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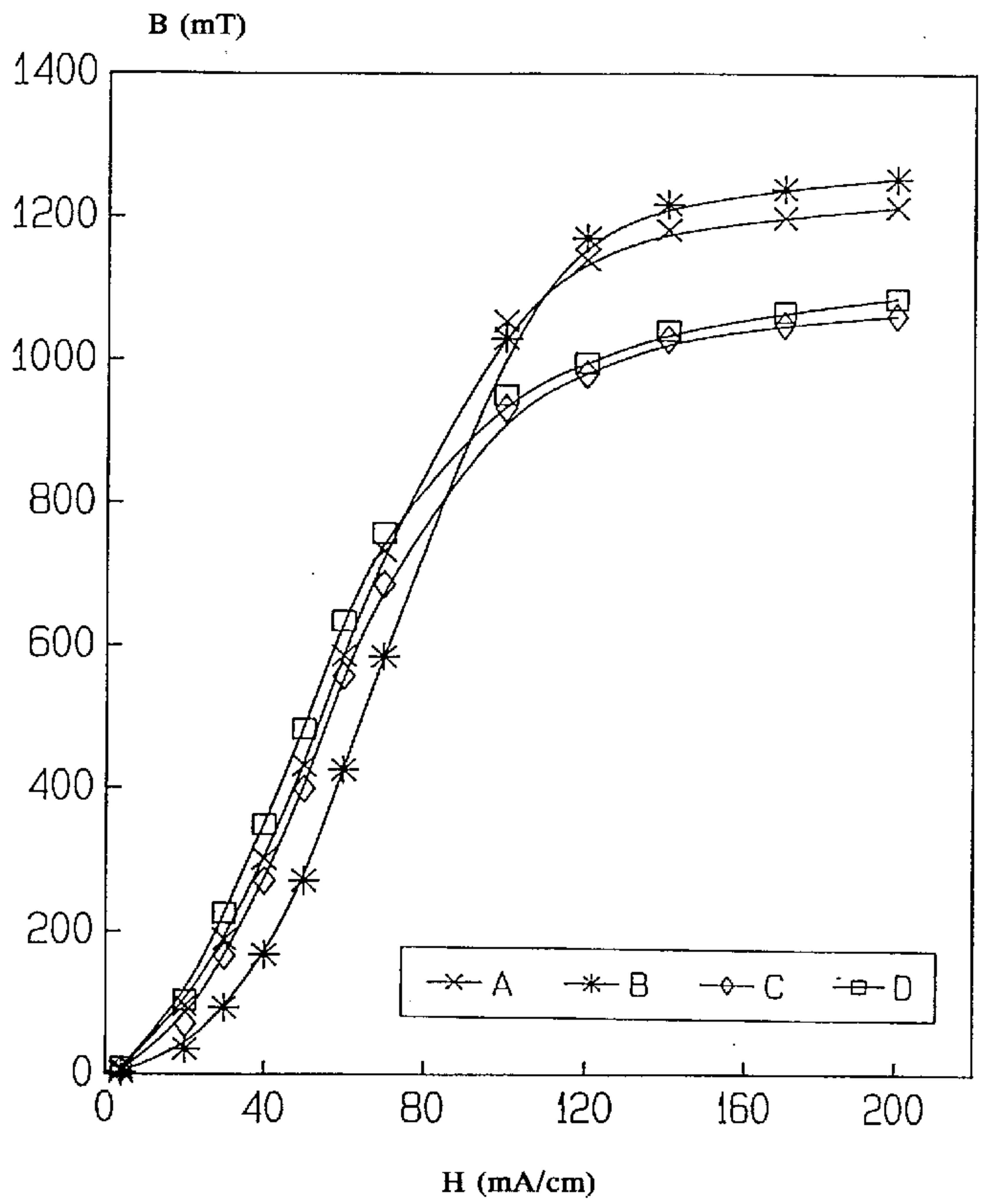
(54) **ALLIAGE FER-NICKEL A PROPRIETES MAGNETIQUES SPECIALES DE FAIBLE INTENSITE**

