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(71) Applicant: **Industry-Academic Cooperation Foundation of Sunchon National University**
Suncheon-si, Jeollanam-do 57922 (KR)

(72) Inventors:
- **SHIN, Se Eun**
  Suncheon-si Jeollanam-do 57922 (KR)
- **KIM, In Gyeong**
  Suncheon-si Jeollanam-do 57905 (KR)
- **PARK, Yong Bum**
  Goyang-si Gyeonggi-do 10501 (KR)

(74) Representative: **Beck & Rössig**
European Patent Attorneys
Denninger Str. 169
81925 München (DE)

(54) HEAT TREATMENT METHOD FOR ELECTROPLATED FE-NI ALLOY FOIL, AND ELECTROPLATED FE-NI ALLOY FOIL

(57) The present invention relates to a heat treatment method capable of achieving a reduction in shape deformation such as curls along with a low thermal expansion coefficient obtained through thermo-mechanical heat treatment of an Fe-Ni alloy foil.

The heat treatment method according to the present invention involves applying pressure to an electroformed Fe-Ni alloy during annealing.

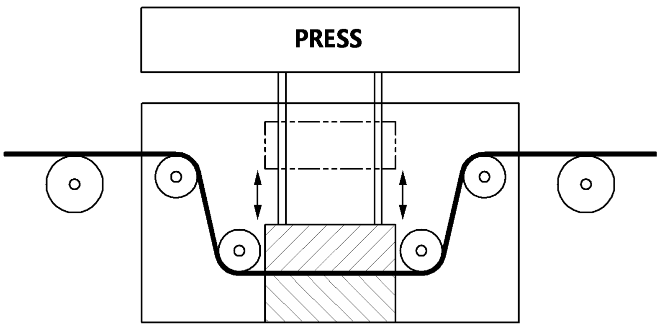


FIG. 1

Processed by Luminess, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a method for heat treating an Fe-Ni alloy foil prepared through electroforming, and more particularly, to a heat treatment method capable of reducing shape deformation such as curls or wrinkles during heat treatment along with a low thermal expansion coefficient obtained through thermo-mechanical heat treatment of an Fe-Ni alloy foil, and an Fe-Ni alloy foil prepared through the method.

[0002] Fine Metal Masks (FMMs) used in OLED display deposition processes are manufactured through a series of processes involving melting, casting, rolling, and etching of invar alloy, which has a very low coefficient of thermal expansion.

[0003] To elevate the resolution of current OLED displays in smartphones from QHD (600 ppi) to the next-generation UHD level (1,000 ppi or higher), the wall thickness of FMM's apertures needs to be reduced to 10 μm or less to prevent obstruction of OLED material deposition.

[0004] However, a rolling process is incapable of producing invar foils below 25 μm in thickness. To address the need for higher-resolution OLEDs, current methods involve rolling and etching foils to a thickness of about 13 μm, but the top-down approach of melting, casting, rolling, and etching hardly produces ultra thin foils below 10 μm in thickness due to inclusions and increased production costs, and also incurs significantly increased manufacturing costs.

[0005] Consequently, electroforming, a bottom-up process, has been explored for manufacturing Fe-Ni alloy foils and fine metal masks.

[0006] Electroformed Fe-Ni alloy foils and FMMs do not have a low coefficient of thermal expansion required for FMMs, which is 3 ppm/°C or less (preferably 2 ppm/°C or less), and thus a heat treatment process is indispensable to reduce the coefficient of thermal expansion and enhance mechanical properties.

[0007] However, the heat treatment process induces significant shape deformation, such as curls or wrinkles in Fe-Ni alloy foils and pattern deformation in FMMs, preventing the current use of those materials in FMM manufacturing.

SUMMARY OF THE INVENTION

[0008] An aspect of the present invention provides a method for heat treating an Fe-Ni alloy foil, which suppresses deformation caused during heat treatment process of an Fe-Ni alloy foil prepared through electroforming and provides a low thermal expansion coefficient and satisfactory mechanical properties.

[0009] Another aspect of the present invention provides an electroformed Fe-Ni alloy foil exhibiting a low thermal expansion coefficient and superior mechanical properties.

[0010] According to an embodiment of the invention, there is provided a method for heat treating an Fe-Ni alloy foil, including annealing an electroformed Fe-Ni alloy foil under pressure.

[0011] In the method for heat treating an Fe-Ni alloy foil, the annealing may be performed at a temperature of 180 to 600 °C.

[0012] In the method for heat treating an Fe-Ni alloy foil, the annealing may be performed for a duration of 1 minute to 12 hours.

[0013] In the method for heat treating an Fe-Ni alloy foil, the pressure applied to the Fe-Ni alloy foil may be at least 0.1 KPa.

[0014] In the method for heat treating an Fe-Ni alloy foil, the Fe-Ni alloy foil may be subjected to both pressure and tensile force in one direction.

[0015] In the method for heat treating an Fe-Ni alloy foil, the Fe-Ni alloy foil may be subjected to both pressure and tensile force in two directions that are perpendicular to each other.

[0016] In the method for heat treating an Fe-Ni alloy foil, after the annealing, gas quenching may be performed in an inert gas atmosphere.

[0017] In the method for heat treating an Fe-Ni alloy foil, the gas quenching may involve cooling in an inert gas environment.

[0018] In the method for heat treating an Fe-Ni alloy foil, the gas quenching may be performed in a sealed chamber filled with an inert gas.

[0019] In the method for heat treating an Fe-Ni alloy foil, the annealing of the Fe-Ni invar alloy foil may be performed through a continuous heat treatment process in which the foil is continuously fed through a heating furnace.

[0020] In the method for heat treating an Fe-Ni alloy foil, during the continuous heat treatment process, a tensile force may be applied in a direction that the Fe-Ni invar alloy foil travels.

[0021] In the method for heat treating an Fe-Ni alloy foil, during the continuous heat treatment process, the pressure may be applied while the travel of the Fe-Ni alloy foil is temporarily halted.

[0022] In the method for heat treating an Fe-Ni alloy foil, during the continuous heat treatment process, a tensile force may be applied in a direction perpendicular to the direction that the Fe-Ni invar alloy foil travels.

[0023] In the method for heat treating an Fe-Ni alloy foil, during the continuous heat treatment process, a tensile force may be applied both in the direction of the Fe-Ni invar alloy foil travels and in the direction perpendicular thereto.

