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(54) **METAL COMPOSITE COMPRISING ALIGNED PRECIPITATE AND PREPARATION METHOD THEREFOR**

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(57) **ABSTRACT**

The present invention provides a metal composite with an oriented precipitate, in which a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate of 40% or more per unit area of 500 μm×500 μm is forcibly created by aging and oriented by plastic working.

The present invention provides a method of manufacturing a metal composite with an oriented precipitate which includes: a material preparing step of preparing a molded alloy; a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area; a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate of 40% or more per unit area of 500 μm×500 μm by aging the alloy containing the solid solution; and a precipitate orienting step of orienting the precipitate by performing plastic working on the alloy containing the precipitate.

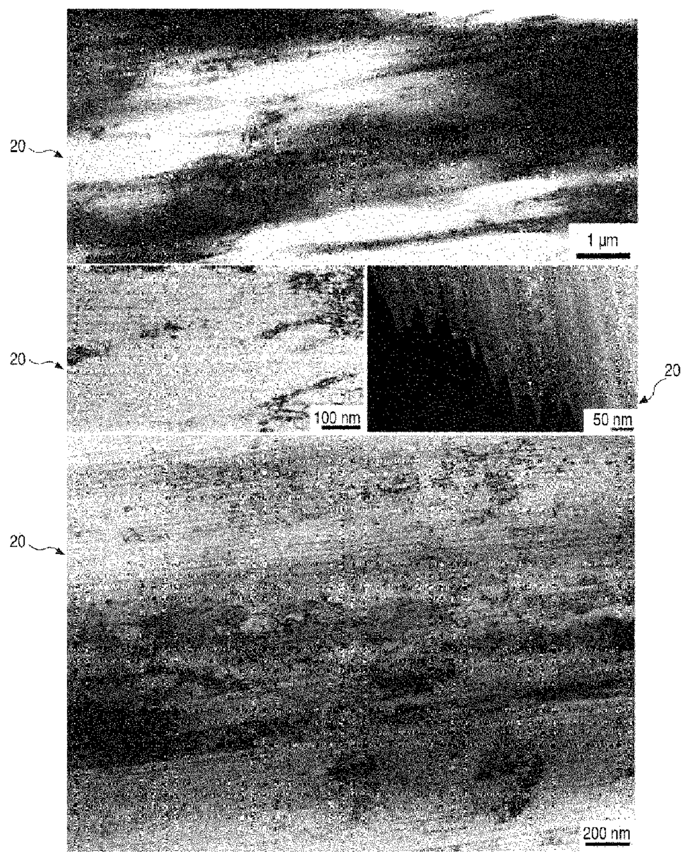


Figure 1

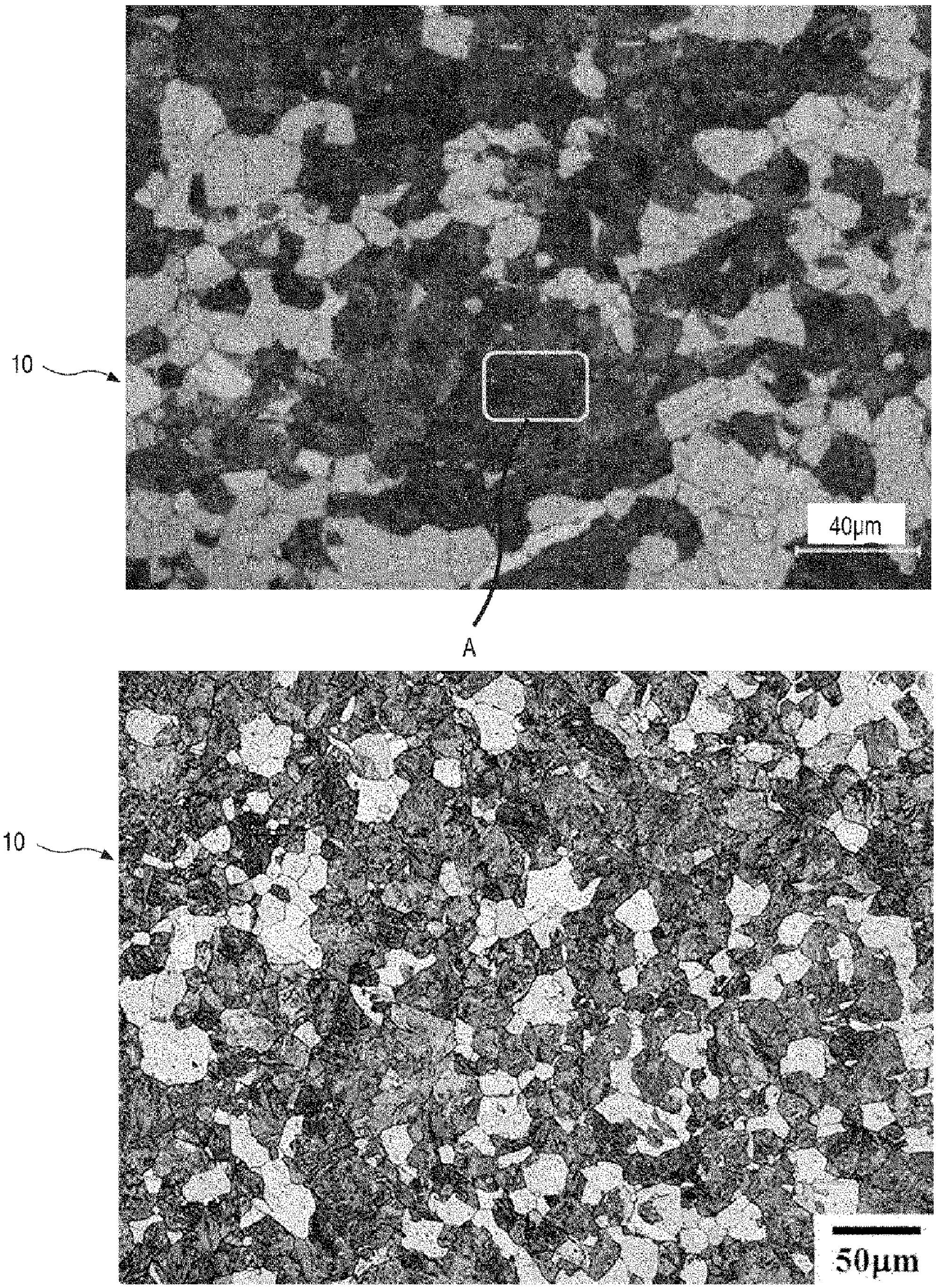


Figure 2

10

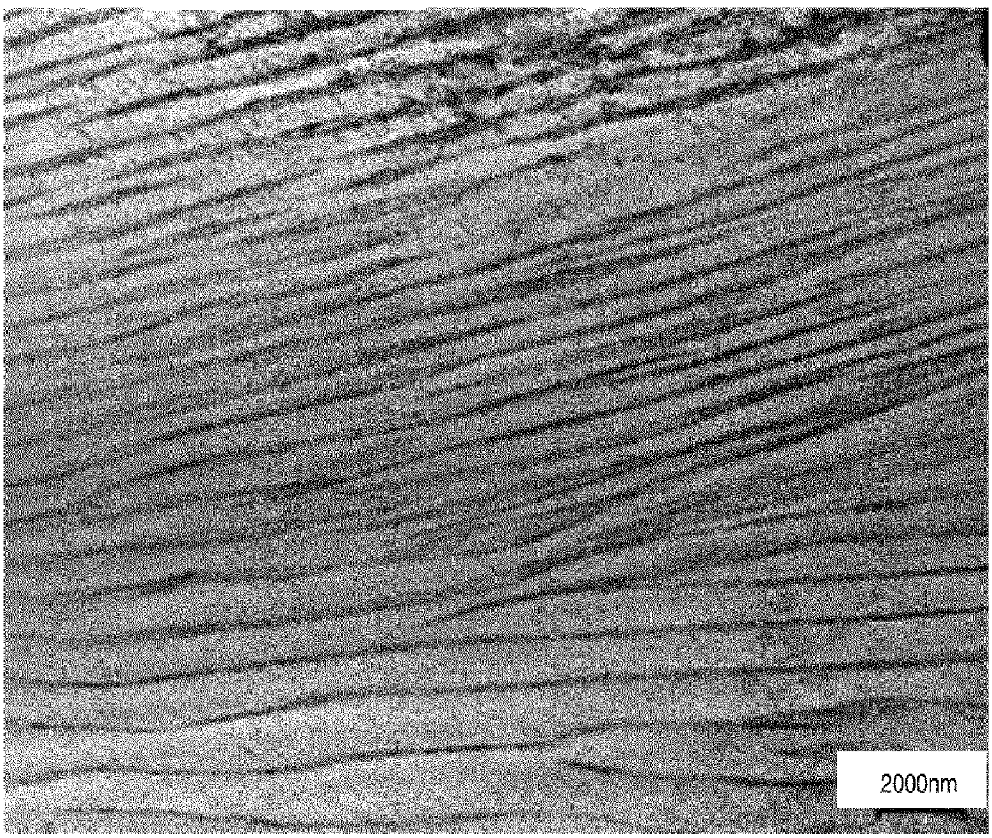


Figure 3

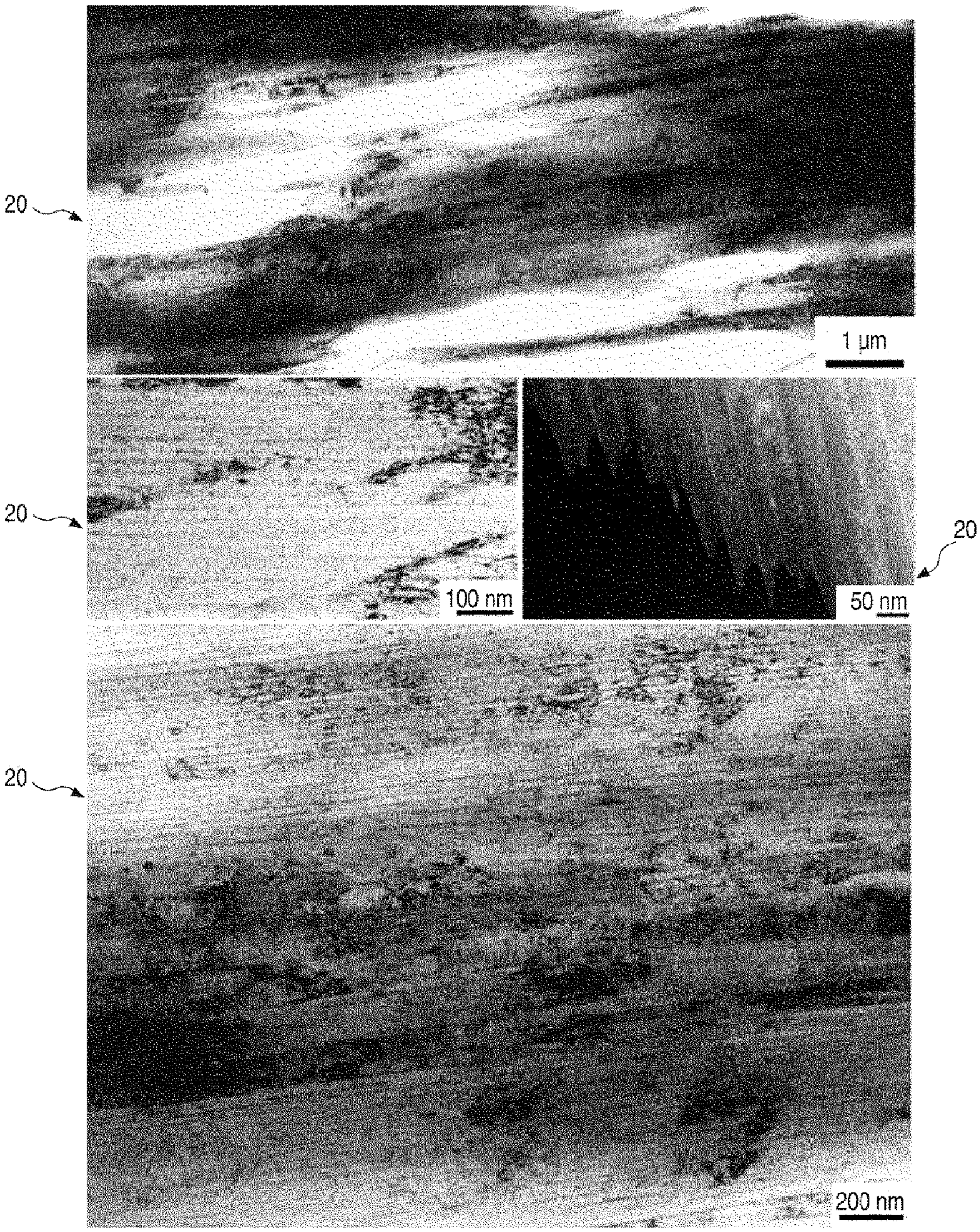


Figure 4

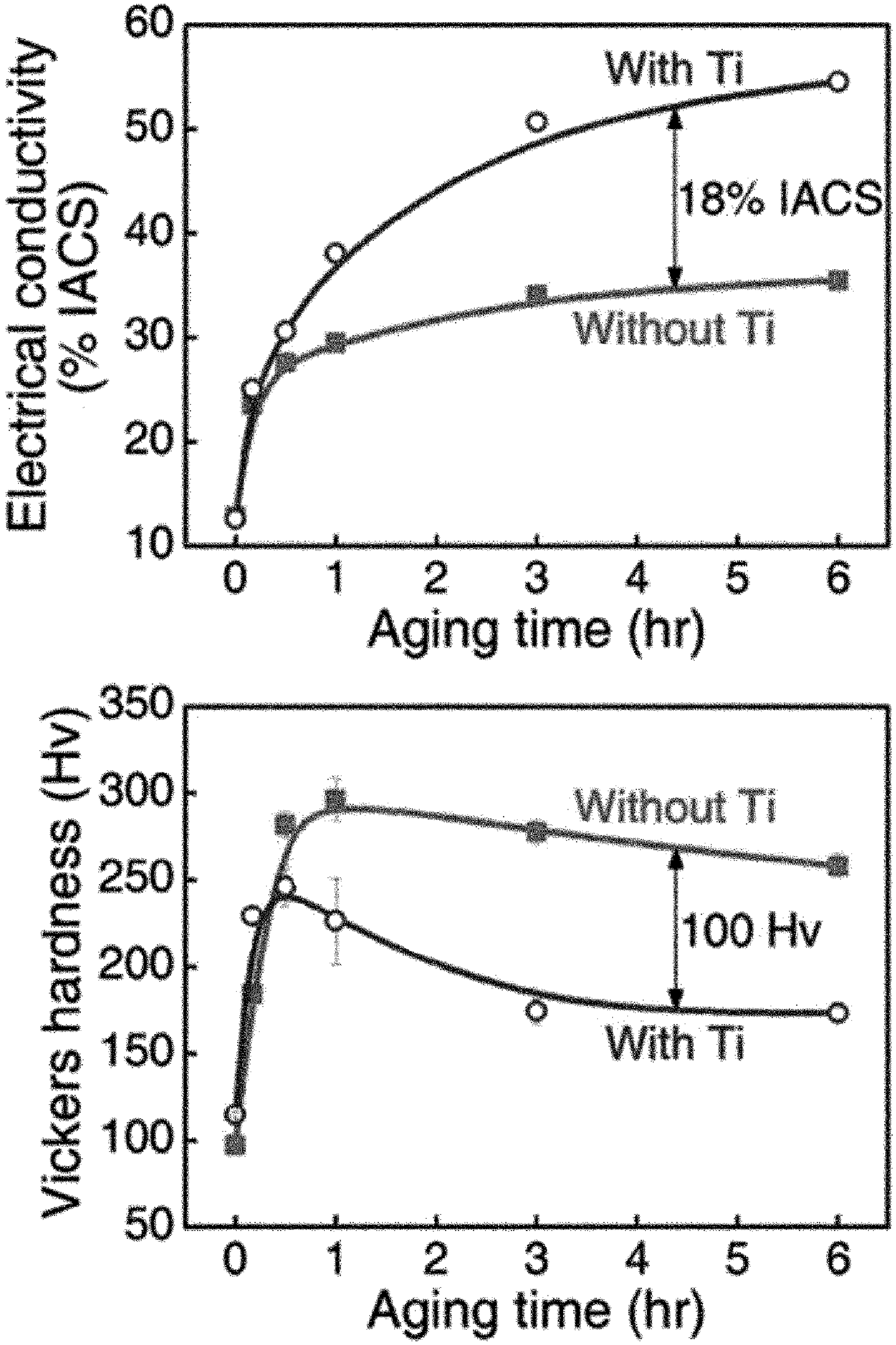

60
50
40
30
20
10
Electrical conductivity (% IACS)
With Ti
18% IACS
Without Ti
0
1
2
3
4
5
6
Aging time (hr)
350
300
250
200
150
100
50
Vickers hardness (Hv)
Without Ti
100 Hv
With Ti
0
1
2
3
4
5
6
Aging time (hr)

Figure 5

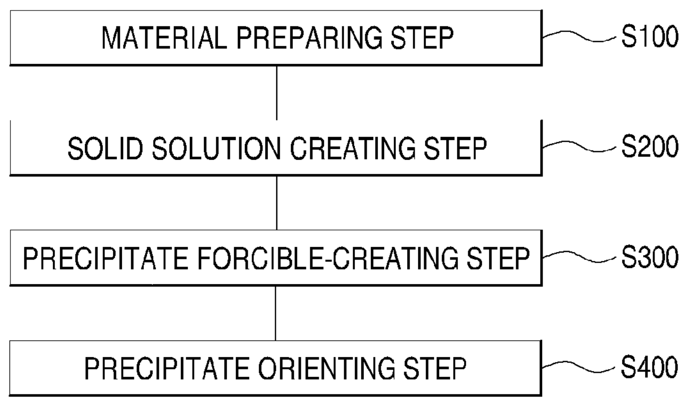

MATERIAL PREPARING STEP
S100
SOLID SOLUTION CREATING STEP
S200
PRECIPITATE FORCIBLE-CREATING STEP
S300
PRECIPITATE ORIENTING STEP
S400