(54) **IRON-NICKEL ALLOY HAVING SPECIAL SOFT MAGNETIC PROPERTIES**



A: Material according to the invention, characterization A
B: Material according to the invention, characterization B
C: Prior art material in fine-grained isotropic structure after 1080 °C/4 h holding time
D: Prior art material in the secondarily recrystallized state after 1150 °C/6 h holding time

(57) The invention relates to a soft magnetic iron-nickel material containing 46-49% nickel, the residue being substantially iron. The characterizing feature of the invention is that after a heat treatment on a strip sample 0.20 mm in thickness, the iron-nickel material has a texture distribution in which of measured (111) polar figures the relative proportions of the texture components having the Euler angles (φ1, Φ, φ2) = (0, 0, 0) are 20 to 50% and (φ1,Φ, φ2) = (26, 45, 30) are 10 to 40%, or having the Euler angles (φ1,Φ, φ2) = (0, 0, 0) are 10 to 40%, (φ1, Φ, φ2) = (26, 45, 30) are 5 to 25% and (φ1, Φ, φ2) = (30, 35, 35) are 10 to 25%.

Abstract:

The invention relates to a soft magnetic iron-nickel material containing 46-49% nickel, the residue being substantially iron. The characterizing feature of the invention is that after a heat treatment on a strip sample 0.20 mm in thickness,the iron-nickel material has a texture distribution in which of measured (111) polar figures the relative proportions of the texture components having the Euler angles ($\varphi 1$, Φ, $\varphi 2$) = (0, 0, 0) are 20 to 50% and ($\varphi 1$, Φ, $\varphi 2$) = (26, 45, 30) are 10 to 40%, or having the Euler angles ($\varphi 1$, Φ, $\varphi 2$) = (0, 0, 0) are 10 to 40%, ($\varphi 1$, Φ, $\varphi 2$) = (26, 45, 30) are 5 to 25% and ($\varphi 1$, Φ, $\varphi 2$) = (30, 35, 35) are 10 to 25%.

RON-NICKEL ALLOY HAVING SPECIAL SOFT MAGNETIC PROPERTIES

The invention relates to a material of an iron-nickel alloy containing 46-49% nickel and having special soft magnetic properties which are achieved by the adjustment of a structure having a predetermined texture distribution following a heat treatment.

It is known that certain magnetic properties can be achieved or positively influenced in iron-nickel alloys having nickel contents between approximately 40 and 65% by the adjustment of textures having a preferred direction <100> in the rolling direction, such as the cubic texture or the (210)<001> texture (F.Pfeifer, Structure of Metals, Deutsche Gesellschaft für Metallkunde e.V., Oberursel (1981), pages 293 et seq.). This is possible because in iron-nickel alloys having medium nickel contents the cube edge <100> of the cubically face-centred lattice is the magnetic preferred direction.

Ranges for the cubic texture (100)<001> and for the (210)<001> texture are determined by the final degree of deformation and the intermediate annealing temperature and also the grain size achieved thereby prior to the last cold shaping, after the final annealing treatment. This dependence of the structure is shown diagrammatically in Fig. 1(a) and (b).

At first with final degrees of deformation up to approximately 80% after the final annealing treatment, a fine-grained isotropic grain structure is formed by primary recrystallization, the grain size generally increasing with increasing final annealing temperature and increasing final degree of deformation. With final degrees of deformation greater than 80% and, on condition that the final annealing temperature is not too high - approximately between 900 and 1050°C - and the holding times are not too long, the cubic texture (100)<001> is formed, whose sharpness increases with increasing final degree of deformation and decreasing intermediate annealing temperature. On a certain fairly high final annealing temperature of approximately 1080°C onwards, with a long enough dwell time at that temperature secondary recrystallization sets in and destroys the cubic layer. The final annealing temperature at which the secondary recrystallization begins depends inter alia on impurities and additives with affinity to oxygen. In general these increase the necessary final annealing temperature. This also affects the range of the final degree of deformation and the intermediate annealing temperature at which secondary recrystallization can take place. This range of suitable intermediate annealing temperatures and degrees of deformation corresponds to that of the cubic texture, since this is a precondition for secondary recrystallization. Over a certain narrowed-down range, due to growth selection during secondary recrystallization preferably grains having the orientation (210)<001> are formed. With higher degrees of deformation, coarse grain is formed.