[0024] In the method for heat treating an Fe-Ni alloy foil, the continuous heat treatment process may be sequentially performed in connection with an electroforming process of the Fe-Ni invar alloy foil in a roll-to-roll manner.

[0025] According to another embodiment of the invention, there is provided an Fe-Ni alloy foil prepared through electroforming, wherein more than 90% of a total volume of the Fe-Ni alloy foil has a face-centered cubic (FCC) structure, and a highest intensity of the (111) peak as determined through XRD analysis.

[0026] In the Fe-Ni alloy foil, the Fe-Ni alloy foil may have an average grain size of 100 nm or less, preferably 80 nm or less, and more preferably 50 nm or less.

[0027] In the Fe-Ni alloy foil, the Fe-Ni alloy foil may have a tensile strength of 0.7 to 1.5 GPa.

[0028] In the Fe-Ni alloy foil, the Fe-Ni alloy may contain 33 to 43 mass% of Ni.

[0029] In the Fe-Ni alloy foil, the Fe-Ni alloy foil may have a 15 μm or less, 14 μm or less, 13 μm or less, 12 μm or less, 11 μm or less, 10 μm or less, 9 μm or less, 8 μm or less, 7 μm or less, 6 μm or less, or 5 μm or less, and the thicknesses are presented as examples and the invention is not intended to exclude a thickness greater than 15 μm.

[0030] In the Fe-Ni alloy foil, the Fe-Ni alloy foil may be used for a fine metal mask or an OLED encapsulation material, but the uses are presented as examples and are not intended to be exhaustive or limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031]

Fig. 1 is a schematic view showing a thermo-mechanical heat treatment method according to an embodiment of the invention;
Fig. 2 shows the shapes of a sample from Example 1 sample (gas quenching) and a sample from Example 2 (no-cooling);
Fig. 3 shows the results of measuring thermal expansion coefficients of a sample from Example 1 (gas quenching) and a sample from Example 2 (no-cooling) in a range of 50 to 100 °C;
Fig. 4 shows the shapes of a sample from Example 3 before and after heat treatment;
Fig. 5 shows the shapes of a sample from Example 4 before and after heat treatment;
Fig. 6 shows the shapes of a sample from Example 5 before and after heat treatment;
Fig. 7 shows the shapes of a sample from Example 6 before and after heat treatment;
Fig. 8 shows the shapes of a sample from Comparative Example 1 before and after heat treatment;
Fig. 9 shows the shapes of a sample from Comparative Example 2 before and after heat treatment;
Fig. 10 shows a process of measuring strain based on changes in length of samples from Examples 7 and 8; and
Fig. 11 shows the results of measuring strain of a patterned sample before heat treatment and samples from Examples 7 and 8.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0032] Hereinafter, the invention will be described in more detail with reference to preferred embodiments. In the following description, descriptions of technologies widely known in the art will be skipped. However, those skilled in the art may easily understand the characteristic configuration and effects of the present invention through the following embodiments, and may implement the present invention without particular difficulty.

[0033] The inventors have found that applying a thermo-mechanical method in which pressure is applied during the heat treatment of an Fe-Ni alloy foil formed through electroforming and a cooling method enables suppression of deformation such as curls caused during heat treatment, reduction in thermal expansion coefficient, and improvement in mechanical properties, completing the invention.

[0034] Fig. 1 is a schematic view for describing a thermo-mechanical heat treatment method according to the present invention.

[0035] As shown in Fig. 1, a continuous heating furnace, which is roughly cuboid in shape, has an inlet on one side for feeding an electroformed Fe-Ni alloy foil and an outlet on the other side for discharging an Fe-Ni alloy foil heat treated for a certain period of time.

[0036] The Fe-Ni alloy foil fed into the heating furnace may be pressurized either by using a press device during heat treatment or by placing a weight thereon for a certain period of time.

[0037] The pressurization is preferably performed while the Fe-Ni alloy foil fed into the heating furnace remains stationary, but, for example, in the case of placing a weight thereon, pressurization may be performed even while the foil is moving.

[0038] In addition, a tensile force may be applied in a direction of travel by rolls on both sides of the Fe-Ni alloy foil along with the pressurization. In addition, a tensile force may be applied to both sides of the Fe-Ni alloy foil in a width direction perpendicular to the direction of travel. That is, a pressurization process using a press may be performed in the condition that a predetermined tensile force is applied in the length and width directions of the Fe-Ni alloy foil.

[0039] Preferably, the applied pressure by the press or weight may be 0.1 KPa or greater, because under an applied pressure of less than 0.1KPa, which is low, deformation such as curls or wrinkles caused during heat treatment is hardly suppressed.

[0040] In addition, in the preparing an Fe-Ni alloy foil through a continuous process such as a roll-to-roll process, when the applied pressure is excessive, the continuous process is hardly applicable, or the Fe-Ni alloy foil may be damaged during the roll-to-roll process.

[0041] Therefore, the applied pressure may be 10M Pa or less, 5 MPa or less, 1 MPa or less, 100 KPa or less, 50 KPa or less, 10 KPa or less, or 5 KPa or less, more preferably 4.5 KPa or less, and most preferably 4 KPa or less.

[0042] Duration for pressurization by the press may range from 1 second to 1 hour, and when the duration for pressurization is less than 1 second, curls are hardly suppressed, and when the duration for pressurization is greater than 1 hour, productivity may be excessively reduced. Desirable duration for pressurization may range from 10 seconds to 30 minutes.

[0043] In addition, preferably, the Fe-Ni alloy foil may have a tensile force of 500 MPa or less, because when the tensile force is greater than 500 MPa, the Fe-Ni alloy foil may be damaged, such as tearing, during the tensile process.

[0044] The heating furnace may be kept at a temperature in a range of 180 to 600 °C based on electroforming conditions. When the heating furnace is kept at less than 180 °C or greater than 600 °C, maintaining a thermal expansion coefficient of the heat-treated Fe-Ni alloy foil to 3 ppm/°C or less (preferably 2 ppm/°C or less, more preferably 1 ppm/°C or less) is hardly achievable.

[0045] In addition, to reduce curls and wrinkles caused during the heating process, the heating temperature may be kept in a range of 440 to 520 °C, and more preferably in a range of 450 to 510 °C.

[0046] The Fe-Ni alloy foil may be held in the heating furnace for a duration longer than the minimum time required for a phase transformation, but no more than 12 hours. Heating duration less than the minimum time required for a phase transformation hardly reduces thermal expansion coefficients, which is undesirable, and heating duration exceeding 12 hours reduces efficiency of the continuous process and incurs excessive energy costs, which is undesirable too. For example, the heating duration (retention time in the heating furnace) may range from 10 minutes to 12 hours.