Figure 6

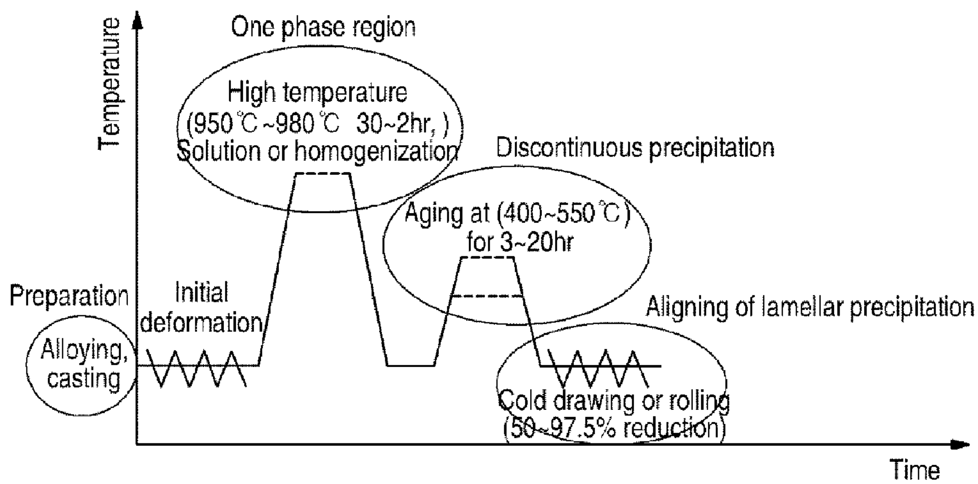
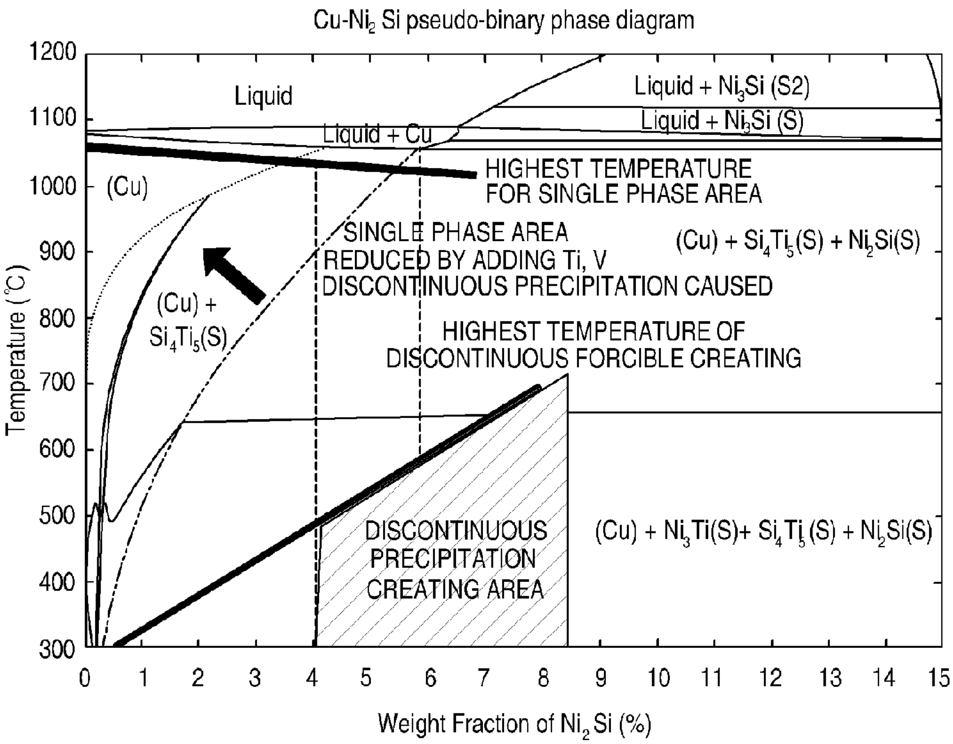

Temperature
One phase region
High temperature
(950℃~980℃ 30~2hr,)
Solution or homogenization
Discontinuous precipitation
Aging at (400~550℃)
for 3~20hr
Preparation
Initial
deformation
Alloying,
casting
Aligning of lamellar precipitation
Cold drawing or rolling
(50~97.5% reduction)
Time

Figure 7



HIGHEST SOLUBILITY: 6%

Figure 8

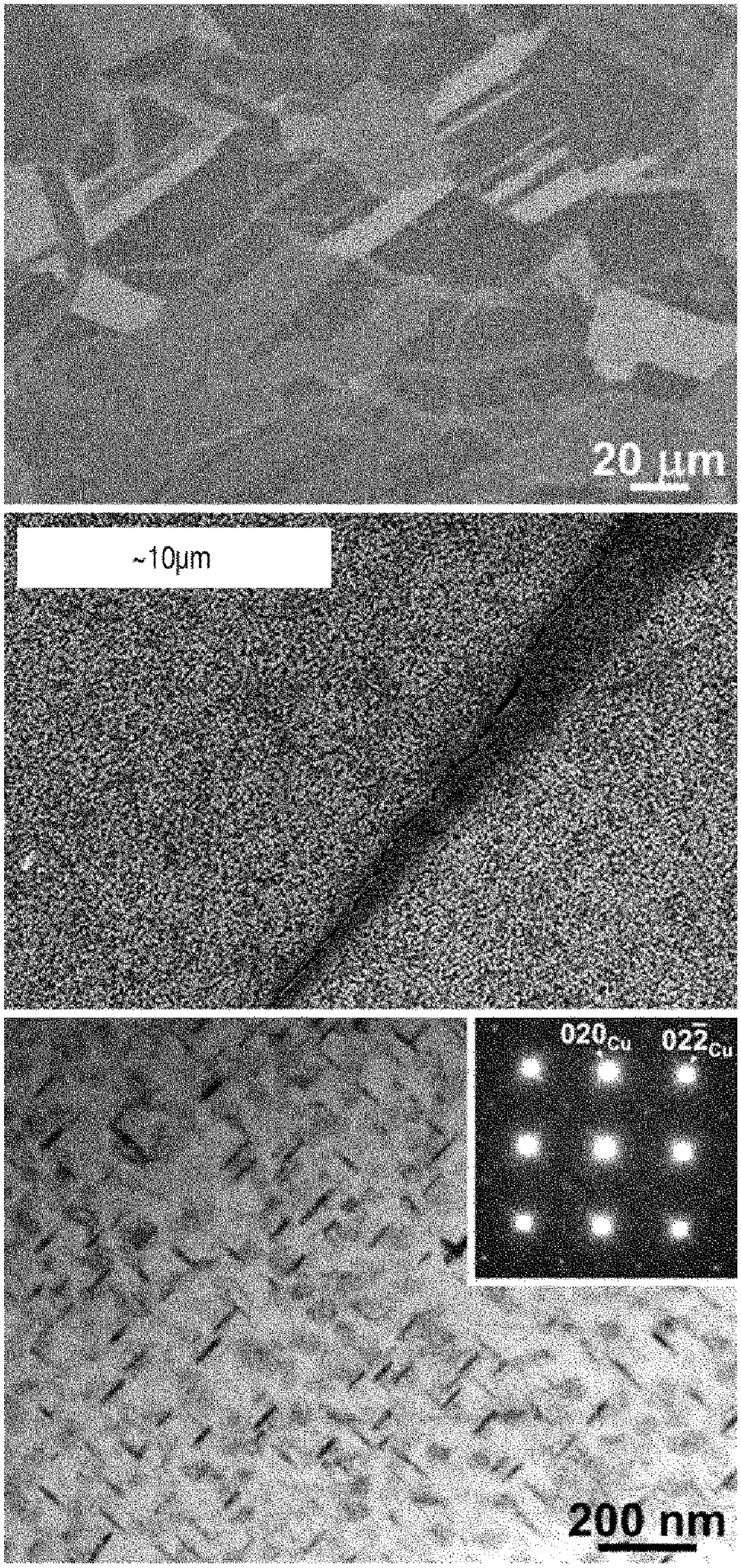


Figure 9

10

10

10

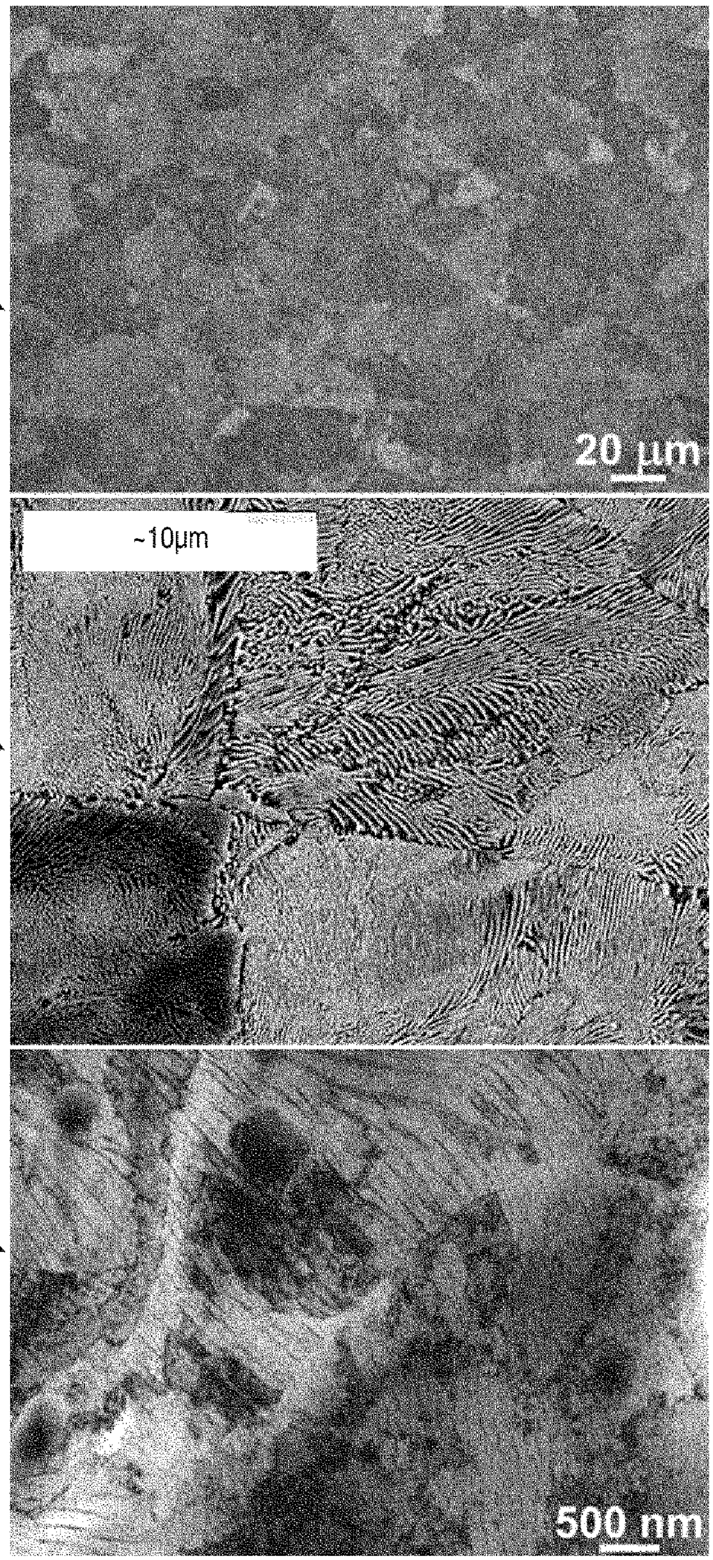
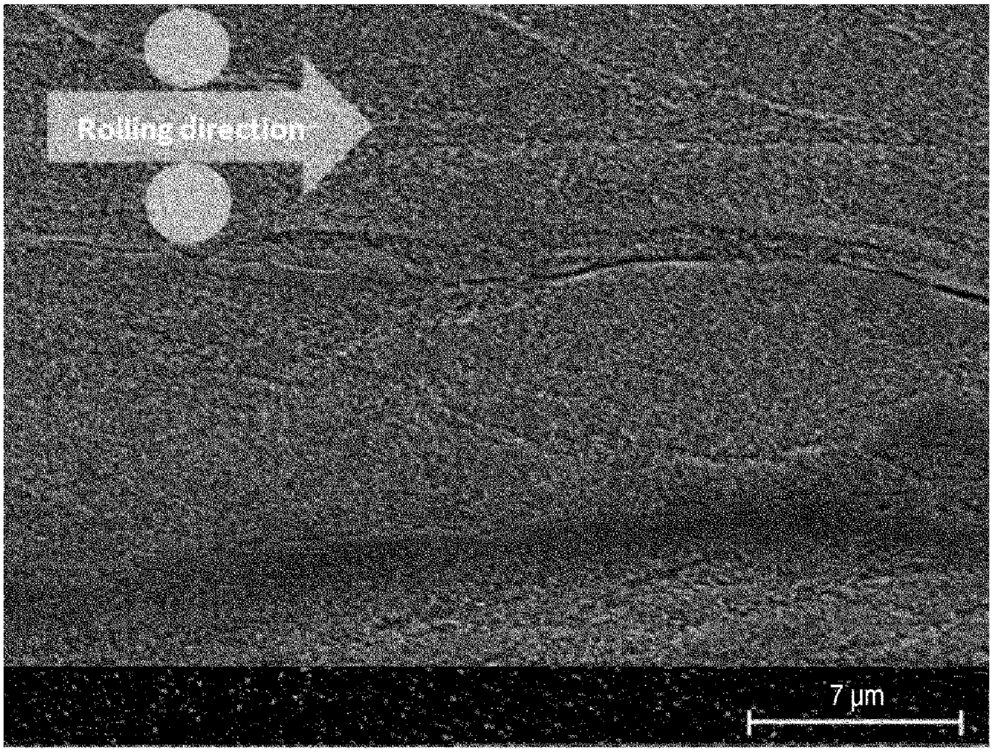