Table 1 shows characteristic magnetic properties for prior art materials having a nickel content of approximately 48% with the aforedescribed structures, in comparison with the material according to the invention for the strip thickness 0.20 mm.

Table 1

Structure	$\mu 4$[1] ($\hat{H}$ = 4 mA/cm)	B($\hat{H}$ = 200 mA/cm) in mT[2]
fine-grained, isotropic prior art materials	6000 - 12000	approx. 1050
secondarily recrystallized	12000 - 20000	approx. 1080
material according to the invention	6000 - 14000	approx. 1100 - 1300

1) Level of initial permeability $\mu 4$, depends on the level of the final annealing temperature and the duration of the dwell time during the final annealing treatment.

2) Magnetic values are measured at 50 Hz.

In comparison with prior art materials, more particularly with fairly high field strengths - for example, $\hat{H}$ = 120 mA/cm or higher, especially, 200 mA/cm -, the material according to the invention achieves substantially higher values for the flux density B i.e., at least 1100 mT, accompanied by still relatively high initial permeabilities. These values are achieved by a purposeful production method; a particular distribution of textural components is adjusted in the primary structure by a predetermined final degree of deformation and a predetermined intermediate annealing temperature after a final heat treatment with strip thickness 0.20 mm.

Using measured {111} polar figures, the material according to the invention is characterized by stating the relative proportion for each textural component, each of which is described by the Euler angle (φ1, Φ, φ2) (Table 2).

Table 2 discloses the relative proportion M for each textural component, each described by the Euler angles (φ1, Φ, φ2), determined for measured {111} polar figures on differently heattreated samples of strip thickness 0.20 mm, whereby the material according to the invention is characterized by two textural distributions A and B. The three Euler angles as defined in G. Goltstein "Rekristallisation metallischer Werkstoffe", 1984, ed.: Deutsche Gesellschaft für Metallkunde e.V., give a determined sequence of three rotation angles, which transfer the sample-solid system of coordinates to the crystal-solid one.

Table 2

Characterization	A				B			
textural components	φ1	Φ	φ2	M / %	φ1	Φ	φ2	M / %
	0	0	0	20-50	0	0	0	10-40
	26	45	30	10-40	26	45	30	5-25
					30	35	35	10-25

The material according to the invention is characterized in that after a heat treatment on a sample or strip thickness 0.20 mm the relative proportions of the textural components having the Euler angles ($\varphi1$, Φ, $\varphi2$) = (0, 0, 0) and ($\varphi1$, Φ, $\varphi2$) = (26, 45, 30) are 20 to 50% and 10 to 40% respectively (characterization A). This textural distribution can be achieved with a heat treatment of, for example, 1080°C and a holding time of 4 hours, based on a fairly long steady annealing.

As Fig. 2 makes clear, the material according to the invention has advantages, since even the high values for the flux density B with medium and fairly high field strengths are reached even with relatively low final annealing temperatures and relatively short annealing times, since in this case secondary recrystallization is not a necessary precondition for the good magnetic properties described. In this case - i.e., after a heat treatment, based on a brief continuous annealing, on a sample of strip thickness 0.20 mm the material according to the invention is characterized in that the relative proportions of the textural components having the Euler angles ($\varphi1$, Φ, $\varphi2$) = (0, 0, 0), ($\varphi1$, Φ, $\varphi2$) = (26, 45, 30) and ($\varphi1$, Φ, $\varphi2$) = (30, 35, 35) are 10 to 40%, 5 to 25% and 10 to 25% respectively (characterization B). This textural distribution can be achieved, for example, by a heat treatment of 1060°C and a dwell time of 20 minutes on a strip sample of thickness 0.20 mm.

The material according to the invention, whose chemical composition is shown in Table 3, is suitable more particularly for brief heat treatments in continuous furnaces at relatively low temperatures. Moreover, the material according to the invention has the maximum saturation flux density for iron-nickel alloys of approximately 1.55 T.