[0047] Preferably, the Fe-Ni alloy foil discharged from the heating furnace may be rapidly cooled through gas quenching. The gas quenching is a process in which the heated Fe-Ni alloy foil is placed and cooled in a predetermined chamber which is sealed, vacuum-treated to have air removed, and then gas injected. The gas used in the gas quenching is preferably an inert gas such as argon, nitrogen, or a mixed gas thereof, but is not necessarily limited thereto.

[0048] Temperature of the gas during the gas quenching may be 50 °C or less, 40 °C or less, 30 °C or less, or 25 °C or less.

<Example 1>

[0049] An Fe-36Ni alloy foil having a thickness of about 10 μm and prepared through electroforming was cut into 50 mm wide and 60 mm long pieces.

[0050] The cut sample was heated at a heating rate of 10 °C/min and heated at 430 °C for 30 minutes. The heating was performed in an air atmosphere, but may also be performed in an inert gas atmosphere such as nitrogen or argon if necessary.

[0051] In addition, a block (weight) weighing 2.5 kg was placed on the Fe-36Ni alloy foil during the heating, applying a pressure of 8.17 kPa for 30 minutes.

[0052] After the heat treatment, gas quenching, in which the heated Fe-36Ni alloy foil was placed and cooled in a sealed chamber filled with argon (about 25 °C) gas, was performed.

<Example 2>

[0053] The same alloy foil as in Example 1 was used and heat treated in the same manner, except that cooling was performed in a furnace after the pressure heat treatment.

<Example 3>

[0054] An Fe-33Ni alloy foil having a thickness of about 10 μm and prepared through electroforming was cut into about 100 mm wide and about 120 mm long pieces.

[0055] The cut sample was heated at a heating rate of 10 °C/min and heated at 480 °C for 30 minutes. The heating was performed in a vacuum atmosphere (1×10^{-3} torr), but in some cases, may also be performed in an air atmosphere or an inert gas atmosphere such as nitrogen, argon, or a mixed gas thereof.

[0056] In addition, a block (weight) weighing 2.5 kg was placed on the Fe-33Ni alloy foil during the heating, applying a pressure of about 2.17 KPa for 30 minutes, and after the heat treatment, gas quenching, in which the heated Fe-33Ni alloy foil was placed and cooled in a sealed chamber filled with argon (about 25 °C) gas, was performed.

<Example 4>

[0057] An alloy foil was heat treated in the same manner as in Example 3, except that the heat treatment was performed at 500 °C.

<Example 5>

[0058] An alloy foil was heat treated in the same manner as in Example 3, except that an Fe-36Ni alloy foil was used and heat treated at 500 °C.

<Example 6>

[0059] An alloy foil was heat treated in the same manner as in Example 3, except that an Fe-42Ni alloy foil was used and heat treated at 500 °C.

<Comparative Example 1>

[0060] An alloy foil was heat treated in the same manner as in Example 5, except that an Fe-36Ni alloy foil was used and heat treated at 530 °C.

<Comparative Example 2>

[0061] An alloy foil was heat treated in the same manner as in Example 6, except that an Fe-42Ni alloy foil was used and heat treated at 430 °C.

<Example 7>

[0062] To examine deformation of the Fe-36Ni alloy foil having a thickness of about 10 μm and prepared through electroforming before and after heat treatment, the foil was subjected to laser patterning with regularly arranged octagonal holes.

[0063] The patterned Fe-36Ni alloy foil was cut into 30 mm in width and 71 mm in length.

[0064] The cut sample was heated at a heating rate of 10 °C/min and heated at 450 °C for 1 hour. The heating was performed in an air atmosphere, but may also be performed in an inert gas atmosphere such as nitrogen or argon if necessary.

[0065] In addition, a block weighing 2.5 kg was placed on the patterned Fe-36Ni alloy foil during the heating, applying pressure for 30 minutes.

[0066] After the heat treatment, gas quenching, in which the heated Fe-36Ni alloy foil was placed and cooled in a sealed chamber filled with argon (about 25 °C) gas, was performed.

<Example 8>

[0067] The same alloy foil as in Example 7 was used and heat treated in the same manner, except that cooling was performed in a furnace after the heat treatment without gas quenching.

Evaluation of curls or wrinkles on Fe-Ni alloy foil

[0068] Fig. 2 shows the shapes of samples from Examples 1 and 2.

[0069] It is determined that the sample from Example 1 cooled by gas quenching after the same pressure heat treatment showed relatively fewer curls than the sample from Example 2 cooled by furnace cooling. Accordingly, it is determined that for the Fe-Ni alloy foil without a pattern formed, performing gas quenching after the pressure heat treatment may be more desirable in reducing deformation of the Fe-Ni alloy foil.

[0070] Figs. 4 to 7 show the shapes of samples from Examples 3 to 6 before and after heat treatment, and Figs. 8 and 9 each show the shapes of samples from Comparative Examples 1 and 2 before and after heat treatment.

[0071] As shown in Figs. 4 to 7, in the heat treatment methods according to Examples 3 to 6 of the invention, even in samples that initially had curls or wrinkles, almost no curls or wrinkles were observed after the heat treatment.

[0072] Meanwhile, as shown in Figs. 8 and 9, Comparative Examples 1 and 2 were observed to have curls and wrinkles after heat treatment, which seems to be attributed to the heat treatment temperatures of 430 °C and 530 °C, respectively, applied to the electroformed Fe-Ni alloy foils.

Measurement of thermal expansion coefficient of Fe-Ni alloy foil

[0073] Fig. 3 shows the results of measuring thermal expansion coefficients in a range of 50 to 100 °C for samples from Examples 1 and 2.

[0074] As shown in Fig. 3, the sample from Example 1 cooled by gas quenching after the same pressure heat treatment exhibited a relatively lower thermal expansion coefficient in the range of 50 to 100 °C than the sample from Example 2 cooled by furnace cooling.

[0075] Accordingly, it is seen that the gas quenching method is desirable in obtaining an Fe-Ni alloy foil having a lower thermal expansion coefficient compared to other cooling methods, even with the same alloy composition.

Evaluation of pattern shape deformation

[0076] Fig. 10 shows a process of measuring strain based on changes in length of samples from Examples 7 and 8, and Fig. 11 shows the results of measuring strain of a patterned Fe-Ni alloy foil sample before heat treatment and samples from Examples 7 and 8.