Figure 10



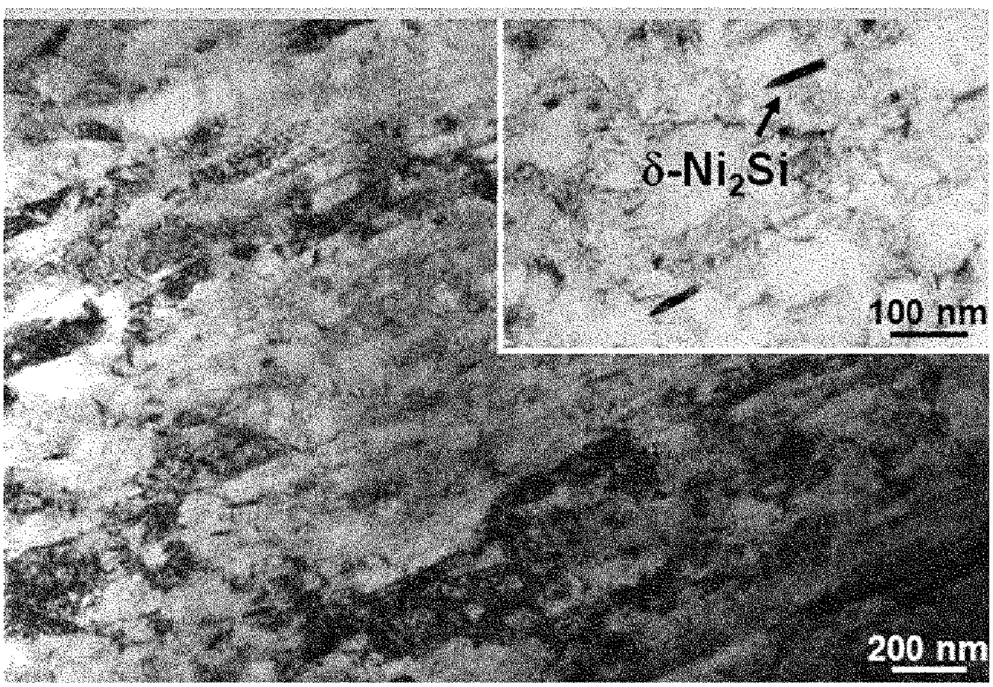


Figure 11

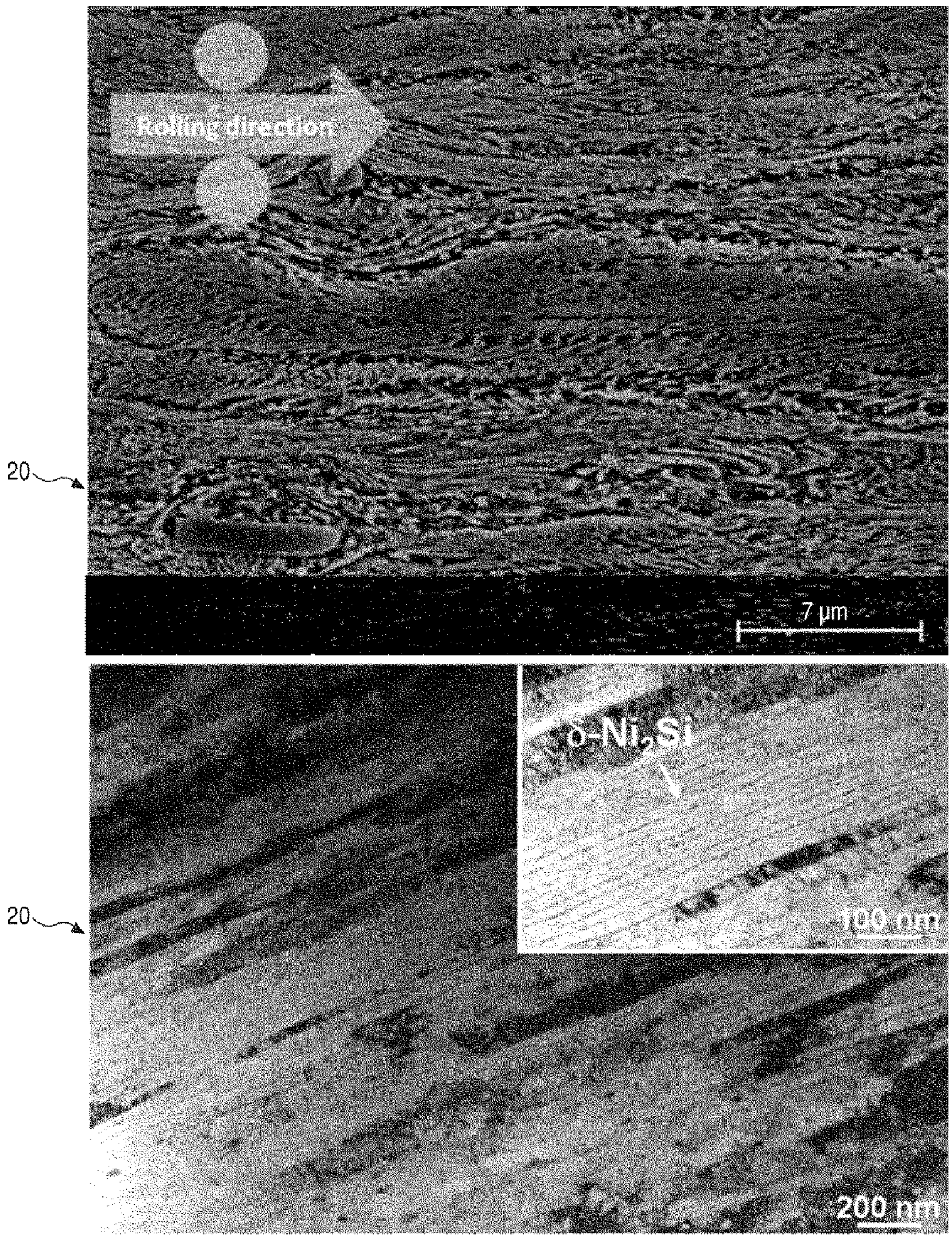


Figure 12

980°C 2hr and slow cooling and 500°C for 3hours

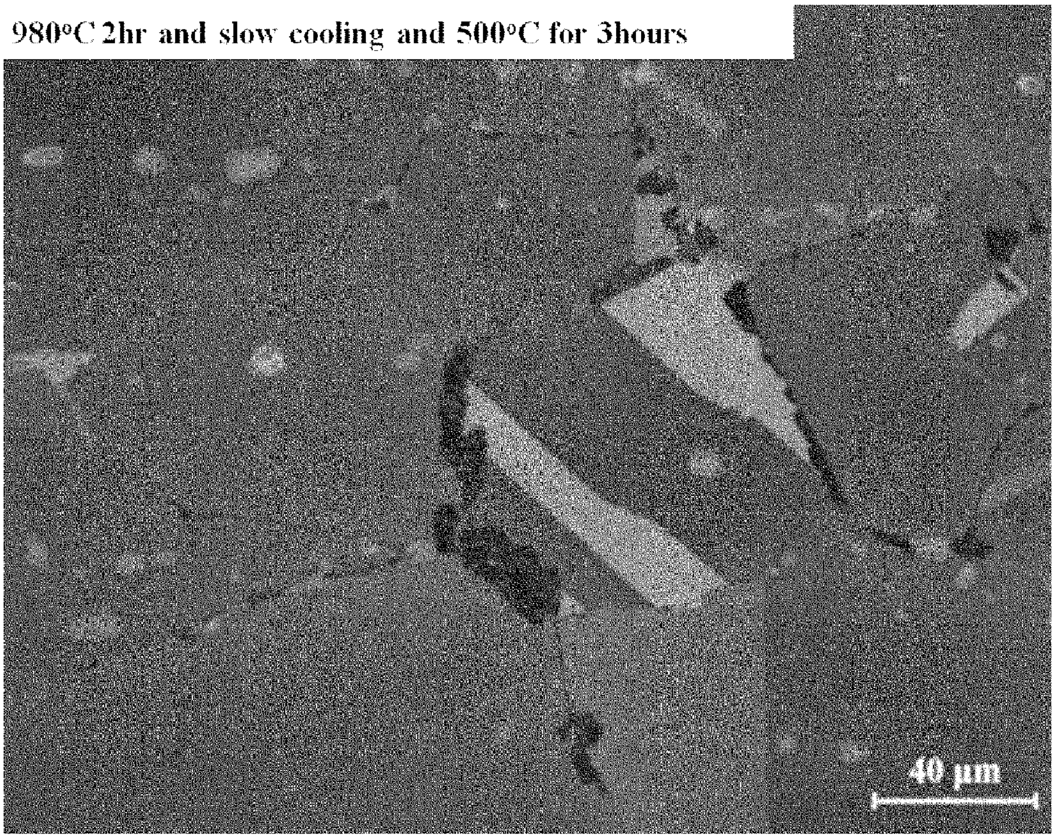


Figure 13

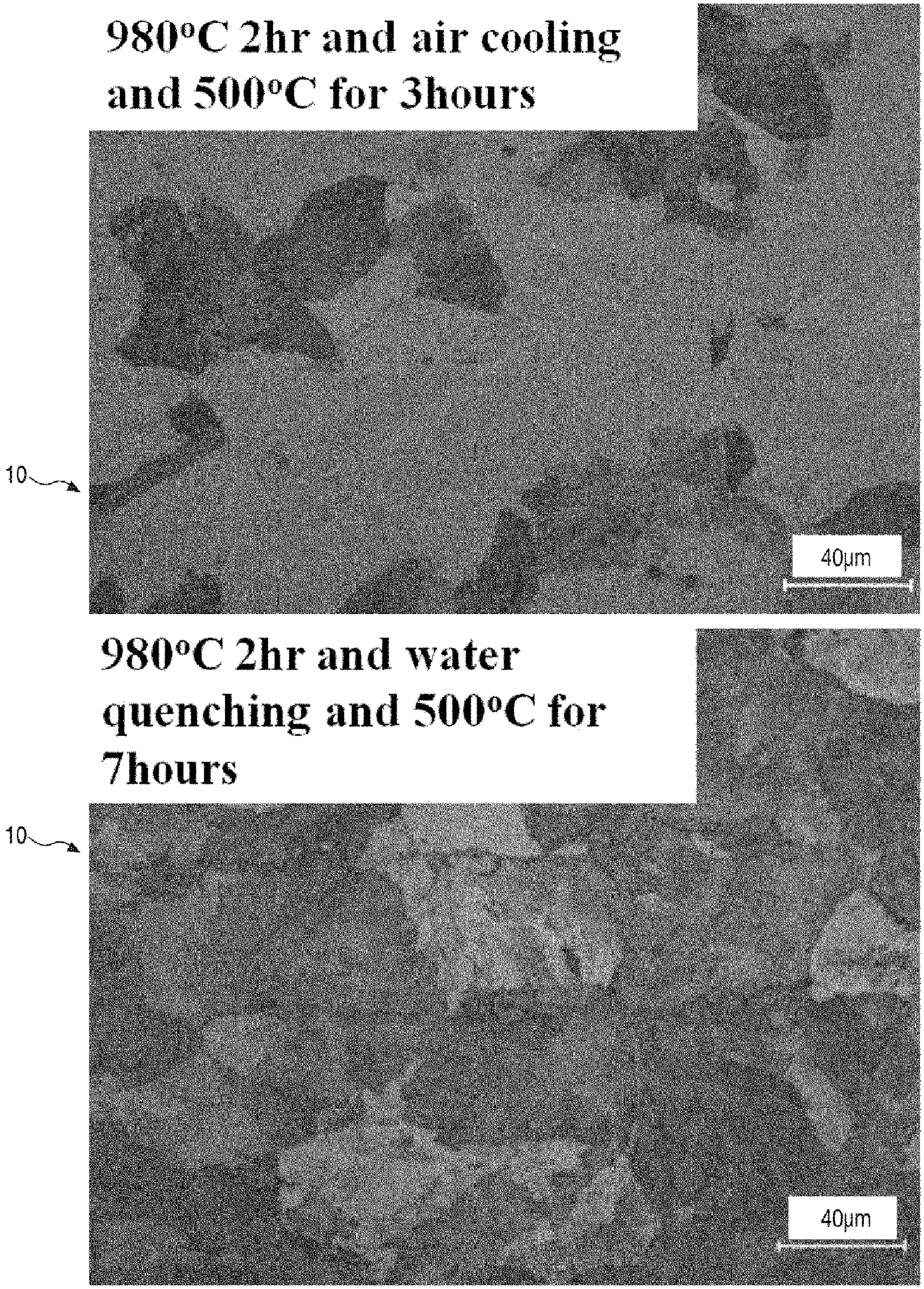

980°C 2hr and air cooling and 500°C for 3hours
10
40μm
980°C 2hr and water quenching and 500°C for 7hours
10
40μm