Table 3
(% by weight)

	W1	W2
Cr	0.05	0.03
Ni	47.65	47.60
Mn	0.52	0.41
Si	0.27	0.23
Mo	0.30	0.06
Ti	0.01	0.01
Nb	0.01	0.01
Cu	0.05	0.05
Fe	51.05	51.50
S	0.002	0.002
P	0.002	0.002
Al	0.005	0.005
Mg	0.001	0.001
Pb	0.001	0.001
Sn	0.01	0.01
Co	0.05	0.05
C	0.016	0.007

The majority of the elements listed in Table 3 in the range up to 0.1% are usual admixtures due to melting. Their total content should be below 0.5%. The elements with more than 0.1% - i.e., Mn, Si, Mo - should be limited to max. 0.1% Mn, max. 0.5% Si, max. 1% Mo.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A heat treated iron-nickel soft magnetic material consisting of 46-49% by weight nickel and the balance of substantially iron, which, when a strip sample 0.20 mm in thickness thereof is measured, has a texture distribution in which of measured {111} polar figures, relative proportions of texture components having the Euler angles ($\varphi1$, ϕ, $\varphi2$) = (0, 0, 0) and ($\varphi1$, ϕ, $\varphi2$) = (26, 45, 30) are 20 to 50% and 10 to 40%, respectively.

2. A heat treated iron-nickel soft magnetic material consisting of 46-49% by weight nickel and the balance of substantially iron, which, when a strip sample 0.20 mm in thickness thereof is measured, has a texture distribution in which of measured {111} polar figures, relative proportions of texture components having the Euler angles ($\varphi1$, ϕ, $\varphi2$) = (0, 0, 0), ($\varphi1$, ϕ, $\varphi2$) = (26, 45, 30) and ($\varphi1$, ϕ, $\varphi2$) = (30, 35, 35) are 10 to 40%, 5 to 25% and 10 to 25%, respectively.

3. A heat treated iron-nickel soft magnetic material according to claim 1, which contains 0.53 wt.% Mn, 0.27 wt.% Si, 0.30 wt.% Mo and less than 0.5 wt.% of total impurities due to melting in addition to nickel and iron.

4. A heat treated iron-nickel soft magnetic material according to claim 2, which contains 0.41 wt.% Mn, 0.23 wt.%

Si, 0.06 wt.% Mo and less than 0.5 wt.% of total impurities due to melting in addition to nickel and iron.

5. A heat treated iron-nickel soft magnetic material according to claim 1 or 3, which is obtainable by final heat treatment at 1080° C for a holding time of 4 hours.

6. A heat treated iron-nickel soft magnetic material according to claim 2 or 4, which is obtainable by final heat treatment conducted at 1060°C for a dwell time of 20 minutes.

7. A heat treated iron-nickel soft magnetic material according to claims 1, 3 or 5, which, with magnetic field strengths H of 120 mA/cm or higher, has a magnetic flux density B of at least 1100 mT, as measured following a slight annealing treatment on core sheet packs of strip thickness 0.20 mm at a frequency of 50 Hz.

8. A heat treated iron-nickel soft magnetic material according to claim 2, 4 or 6, which is obtainable by final heat treatment at 1080°C for a holding time of 4 hours.

9. A heat treated iron-nickel soft magnetic material according to claim 7, wherein the magnetic flux density B is 1100 - 1300 mT.

10. A heat treated iron-nickel soft magnetic material according to claim 8, wherein the magnetic flux density B is 1100 - 1300 mT.

11. A heat treated iron-nickel soft magnetic material according to any one of claims 1 to 10, which has an initial permeability $\mu 4$ of 6,000 to 14,000 as measured at a field strength $\hat{H}$ of 4 mA/cm using the strip sample 0.20 mm in thickness.