[0077] Fig. 10 shows, on the left, a 16×16 pattern, with each unit consisting of 16 holes in both the horizontal and vertical directions based on a single octagonal hole with a symmetrical structure, and on the right, horizontal length (hereinafter, A1), vertical length (hereinafter, A2), and diagonal lengths (hereinafter, B1 and B2) of the pattern, measured to compare and analyze non-heat treated samples and heat treated samples (Examples 7 and 8).

[0078] Subsequently, strain was measured from changes in length and shown in Fig. 11.

[0079] The heat treated samples of Example 7 and Example 8 showed relatively low strain levels of 0.86 to 0.40 across the four lengths A1 to B2, but the gas quenched sample form Example 7 showed a relatively lower strain overall than the sample from Example 8, but with a larger variation in strain within the sample. This indicates that there may be differences in shape deformation characteristics depending on the cooling method.

[0080] According to the invention, deformation such as curls or wrinkles that are caused during a heat treatment process of an Fe-Ni alloy foil prepared through electroforming may be reduced.

[0081] In addition, according to the invention, an ultra-thin Fe-Ni alloy foil having a thickness of 10 μm or less may be mass-produced.

[0082] In the above, description has been made with reference to preferred embodiments of the present invention, but it should be understood that the present invention is not limited to or by such embodiments. That is, the present invention may be variously modified and altered within the scope of the claims described below, and such modifications and alterations fall within the scope of the present invention. Accordingly, the present invention is limited only by the scope of the claims and equivalents thereof.

Claims

1. A method for heat treating an Fe-Ni alloy foil, the method comprising annealing an electroformed Fe-Ni alloy foil under pressure.

2. The method according to Claim 1,
wherein said annealing is performed at a temperature of 180 to 600 °C for a duration of 10 minutes to 12 hours.

3. The method according to Claim 1,
wherein the pressure is at least 0.1 KPa.

4. The method according to Claim 1,
wherein the Fe-Ni alloy foil is subjected to both pressure and tensile force.

5. The method according to Claim 4,
wherein the tensile force is applied in two directions that are perpendicular to each other.

6. The method according to any one of Claims 1 to 5,
wherein after said annealing, gas quenching is performed in an inert gas atmosphere.

7. The method according to Claim 1,
wherein said annealing is performed through a continuous heat treatment process in which the Fe-Ni alloy foil is continuously fed through a heating furnace.

8. The method according to Claim 7,
wherein during the continuous heat treatment process, the pressure is applied while the travel of the Fe-Ni alloy foil is temporarily halted.

9. The method according to Claim 7,
wherein during the continuous heat treatment process, a tensile force is applied in a direction that the Fe-Ni alloy foil travels.

10. An Fe-Ni alloy foil prepared through electroforming,

    wherein the Fe-Ni alloy contains 33 to 43 mass% of Ni, and
    more than 90% of a total volume of the Fe-Ni alloy foil has a face-centered cubic (FCC) structure, and a highest intensity of the (111) peak as determined through XRD analysis.

11. The method according to Claim 10,
wherein the Fe-Ni alloy foil has an average grain size of 50 nm or less.

12. The method according to Claim 10,
wherein the Fe-Ni alloy foil has a thickness of 15 μm or less.

13. The method according to Claim 10,
wherein the Fe-Ni alloy foil is for a fine metal mask or an OLED encapsulation material.