Figure 14

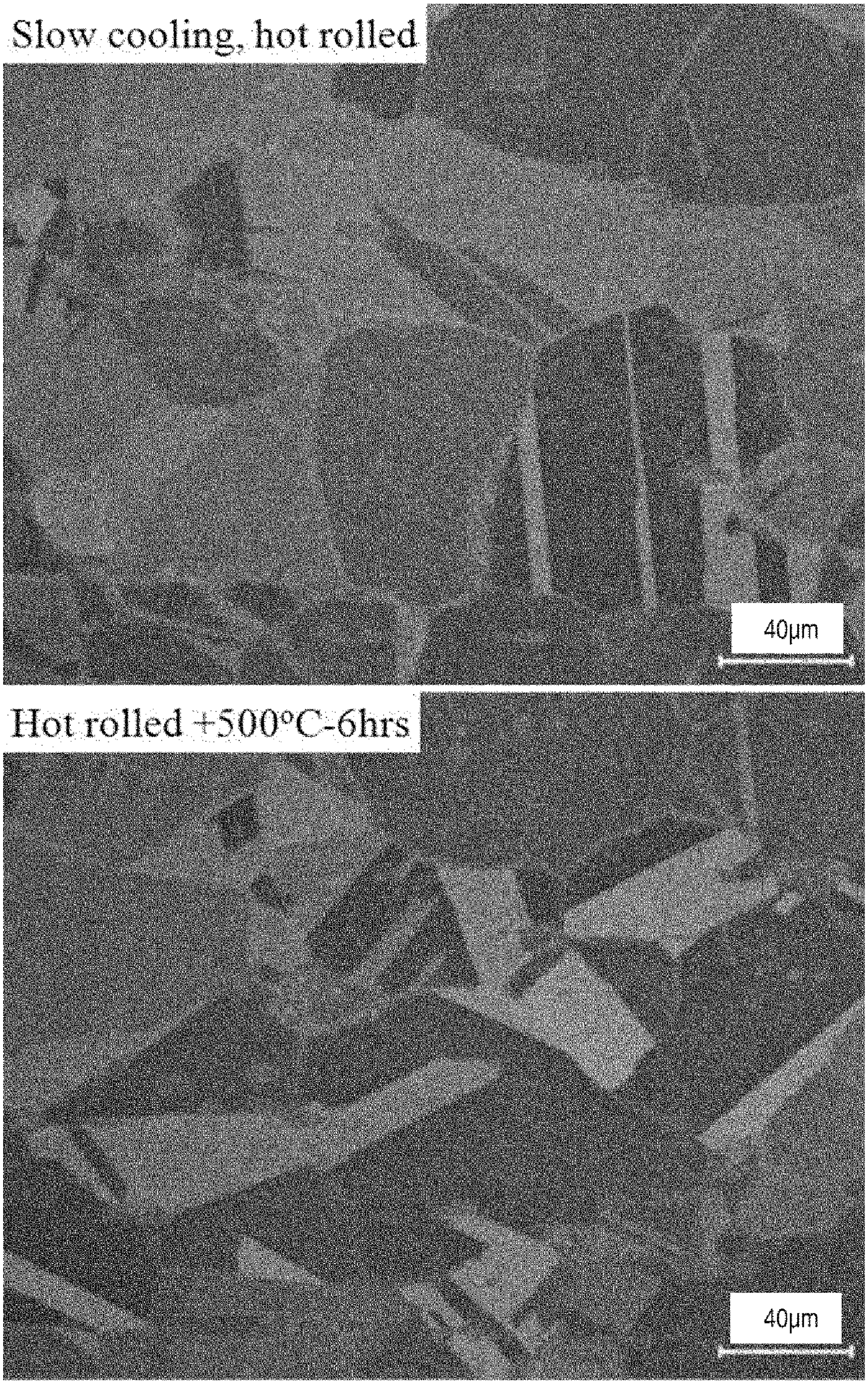


Figure 15

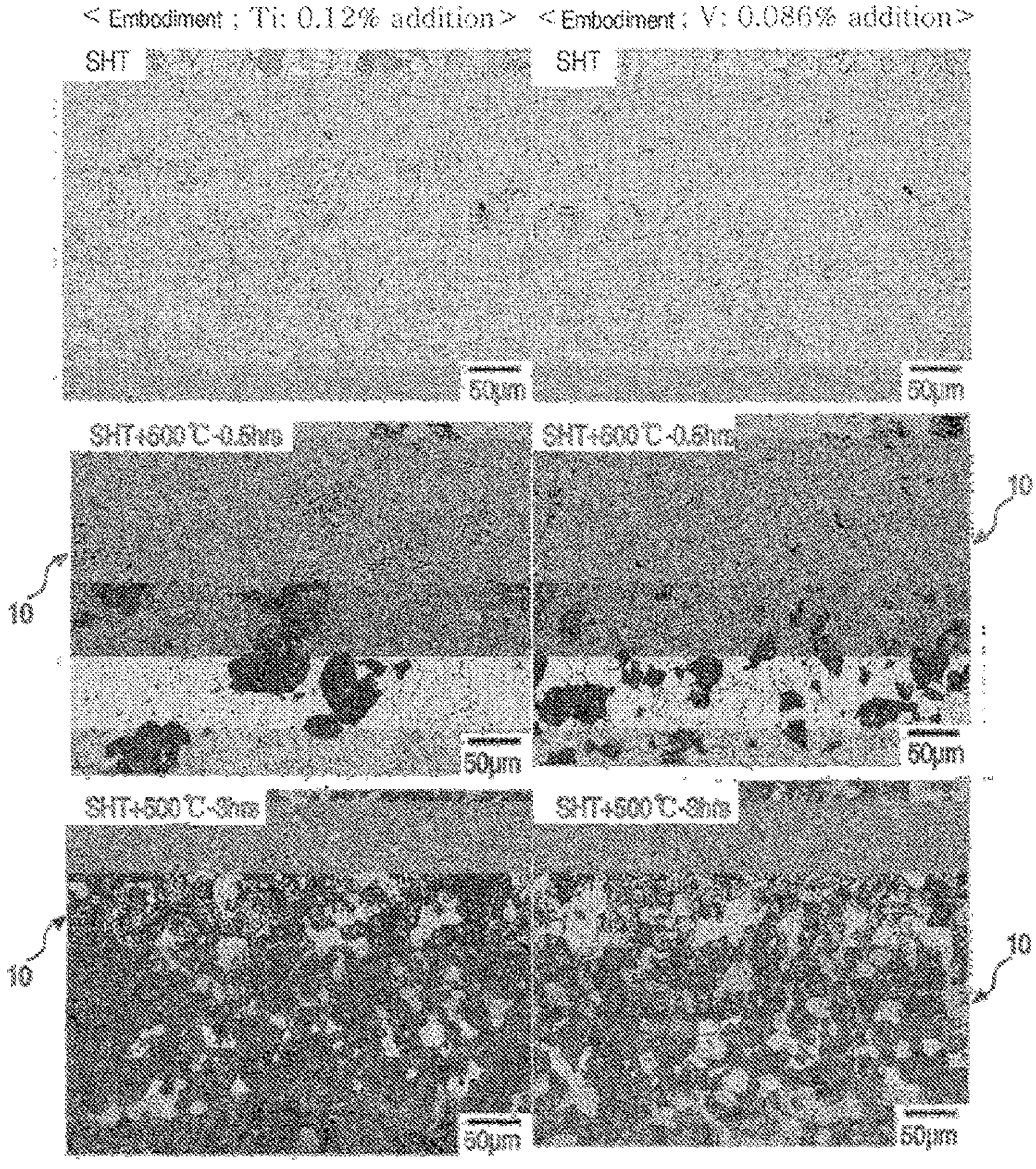

< Embodiment ; Ti: 0.12% addition >
< Embodiment ; V: 0.086% addition >
SHT
SHT
50μm
50μm
SHT+500℃-0.5hrs
SHT+500℃-0.5hrs
10
10
50μm
50μm
SHT+500℃-3hrs
SHT+500℃-3hrs
10
10
50μm
50μm

Figure 16

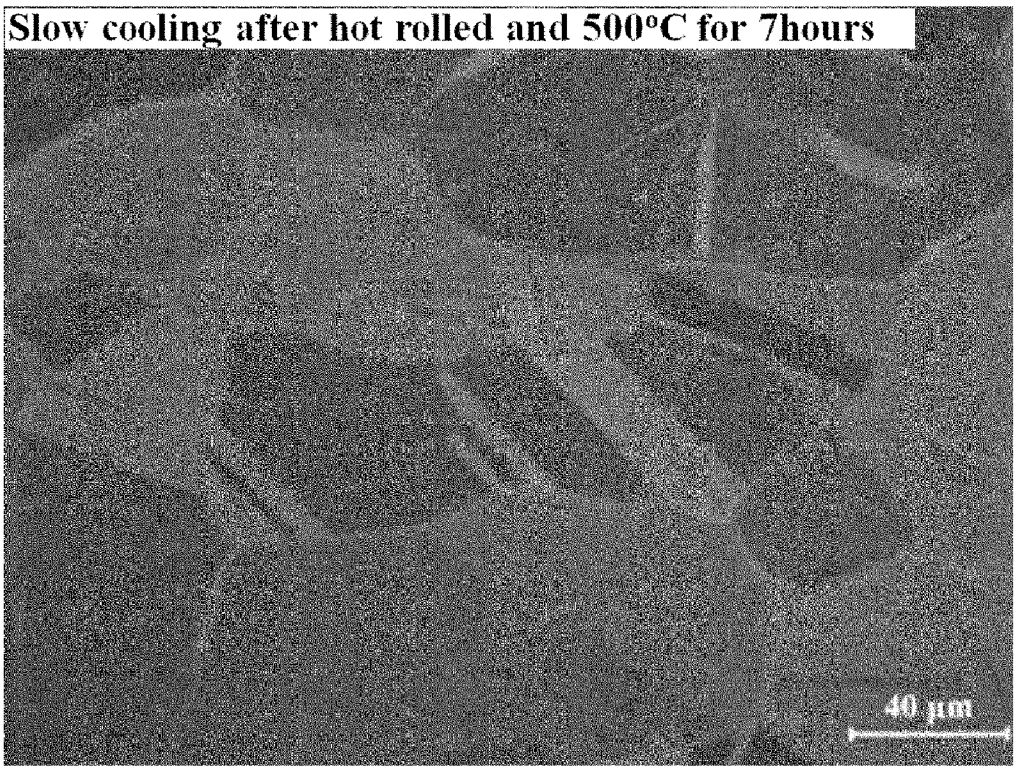


Figure 17

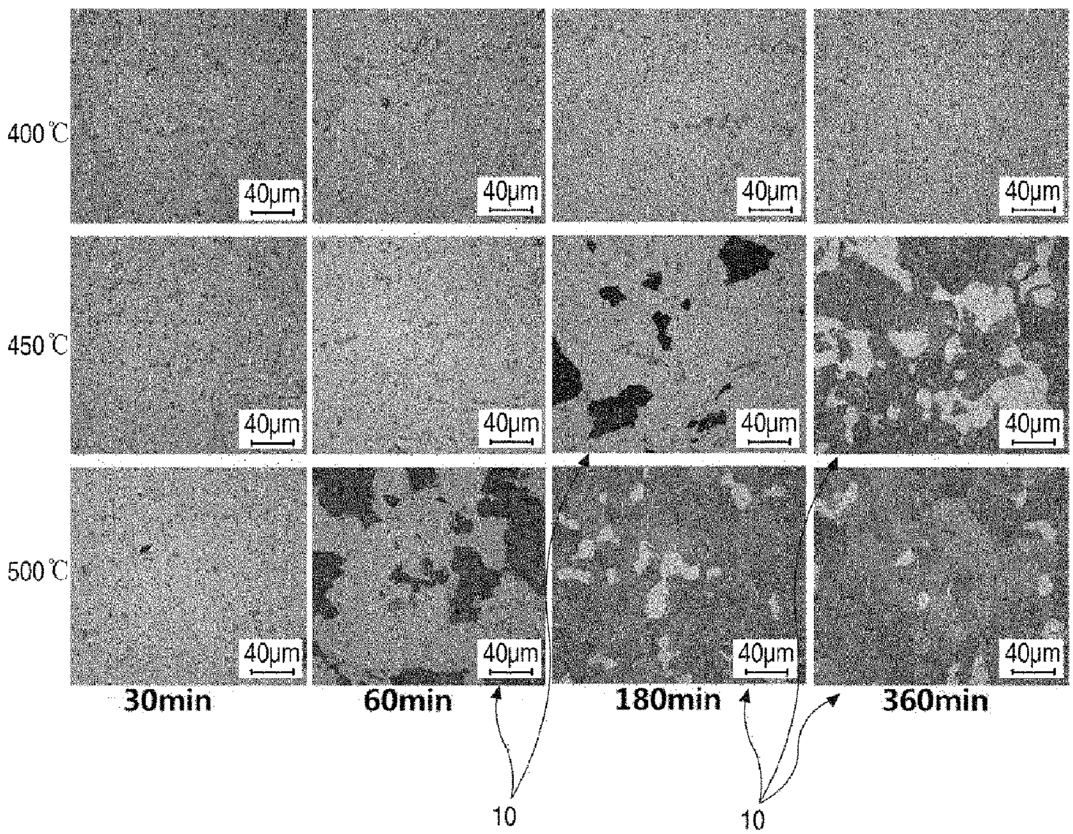


Figure 18

Alloy	Cu	Ni	Si	Ti
C3NS	Bal.	2.94	0.73	-
C3NST - 03	Bal.	3.20	0.74	0.025
C3NST - 05	Bal.	3.13	0.71	0.045
C4NS	Bal.	4.47	0.99	-
C4NST - 05	Bal.	4.50	0.97	0.09
C4NST - 10	Bal.	4.46	0.85	0.17

