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IRON-NICKEL-COPPER ALLOY
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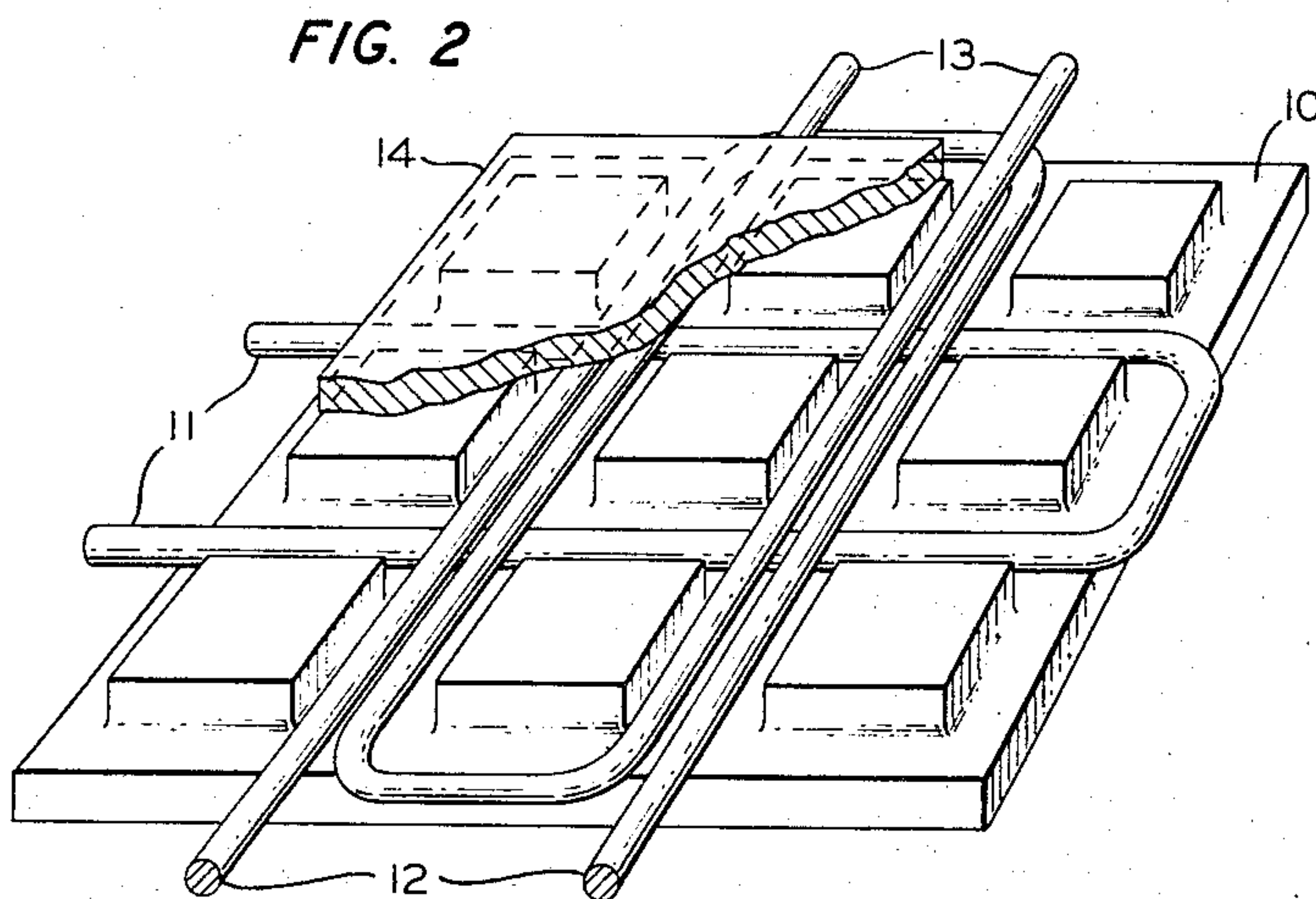
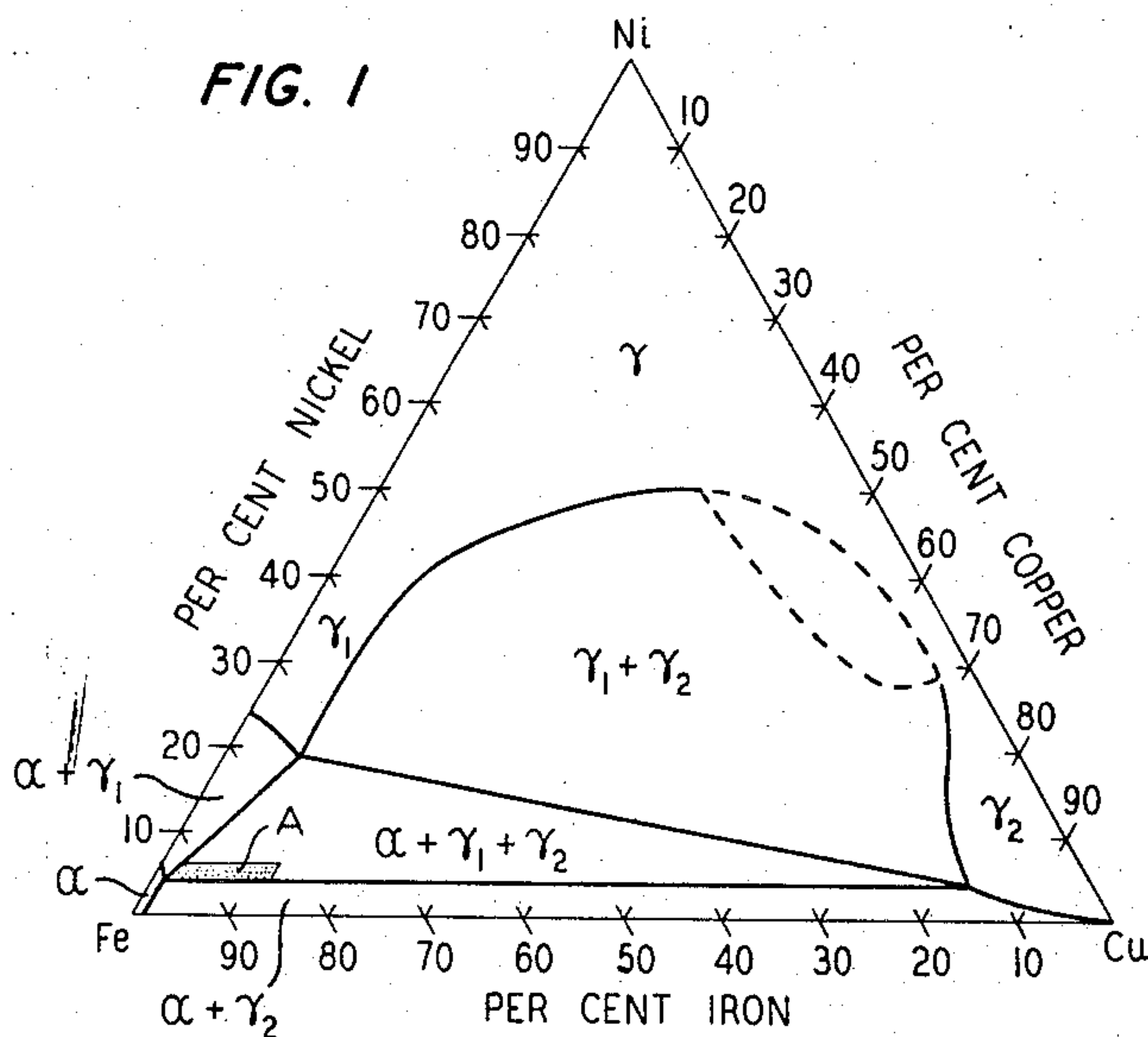