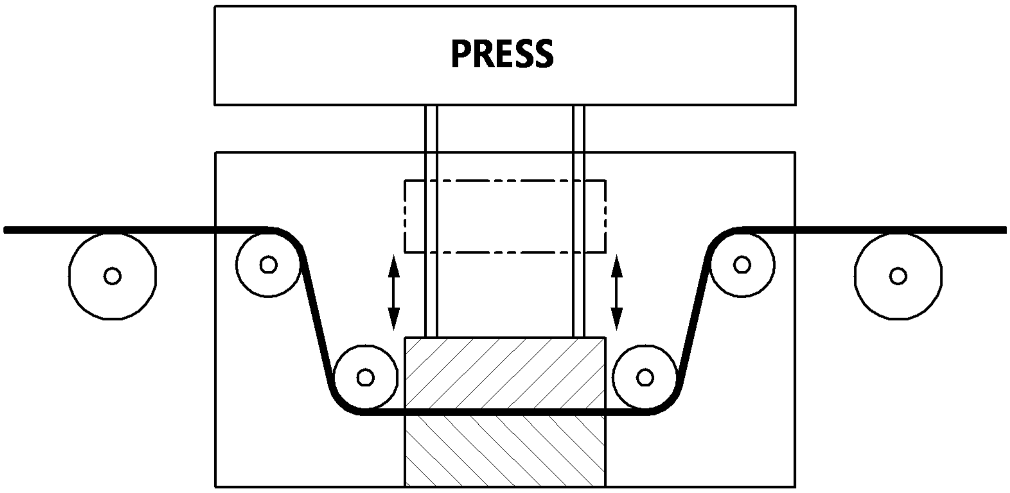


FIG. 1

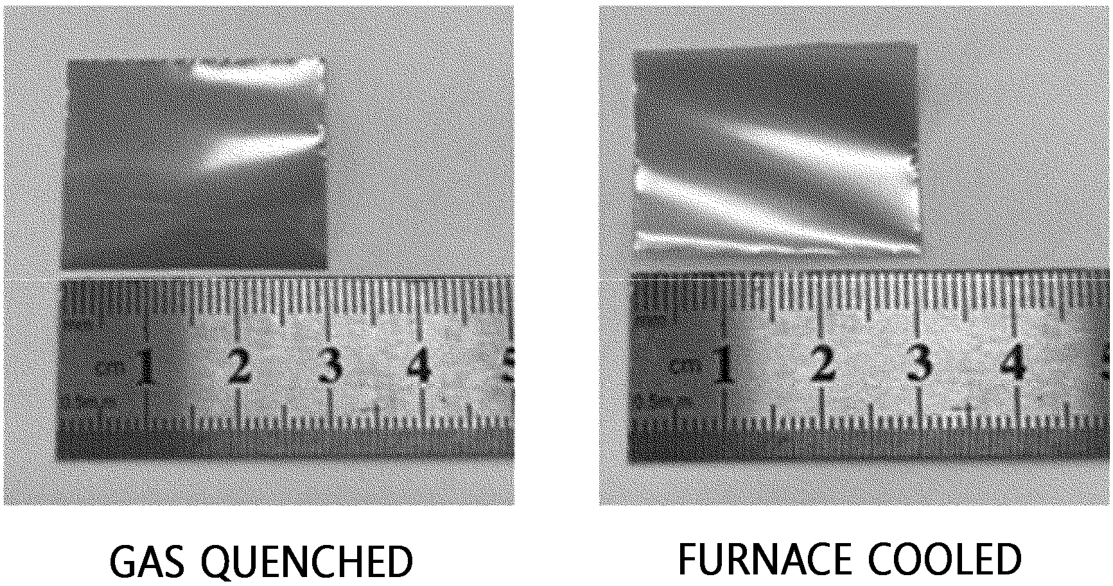


FIG. 2