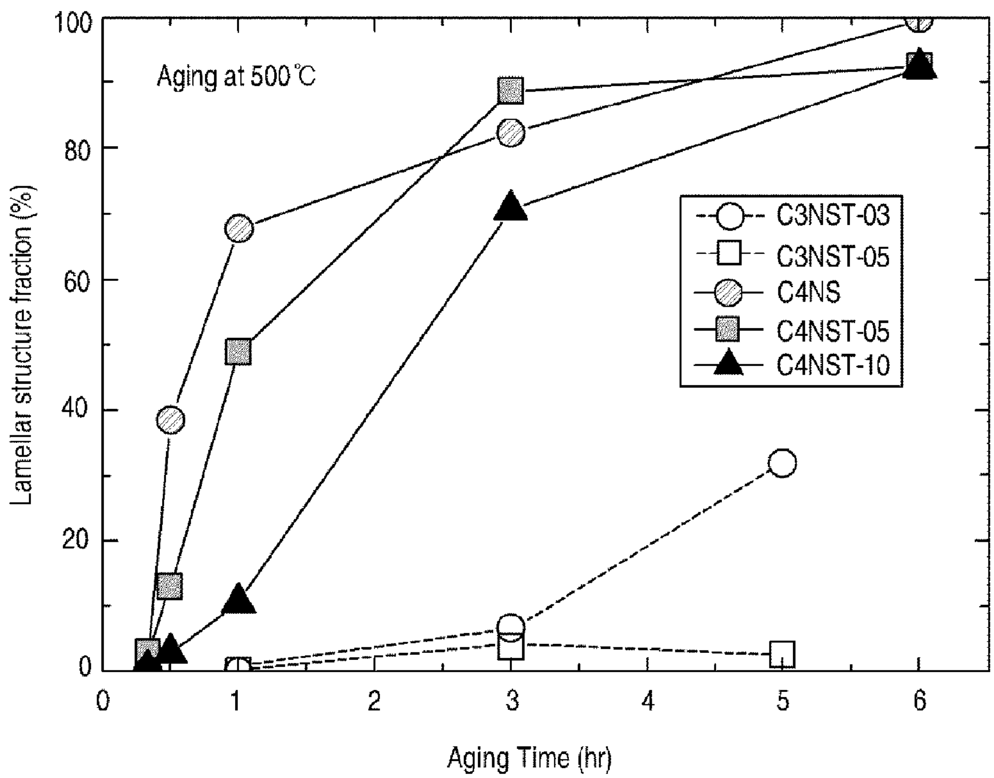


Figure 19

Alloy	Cu	Ni	Si	Ti
C4NSL	Bal.	3.99	0.88	-
C4NSLT - 03	Bal.	4.02	0.93	0.023
C4NSLT - 05	Bal.	4.05	0.92	0.041
CNS	Bal.	5.98	1.43	-
CNST - 10	Bal.	5.98	1.29	0.13