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PATENT AGENTS

Fig. 1

a)

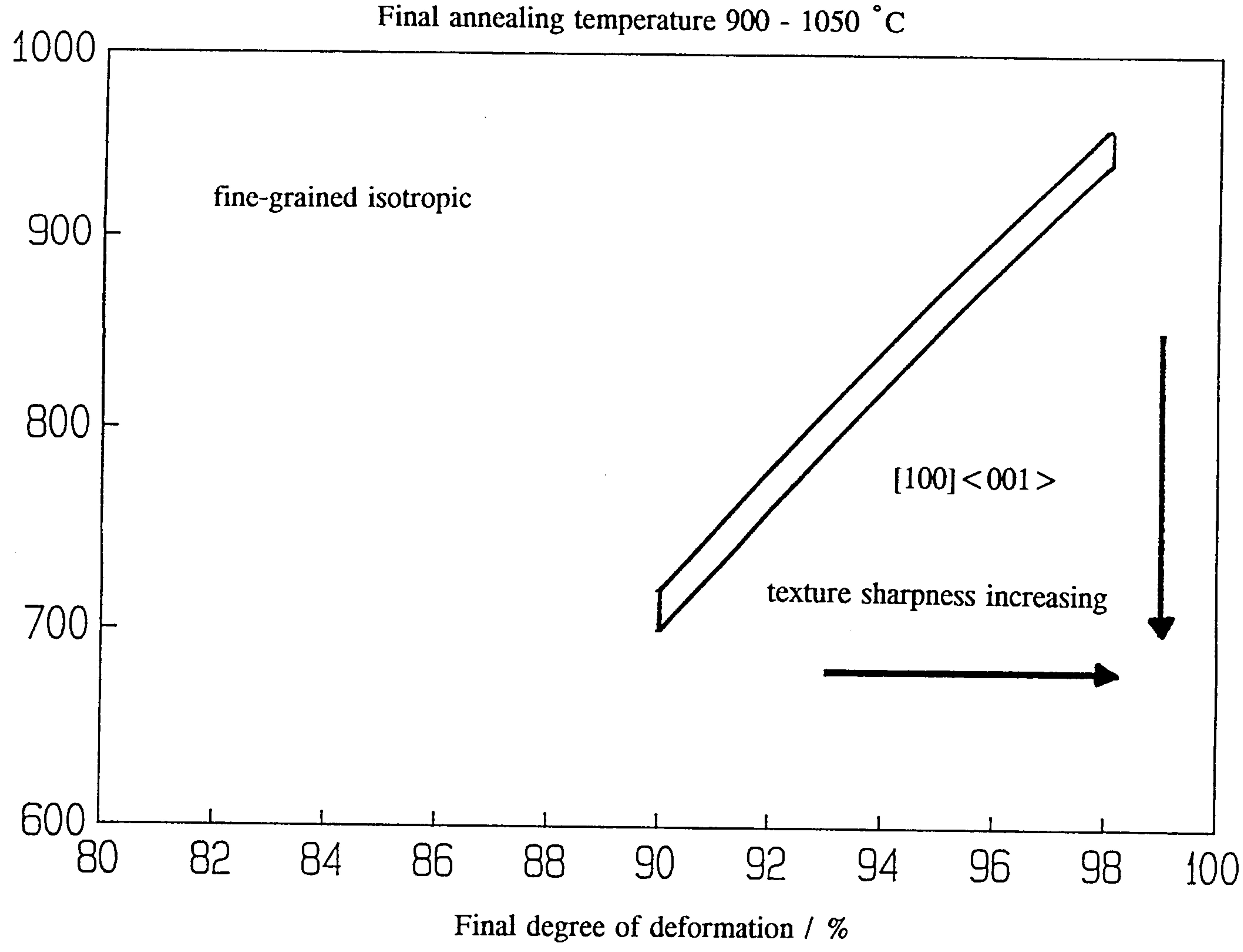

Fig. 1: Diagrammatic structure in dependence on the final degree of deformation and the annealing temperature in the intermediate annealing treatment prior to the final cold deformation for an iron-nickel alloy having approximately 48 % nickel for two final annealing temperature ranges of 900 - 1050 °C and 1050 - 1200 °C