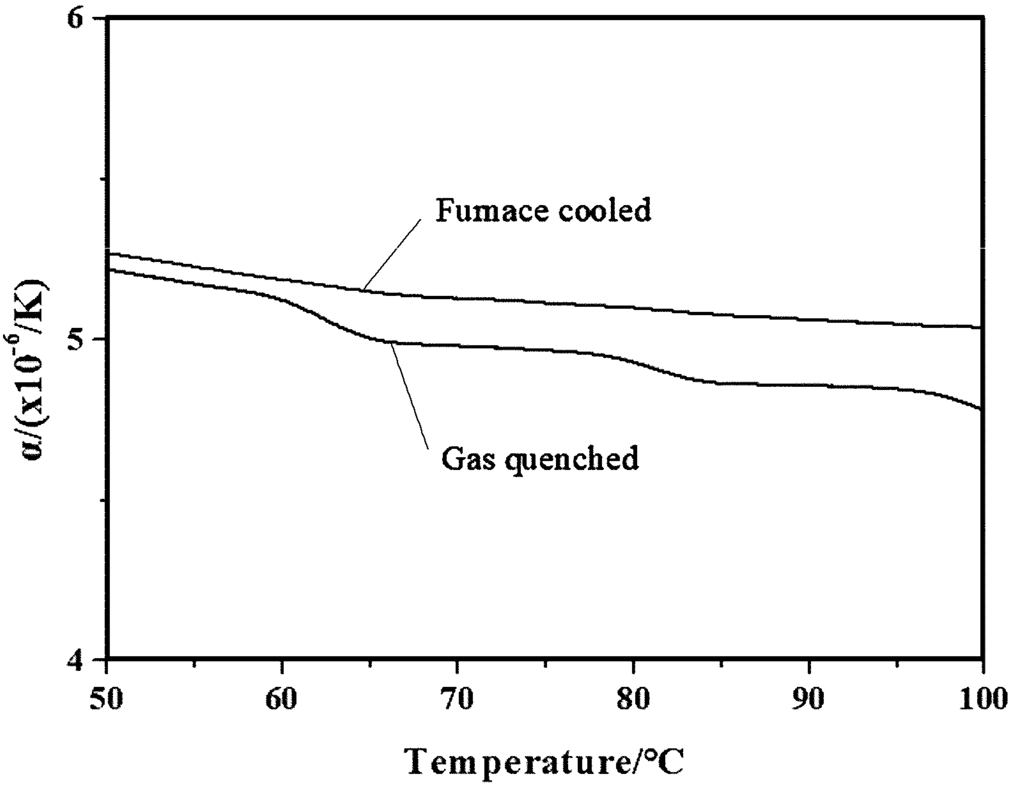
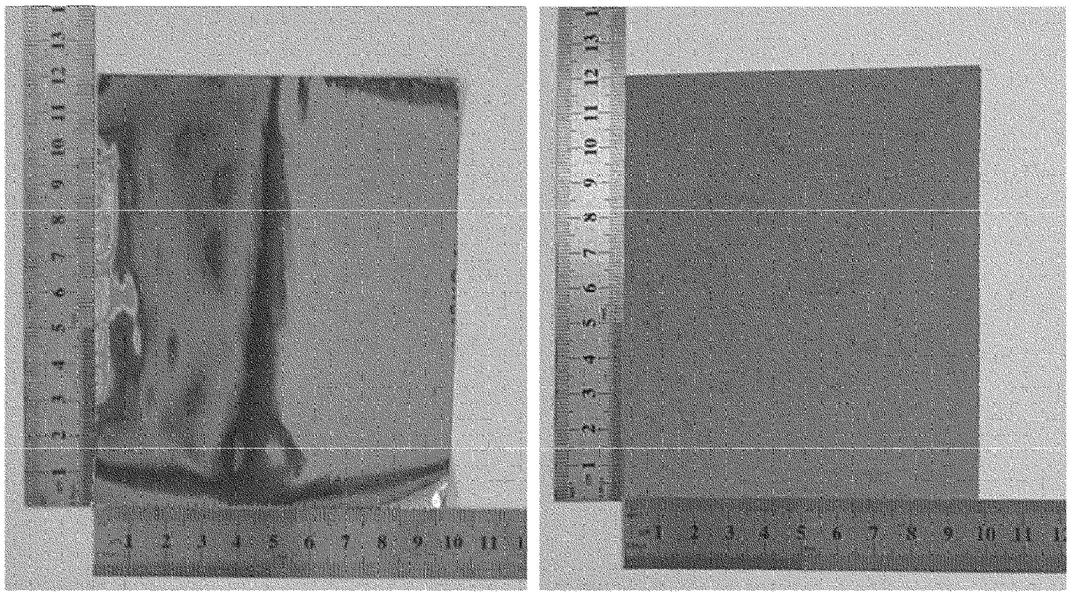
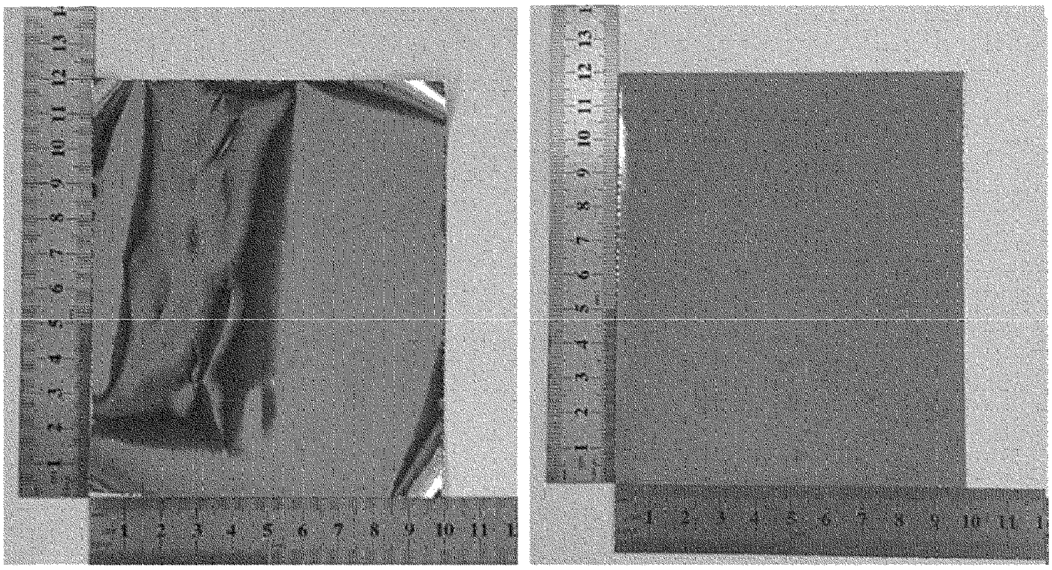