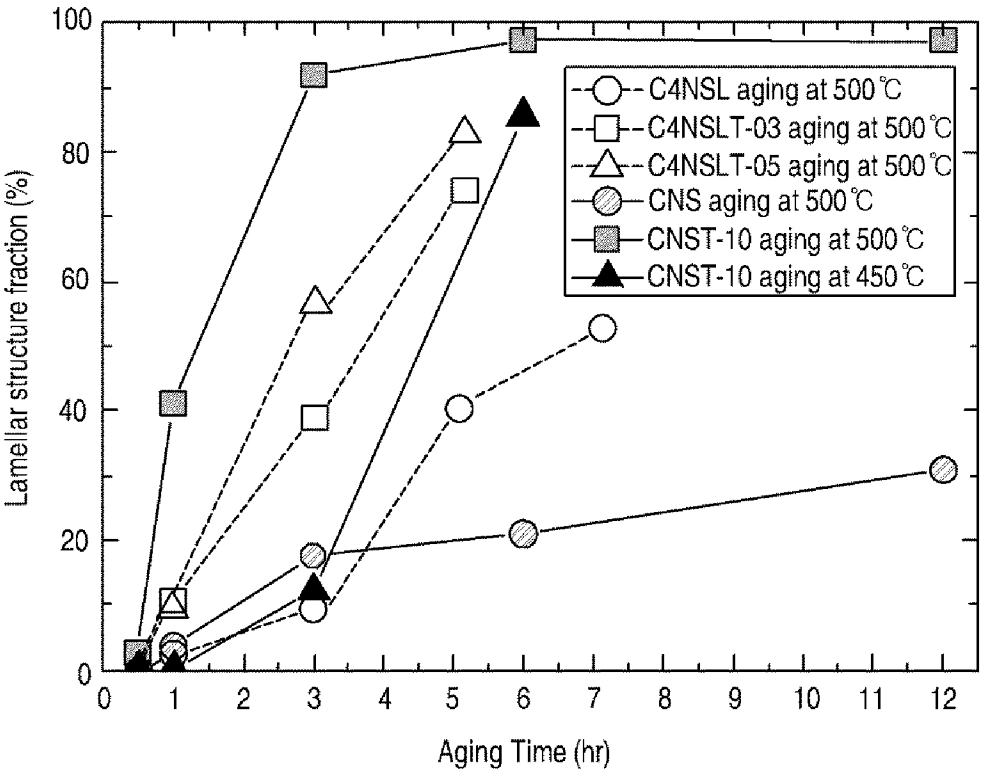


Figure 20

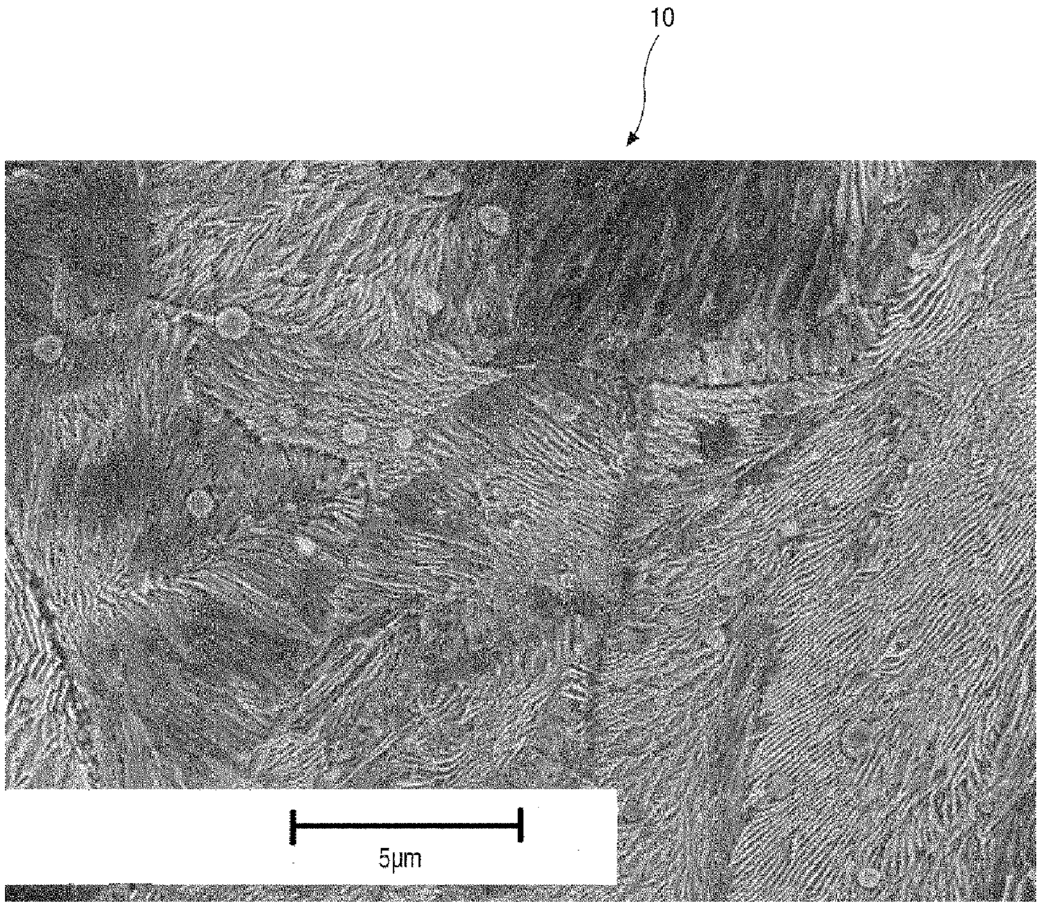


Figure 21

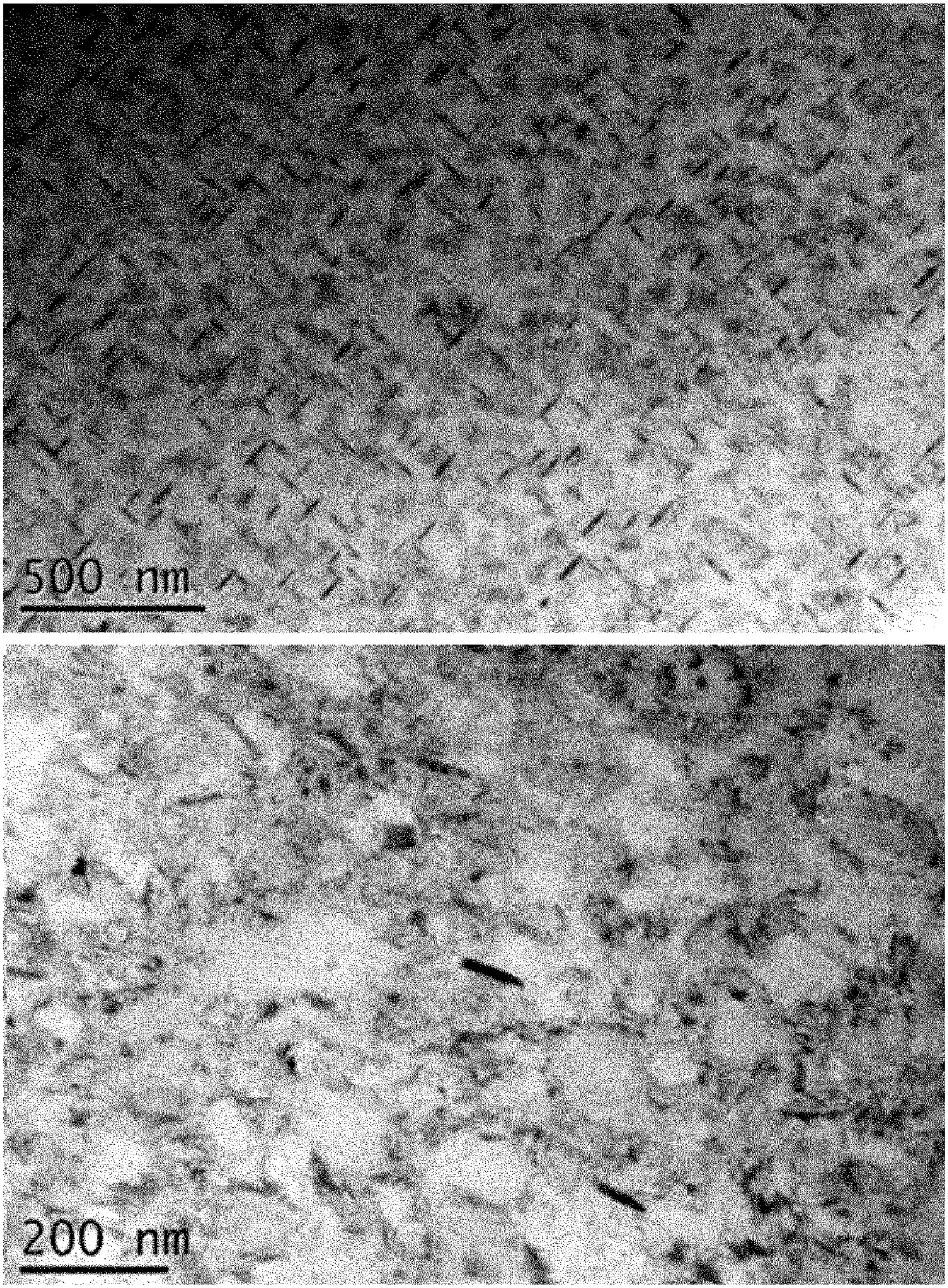


Figure 22

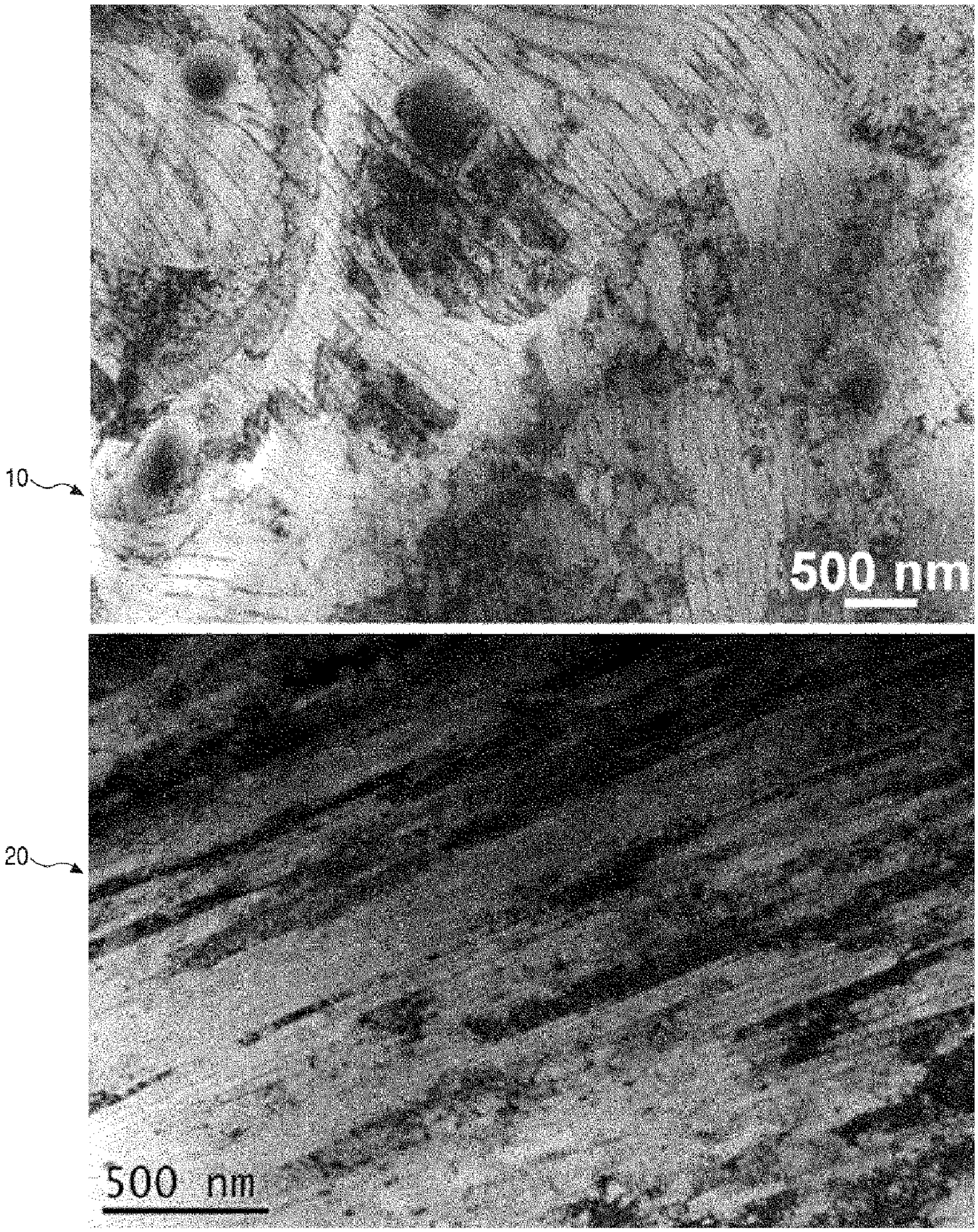


Figure 23

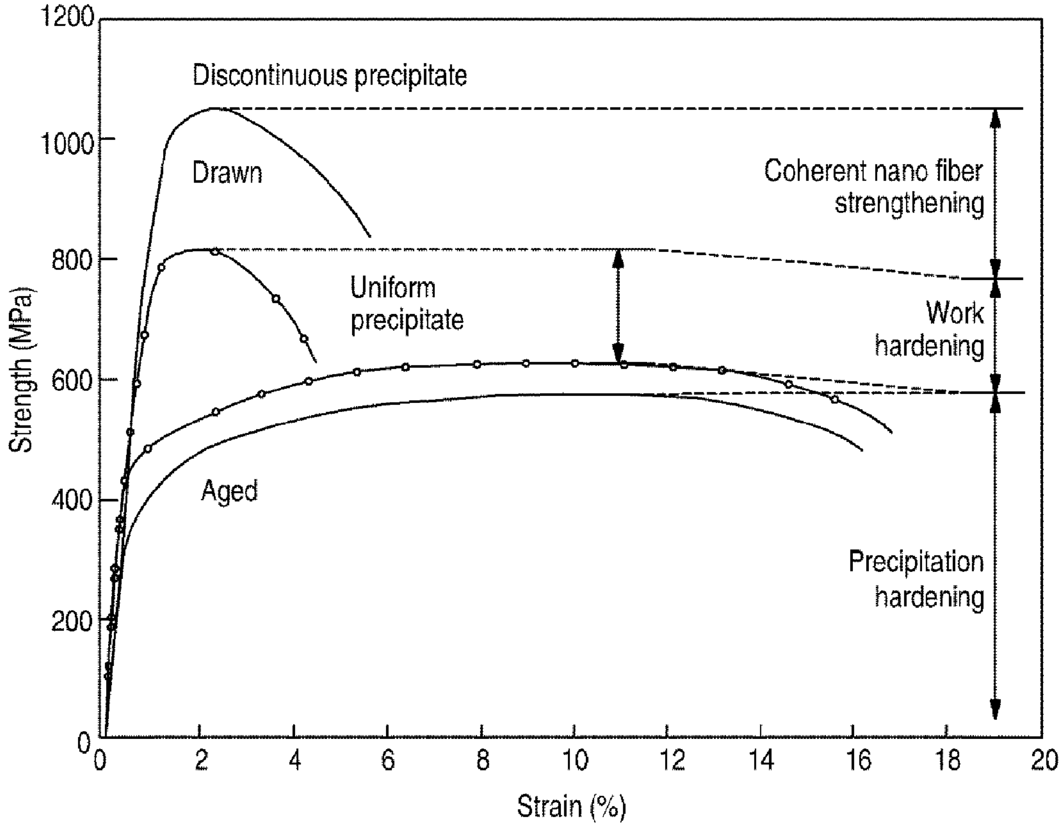

