 Also documents D11 (claims 1 and 5) and D12 (claims 1 and 5) refer to Permalloy® and other Fe-, Co- or Ni-alloys. The more relevant document D11 suggests values of thickness for the magnetic layers of 100 to 400Å (column 2, lines 3 to 11). The non-magnetic interlayer may be composed of Cu with a thickness in the range of 10 to 40Å (column 2, lines 26 to 29; claim 4). Antiparallel alignment is taught to be achieved in several ways: field-induced coupling of decoupled layers (figure 4: $SmCo_5$/Au/Fe; column 3, lines 41 to 50), antiferromagnetically coupled (figure 4: Fe/Cr/Permalloy®; column 3, lines 51 to 66), or obtained by exchange anisotropy between a ferromagnetic (Permalloy®) and a neighbouring antiferromagnetic layer (Fe-Mn) when an external field is applied (figure 5: Permalloy®/Cu/Permalloy®/Fe-Mn; column 2, lines 40 to

60; column 3, lines 56 to 66).

5.5 Similarly, also document D9 refers to uncoupled Permalloy®-layers separated by thin Cu-layers (phenomenon referred to as "spin-valve effect") as well as to ferromagnetic pairs wherein one was free to rotate while the other was constrained by exchange anisotropy through contact with antiferromagnetic Fe-Mn (page 1297, left-hand column). A large observed gmr-effect is attributed to a change of the magnetizations in the two ferromagnetic layers (antiparallel alignment in fields between 2 Oe and 135 Oe, otherwise parallel; page 1297, right-hand column). The influence of the interlayer thickness is described as yielding a broad, rounded maximum in the magnetoresistance curve, for a layer thickness of 20Å, due to consecutive switching of the magnetizations in the ferromagnetic layers because their hysteresis loops are nearly separated. The document further explains that a slightly smaller effect is observed when Ni-Co is substituted for Ni-Fe (figures 1 to 3, page 1299, left-hand column, first new paragraph).

Although the thickness of the different ferromagnetic layers (Permalloy®: 50Å) and that of the non-magnetic interlayers (Cu: 10 to 26Å) of these examples fall within the range of the present claims 1 to 5, it has to be noted that the Cu-layers are not alternately laminated with, or sandwiched between, the specified ferromagnetic layers.

5.6 Document D1 and, to a lesser degree of relevance, D2 refer to Co/Cu systems. D1 describes Co/Cu superlattices with values of layer thickness (Co: 5 to 40Å; Cu: 25Å in document D1) in the ranges specified in claims 1 to 5 of the contested patent.

5.7 None of the documents falling under Article 54(2) EPC clearly discloses oscillations of the magnetoresistance dependent on the thickness of a Cu-layer suggesting a maximum of magnetoresistance at about 20Å, although D6 (page 535, lines 5 to 15) and D3 (page 877, Abstract and Table I) refer to such oscillations in a very general manner. Document D2 (page 475, left-hand column, paragraph 1 and page 477, left-hand column, last paragraph) refers to oscillations between ferromagnetic and antiferromagnetic states for Co-monolayers separated by Cu-layers.

5.8 Starting from a Permalloy®/Cu/Permalloy® system as disclosed in document D4, the person skilled in the art would have to carry out a series of steps to arrive at the subject-matter of claim 5 of the contested patent: choose Ni-Fe-Co, as specified in the claim, instead of Permalloy®;
reduce the thickness of these layers to at most 100Å;
choose an appropriate Cu-interlayer thickness (in the vicinity of the magnetoresistance peak at about 25Å);
and arrange a plurality of such magnetic and non-magnetic layers, alternately laminated.

5.8.1 The board cannot agree with the appellant that this would be a matter of a simple replacement of a typical soft magnetic material by another known one. The only document which hints at including Co in the specified amount is document D7 (page 1130, right-hand column). However, this document (Abstract; page 1128, chapter II) refers to thin films which are much thicker (3000Å) and which are not separated by a Cu-layer.

5.8.2 Document D9 (page 1297, left-hand column, lines 16 to 11 from the bottom; page 1299, left-hand column, first new paragraph), which also refers to Ni-Co as an alternative material, suggests its use in a different context ("exchange anisotropy" with Fe-Mn, see above), indicates that the effect with Ni-Co is slightly smaller than with Ni-Fe and does not disclose a plurality of Cu-layers laminated between Ni-Co-layers.

5.8.3 Other documents which only refer to Ni, Fe, Co and their ferromagnetic alloys (eg document D8, column 3, lines 1 to 5 and Table) only confirm that such alloys were known to the person skilled in the art, but do not suggest the specific alloys and layer thicknesses as specified in the claims of the contested patent.

5.9 Starting from a Permalloy®/Cr/Co system as disclosed in document D4, similar steps to those mentioned in paragraph 5.8 above would be necessary to arrive at the subject-matter of one of claims 1 to 4 of the contested patent.

Here, the thickness of the magnetic layers (100Å) is at the limit of the range specified in the claims. However, the interlayer material (Cr) is different and of smaller thickness than that of the alternatively proposed Permalloy®/Cu/Permalloy® system (see figure 5 of D4). Similar considerations as set out in paragraphs 5.8.1 and 5.8.2 above apply to the use of Ni-Co instead of Permalloy® and the choice of a plurality of magnetic layers and Cu-layers sandwiched therebetween.

5.10 The board cannot see any convincing reason why the person skilled in the art, starting from a Co/Cu superlattice as disclosed eg in D1, would arrive at the subject-matter of one of claims 1 to 5 by simply testing other known magnetic alloys.

Although there are plenty of experimental results available, no indication can be fond, for the reasons already set out above, that the particular alloy combinations arranged as specified in the contested patent would provide large magnetoresistance changes in the particular range of Cu-layer thickness. Therefore, such reasoning is based on hindsight knowledge of the contested patent.

5.11 Summarising the available information at the priority date of the contested patent, it should be noted that high activity of the specialist in this field characterizes a situation where only poor theoretical knowledge was available for explaining the gmr-effect found with certain multilayer structures. The person skilled in the art therefore had a high degree of freedom of varying parameters, such as the composition of the magnetic layers and that of the non-magnetic layers as well as their respective thicknesses. In such a situation, the finding of a particularly advantageous combination of parameters producing a new effect, ie a high magnetoresistance change in low magnetic fields which is maintained even in high magnetic fields, cannot be considered as an obvious choice of materials and parameters which would have the usually expected effect.

5.12 The subject-matter of claims 1 to 5 of the main request is therefore considered as involving an inventive step (Article 56 EPC).

6. In the result, the board is of the opinion that the patent, as amended according to the respondent's main request, and the invention to which it relates, meet the requirements of the EPC. The respondent's auxiliary requests therefore do not need to be considered.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to maintain the patent in amended form with:

   - description, pages 2 to 7, filed at the oral proceedings;

   - claims 1 to 5, filed at the oral proceedings;

   - drawings as in the patent specification.

The Registrar:

J. Rückerl

The Chairman:

W. J. L. Wheeler