FIG. 3



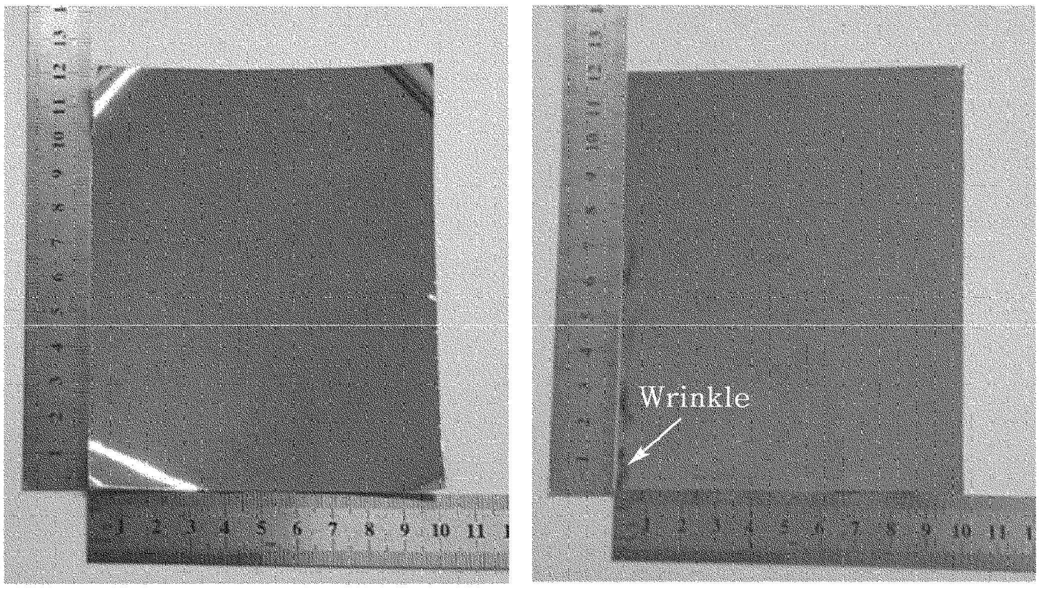
BEFORE HEAT TREATMENT AFTER HEAT TREATMENT

FIG. 4



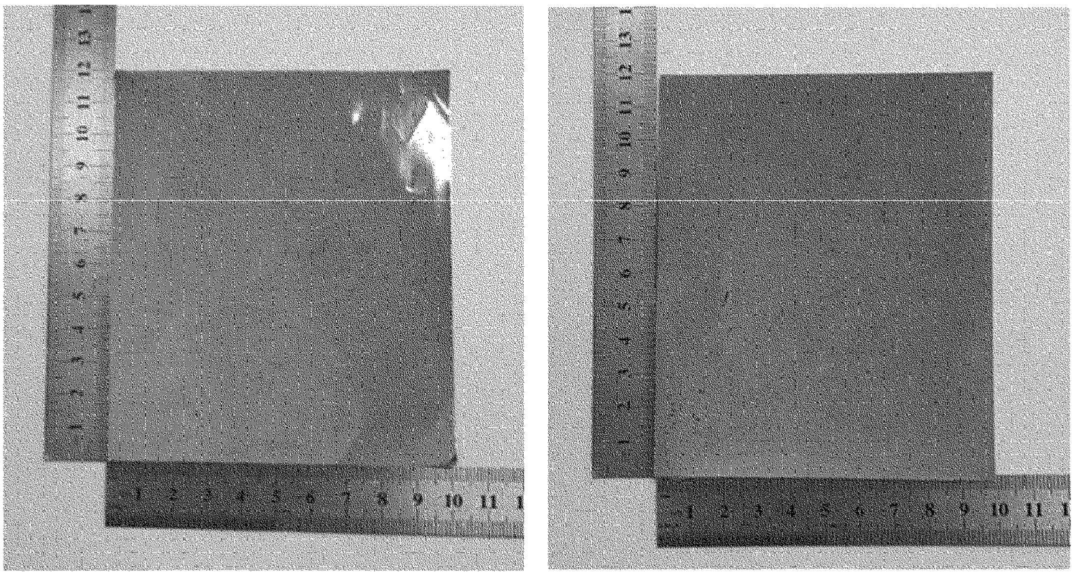
BEFORE HEAT TREATMENT AFTER HEAT TREATMENT

FIG. 5



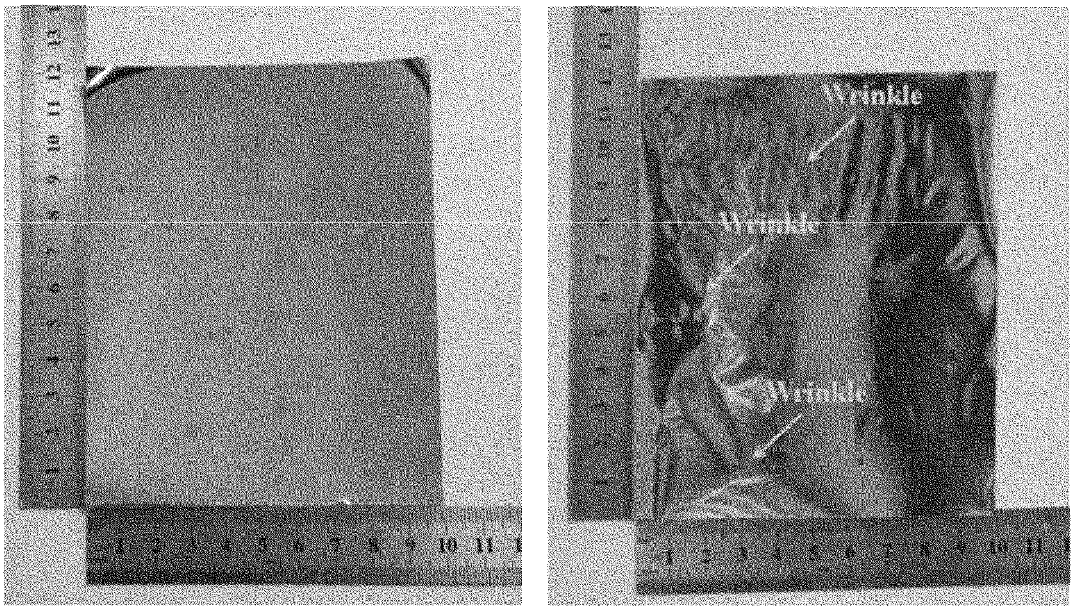
BEFORE HEAT TREATMENT AFTER HEAT TREATMENT

FIG. 6



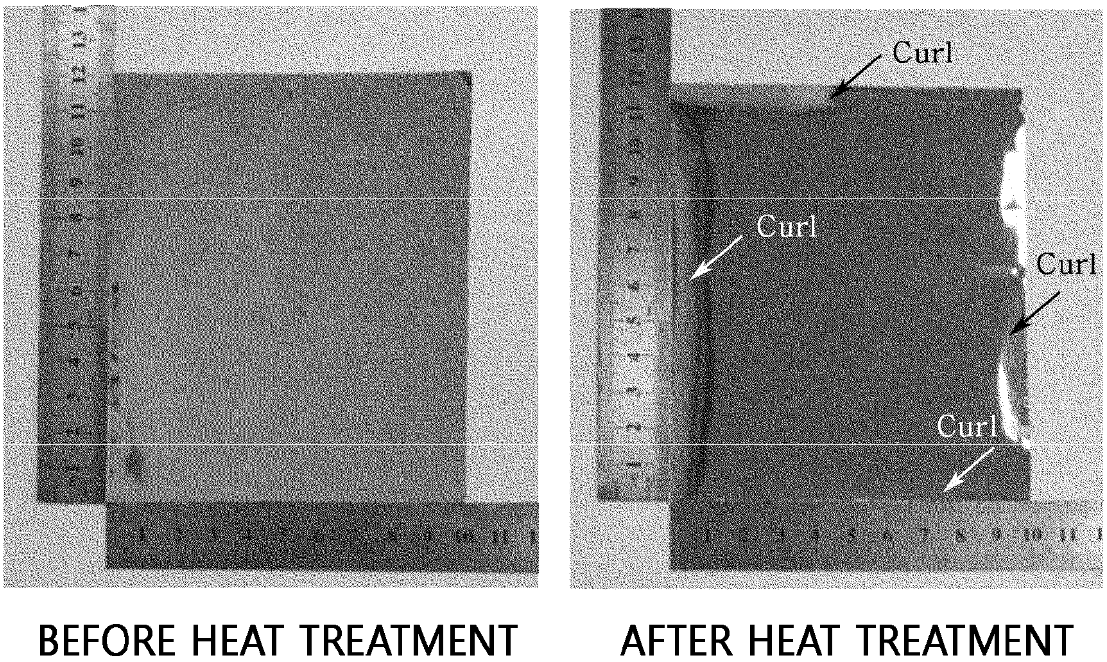
BEFORE HEAT TREATMENT AFTER HEAT TREATMENT

FIG. 7



BEFORE HEAT TREATMENT AFTER HEAT TREATMENT

FIG. 8


Curl
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BEFORE HEAT TREATMENT
AFTER HEAT TREATMENT