FIG. 3

ACRYLOID LACQUER $\sim 18,000 \text{ \AA}^\circ$
84 Fe - 11 Cu - 5 Ni $\sim 7,000 \text{ \AA}^\circ$
GOLD $\sim 10,000 \text{ \AA}^\circ$
OXYGEN FREE HIGH CONDUCTIVITY COPPER SUBSTRATE

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MEMORY ELEMENT WITH A MAGNETICALLY ISOTROPIC IRON-NICKEL-COPPER ALLOY

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ABSTRACT OF THE DISCLOSURE

The disclosure describes a range of magnetic alloy compositions which contain iron, nickel and copper and which exhibit very low anisotropy. This property makes the alloys especially useful in magnetic memory devices such as the "waffle iron" memory. Procedures for making these devices are described.

This invention relates to magnetic materials and to devices incorporating their use.

Magnetic memory devices typically require materials with a large magnetic anisotropy so that an "easy direction" exists to provide a simple and reliable switching pattern. However, an occasional application arises in which a reliable square-loop material is desired which is essentially isotropic in magnetic behavior. An exemplary case is found in the now well-known cubic waffle-iron memory described and claimed in United States Patent 3,274,571, issued Sept. 20, 1966 to A. H. Bobeck and J. L. Smith.

This invention is directed to novel magnetic alloys which provide useful and favorable magnetic behavior that is essentially equivalent in any crystal orientation. The invention is defined by a restricted range of compositions in the iron-nickel-copper system. The range is defined as follows:

	Wt., percent
Fe	81-95
Ni	4-6
Cu	1-13

A range of compositions formed to provide particularly useful properties for the waffle-iron memory device is defined as:

	Wt., percent
Fe	82-88
Ni	4-6
Cu	8-12

A typical magnetic device operating with a magnetic film having an alloy composition: 84% iron, 5% nickel, 11% copper revealed the following magnetic characteristics for the alloy:

Coercive force, oersteds	10
Squareness ratio B_R/B_S	0.9
Thickness, A.	7,000
Switching coefficient, oe.-μsec.	0.52
Anisotropy constant, ergs/cm. ³	1500
Output uniformity, percent	±10

A low anisotropy constant (less than 1800 ergs/cm.³) was found to be characteristic of all alloys in the compositional range indicated.

These and other aspects of the invention will become more apparent from an examination of the following detailed description. In the drawing:

FIG. 1 is a ternary phase diagram showing, within the shaded area A, the range of alloy compositions upon which this invention is based;

FIG. 2 is a perspective view partly cut away showing

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an exemplary device using the magnetic alloy of the invention; and

FIG. 3 is a schematic representation of a multilayer film useful as the overlay 14 of FIG. 2.

The alloy compositions falling within the scope of this invention are shown in the shaded region A of FIG. 1. The composition of phases α , γ_1 and γ_2 are described in J. Inst. Metals 67, pp. 189-201.

An exemplary magnetic memory device which advantageously utilizes the isotropic alloys of this invention is shown in FIG. 2. The origin of the term "waffle iron" is evident from the configuration of the base plate 10 which typically is made from a square-loop ferrite such as Ferroxcube. The word-select winding 11, digit-select winding 12 and sense-winding 13 are placed orthogonally in the ferrite slots. The overlay 14, shown partly cut away, consists of an alloy of this invention. The details of the overlay and its fabrication for this particular type of memory unit are described in the following paragraphs. The operation of the device and the specific aspects of its over-all construction are detailed in United States Patent 3,274,571, issued Sept. 20, 1966 to A. H. Bobeck and J. L. Smith.

A typical waffle-iron baseplate is designed for 64 words with 32 bits per word or a total capacity of 2048 bits. The overlay has dimensions of 1¼ in. x 2½ in. x 0.040 in. and an equivalent storage capacity for a bit density of 656 bits/in.². Each bit occupies an area of 30 mils x 30 mils.

The detailed construction of a suitable overlay for the device of FIG. 2 is shown in FIG. 3. This is a thin composite film consisting of a 0.04 in. copper substrate, a gold film ~10,000 A. thick, the iron-nickel-copper alloy ~7,000 A. and an insulating and corrosion protecting film of Acryloid lacquer ~18,000 A.

The gold film and the alloy film are electroplated. The gold film serves to fill surface imperfections and generally a thickness of 8,000 A. to 12,000 A. is adequate for this purpose.

The overlay of FIG. 3 was produced in accordance with the following specific procedure:

An oxygen-free high conductivity copper substrate is hand-ground with 2/0 and then 4/0 silicon carbide polishing paper until flat, and then polished for twenty minutes with an abrasive such as Linde A using a metallographic polishing wheel. This is followed by nondirectional abrasion of the surface with 22 micron Carborundum using the wheel. The last step serves the following purposes:

(1) The anisotropy constant of the electrodeposited film, although small, is more accurately reproduced from sample to sample.

(2) The uniformity of the output signals is improved when used as an overlay in the cubic waffle-iron.