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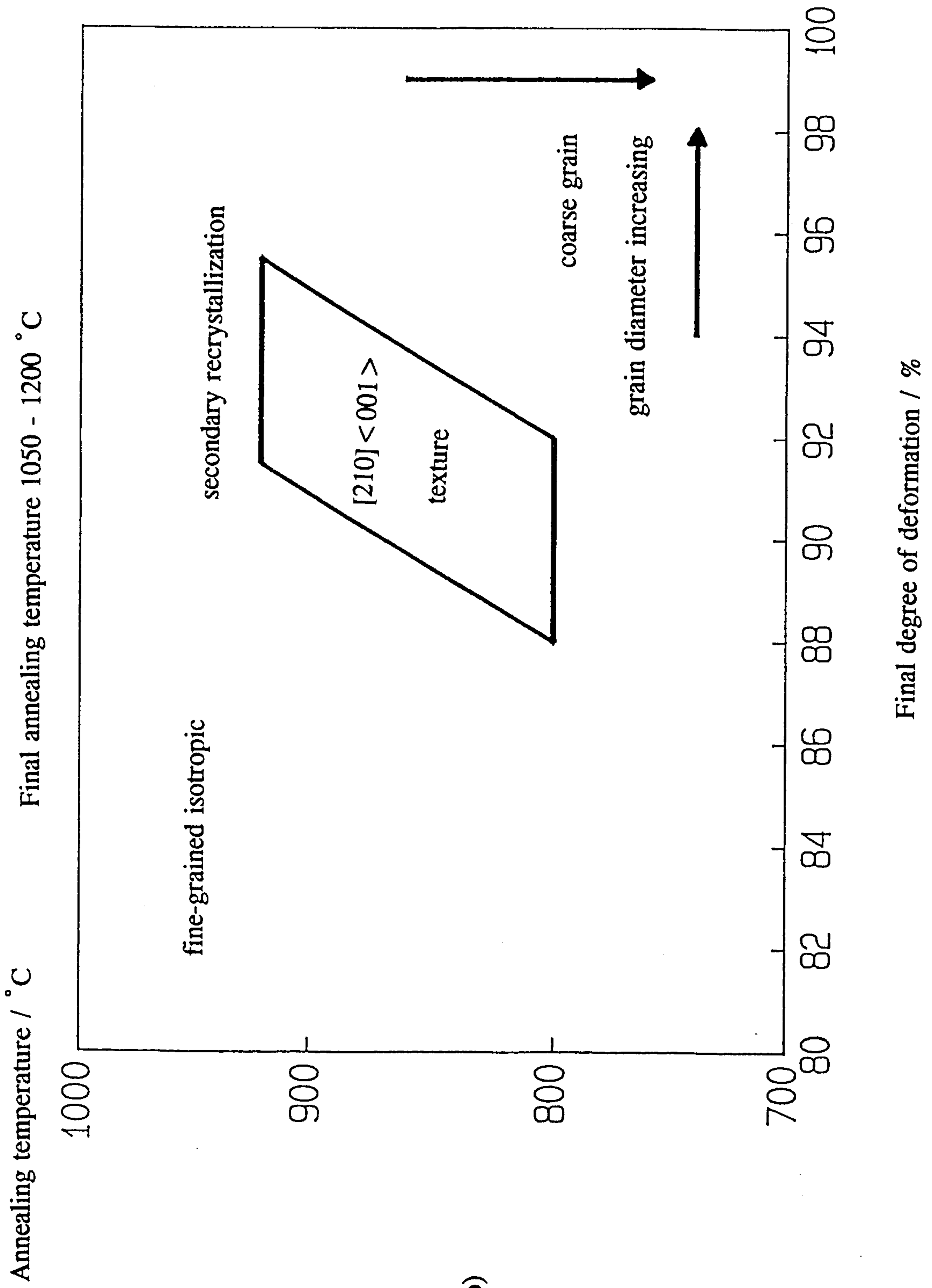
Fig. 1



b)