FIG. 9

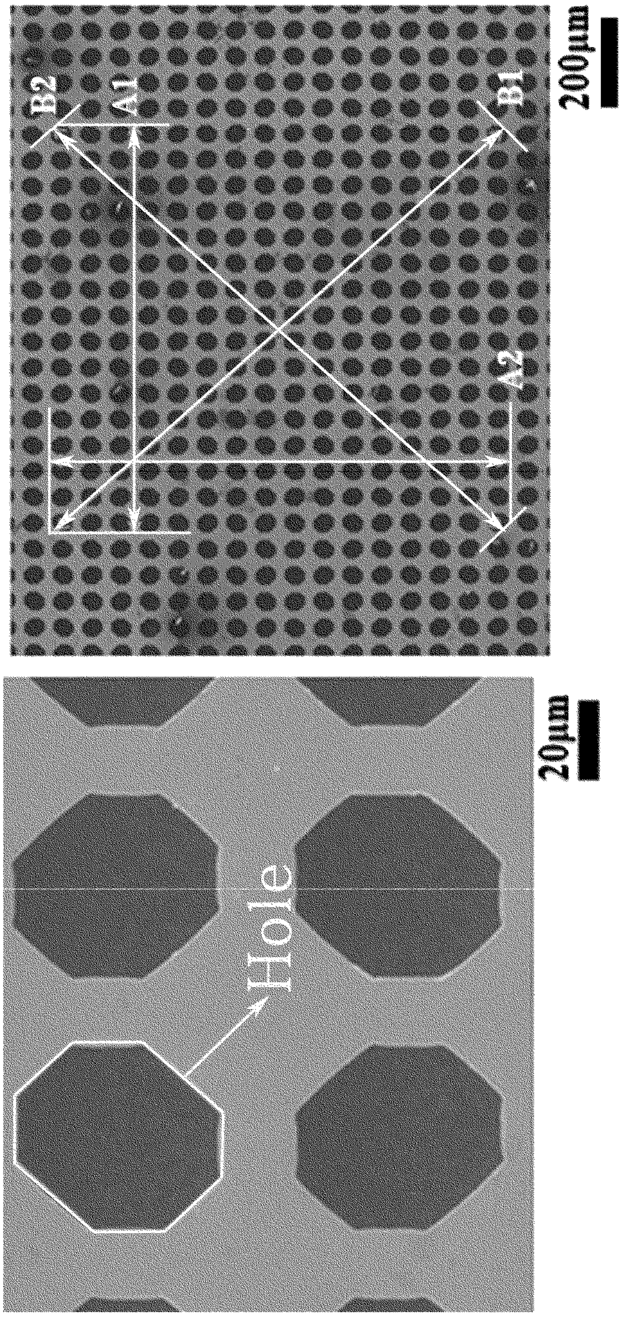


FIG. 10

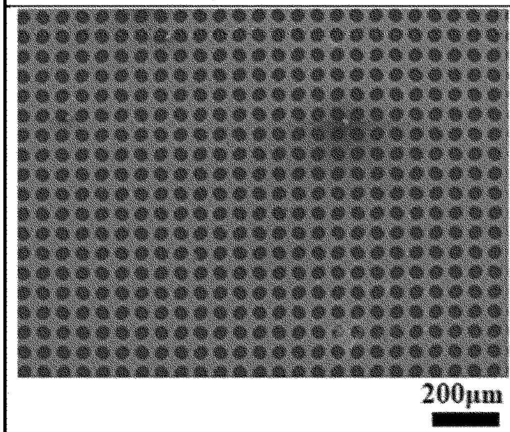
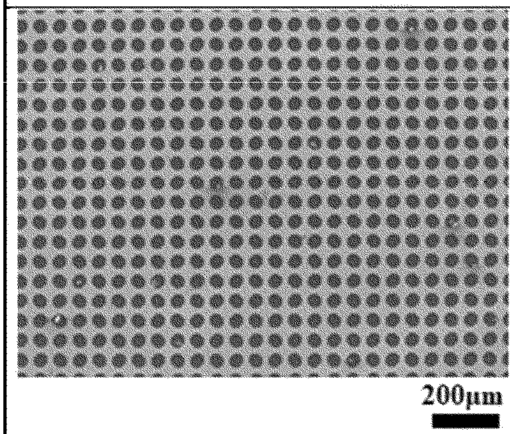
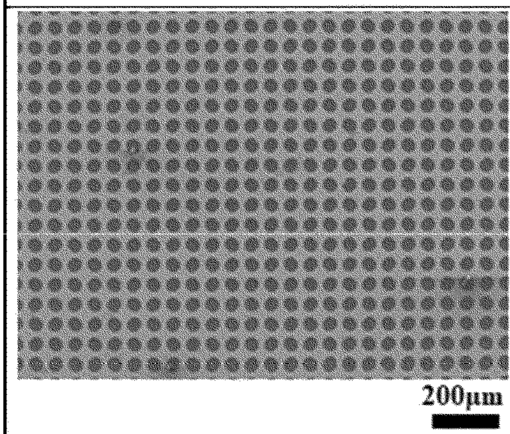
Specimens	MEASURED LENGTH (μm)	STRAIN (%)
 SAMPLE BEFORE HEAT TREATMENT	A1 : 956.422	
	A2 : 964.679	
	B1 : 1338.369	
	B2 : 1338.270	
 HEAT TREATED SAMPLE 1	A1 : 949.201	0.76
	A2 : 957.534	0.74
	B1 : 1328.974	0.70
	B2 : 1332.853	0.40
 HEAT TREATED SAMPLE 2	A1 : 948.231	0.86
	A2 : 958.333	0.66
	B1 : 1328.855	0.71
	B2 : 1328.984	0.69

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2023/008819

A. CLASSIFICATION OF SUBJECT MATTER

C21D 9/56(2006.01)i; **C21D 9/573**(2006.01)i; **C21D 9/46**(2006.01)i; **C25D 1/04**(2006.01)i; **C21D 1/26**(2006.01)i; **C21D 1/613**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21D 9/56(2006.01); C21D 1/18(2006.01); C21D 1/26(2006.01); C21D 8/02(2006.01); C21D 9/00(2006.01); C21D 9/46(2006.01); C22C 38/08(2006.01); C25D 1/04(2006.01); C25D 5/00(2006.01); H01L 31/04(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 전주도금(electroforming), 박막(film), 니켈(Ni), 소둔(annealing), 압력(pressure), 냉각(quenching), 마스크(mask)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2020-0058004 A (POSCO) 27 May 2020 (2020-05-27) See paragraphs [0037], [0039] and [0041], claim 1 and figure 1.	1-9
Y	JP 09-165618 A (FURUKAWA ELECTRIC CO., LTD.) 24 June 1997 (1997-06-24) See paragraphs [0014] and [0017]-[0018] and claims 1-2.	1-9
X	KR 10-1819367 B1 (POSCO) 17 January 2018 (2018-01-17) See paragraphs [0001], [0009] and [0077], claims 1 and 6 and figure 3.	10-13
A	JP 02-104624 A (HITACHI METALS LTD.) 17 April 1990 (1990-04-17) See page 2 and claim 1.	1-13
A	KR 10-2017-0075134 A (POSCO) 03 July 2017 (2017-07-03) See claims 1 and 5-6.	1-13

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 September 2023	**21 September 2023**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208** Facsimile No. **+82-42-481-8578**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2023/008819

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-1010583 B1 (URI FINE PLATING CO., LTD.) 24 January 2011 (2011-01-24) See claims 1, 4, 8 and 11.	1-13
A	KR 10-2013-0054909 A (KOREA INSTITUTE OF INDUSTRIAL TECHNOLOGY) 27 May 2013 (2013-05-27) See paragraphs [0014]-[0016], [0026] and [0043].	1-13

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2023/008819

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1-9 pertain to a heat treatment method of an Fe-Ni alloy foil prepared by electroforming,
Claims 10-12 pertain to an Fe-Ni alloy foil prepared by electroforming, which comprises33-43 wt% Ni and has a face-centered cubic structure that is at least 90% of the total volume.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☑ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2023/008819

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2020-0058004 A	27 May 2020	KR 10-2175740 B1	06 November 2020
JP 09-165618 A	24 June 1997	None	
KR 10-1819367 B1	17 January 2018	CN 107805761 A	16 March 2018
		CN 107805761 B	11 February 2020
		JP 2018-040055 A	15 March 2018
		JP 6625102 B2	25 December 2019
JP 02-104624 A	17 April 1990	None	
KR 10-2017-0075134 A	03 July 2017	KR 10-1758510 B1	17 July 2017
KR 10-1010583 B1	24 January 2011	KR 10-2010-0009663 A	29 January 2010
KR 10-2013-0054909 A	27 May 2013	JP 2015-504599 A	12 February 2015
		JP 6246727 B2	13 December 2017
		KR 10-1422609 B1	24 July 2014
		US 2014-0332069 A1	13 November 2014
		WO 2013-073778 A1	23 May 2013

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