(3) Under nominal operating conditions the ratio of disturbed output to undisturbed output increases. The disturbed output is that which results from applying a series of opposite polarity bit currents prior to read-out and approximates the minimum output under store conditions.

The substrate is then cleaned with a camel hair brush and an alkaline detergent to remove the Carborundum particles. The entire operation from flattening to cleaning normally takes an hour.

Before electroplating, the substrates are etched in a 20% HNO₃ solution for fifteen seconds at 25° C. This partially removes the layer of disturbed metal on the surface and leads to greater uniformity in the film.

The plating line is a four-step process and includes cleaning in alkali, pickling in 20% H₂SO₄, gold plating, and finally Fe-Ni-Cu plating. The alkali serves to remove any dirt or grease that may have gotten on the substrate during storage. The pickling removes oxides that formed during storage. The gold plating is used to cover many

imperfections in the surface and serves to improve uniformity. The use of gold has also permitted salvaging a substrate since a faulty Fe-Ni-Cu layer can be removed with dilute HNO_3 without attacking the gold.

The gold plating was accomplished by the following procedure:

Potassium gold cyanide (KAuCN)	gms./liter	5.1
Potassium cyanide (KCN)	gms./liter	15.0
Sodium phosphate ($\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$)	gms./liter	4.0
pH		10.0
Temperature	$^{\circ}\text{C}$	70
Current density	amps/in. ²	0.02
Plating time	minutes	5.0
Agitation		None

The Fe-Ni-Cu film is deposited from an all-chloride bath as follows:

Ferrous chloride ($\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$)	gms./liter	315
Calcium chloride (CaCl_2)	gms./liter	180
Nickelous chloride ($\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$)	gms./liter	10
Cupric chloride ($\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$)	gms./liter	1.25
Hydrochloric acid (HCl)	ml	10
Duponal (wetting agent)	Pinch	
pH		0.8-1.0
Temperature	$^{\circ}\text{C}$	75
Current density	amps/in. ²	0.22
Plating time	seconds	90
Agitation		None

The substrates are rinsed thoroughly between steps and are not permitted to dry.

As a final step, the electrodeposited film is coated with Acryloid lacquer, chosen because it is easily applied and produces a uniform, relatively pin-hole free layer. This layer provides corrosion protection and electrical insulation of the magnetic film. An appropriate thickness for this coating is prescribed by the range 13,000 A. to 26,000 A. Other protective coatings found useful are cadmium, zinc, 50-50 nickel-cobalt, chromated zinc, arsenic, trisulfide and silicon dioxide. However this invention does not rely on the specific composition and properties of the film.

These and other aspects of the invention will become apparent to those skilled in the art. All such variations and deviations which basically rely on the teachings through which this invention has advanced the art are properly considered within the spirit and scope of this invention.

What is claimed is:

1. A magnetic alloy consisting of the composition:

	Wt., percent
Fe	82 to 88
Ni	4 to 6
Cu	8 to 12

2. A memory element comprising a ferrite base plate having raised portions spaced at regular intervals over its surface and defining two orthogonal channels, conductor wires disposed in said channels and an overlay in contact with said raised portions and enclosing the conductor wires in the orthogonal channels, said overlay comprising a magnetic alloy having the composition:

	Wt., percent
Fe	81 to 95
Ni	4 to 6
Cu	1 to 13

3. The device of claim 2 wherein the overlay consists of a copper substrate, a gold film overlying said substrate, said magnetic alloy overlying the gold film and an insulating protective film overlying the magnetic alloy.

4. An isotropic magnetic alloy consisting of the composition:

	Percent
Fe	84
Ni	5
Cu	11

5. A magnetic overlay for a cubic waffle-iron memory element comprising a 40 mil copper substrate, a gold film approximately one micron in thickness covering said copper substrate, and a magnetic film approximately 0.7 micron covering said gold film, said magnetic film having the approximate composition:

	Percent
Fe	84
Ni	5
Cu	11

6. The overlay of claim 5 additionally including a protective and insulating film of Acryloid lacquer approximately 2-3 microns in thickness.

References Cited

UNITED STATES PATENTS

2,196,824 4/1940 Dahl 75-125

FOREIGN PATENTS

405,643 1/1934 Great Britain.

HYLAND BIZOT, Primary Examiner.