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Fig. 2

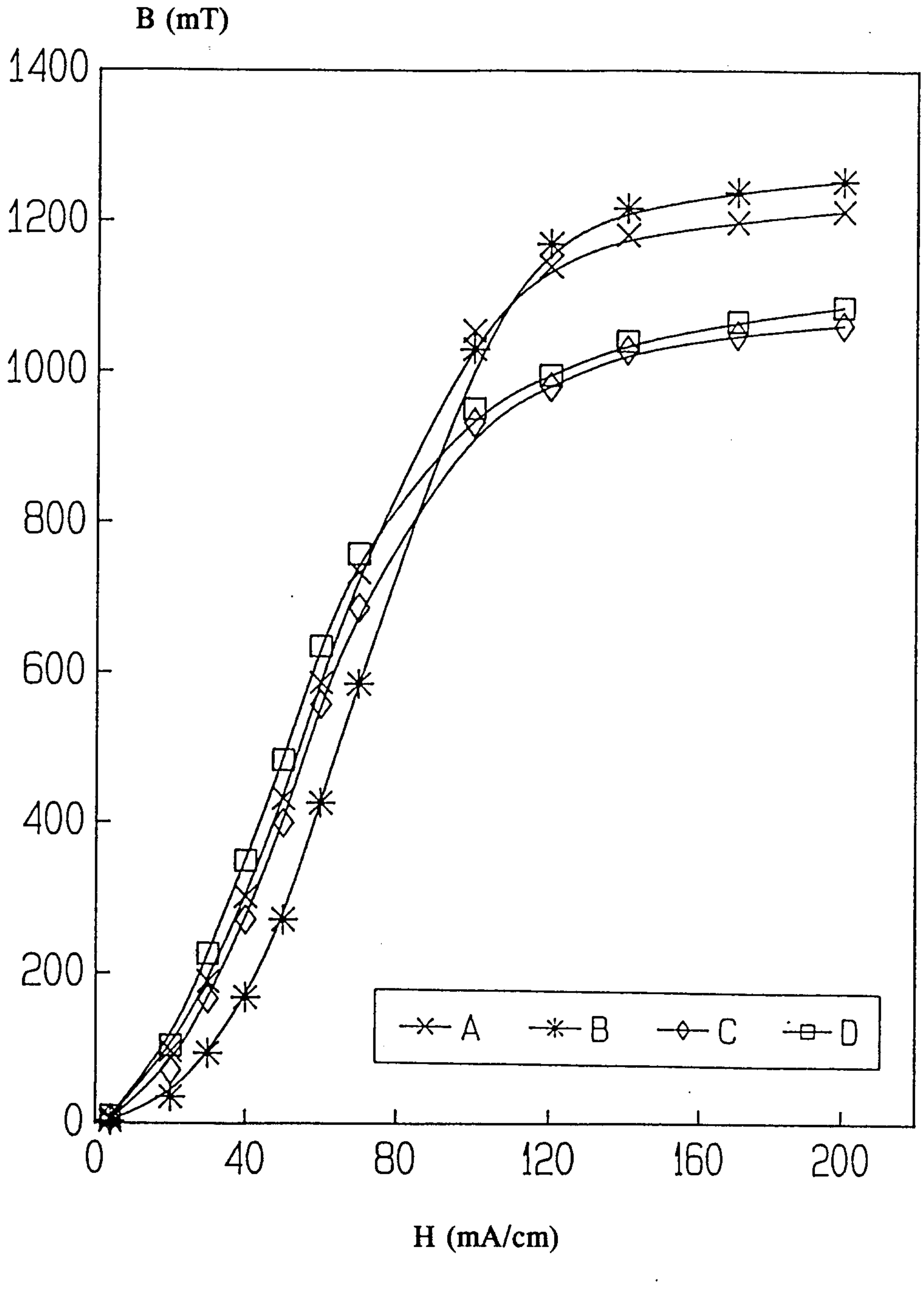

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Fig. 2 Flux density/field strength curves of an iron-nickel alloy containing approximately 48 % nickel in the structures "fine-grained, isotropic" and "secondarily recrystallized, (210)<001> texture" for a strip thickness of 0.20 mm, measured at 50 Hz on M42 core sheet packs, in comparison with the material according to the invention.

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