Discontinuous precipitate
Drawn
Coherent nano fiber strengthening
Uniform precipitate
Work hardening
Aged
Precipitation hardening
Strength (MPa)
Strain (%)
0
200
400
600
800
1000
1200
0
2
4
6
8
10
12
14
16
18
20

Figure 24

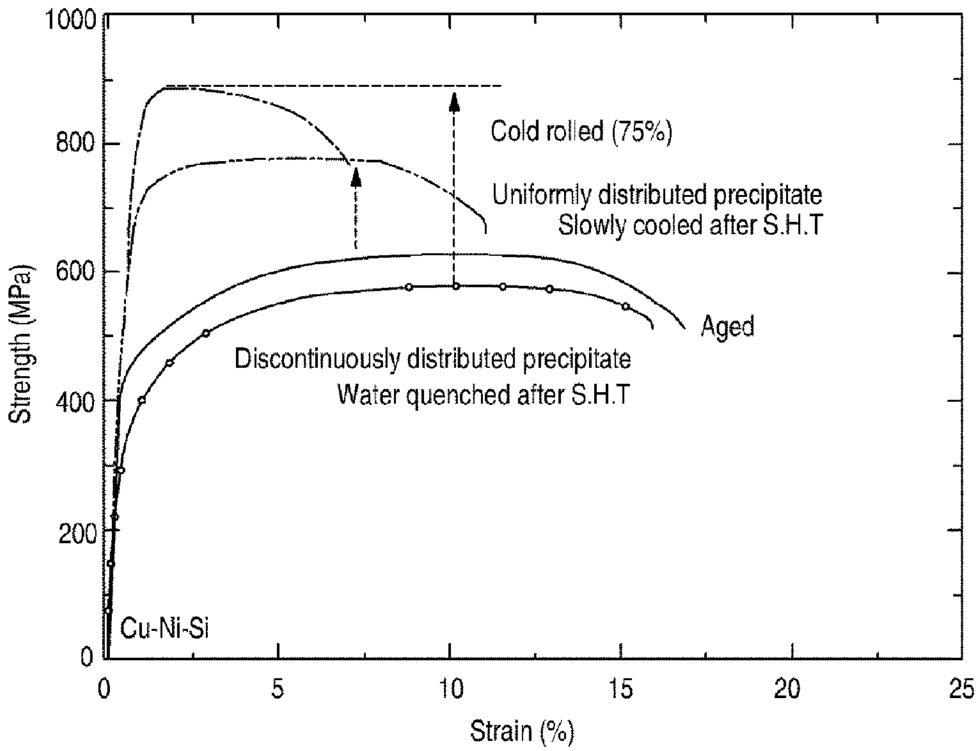
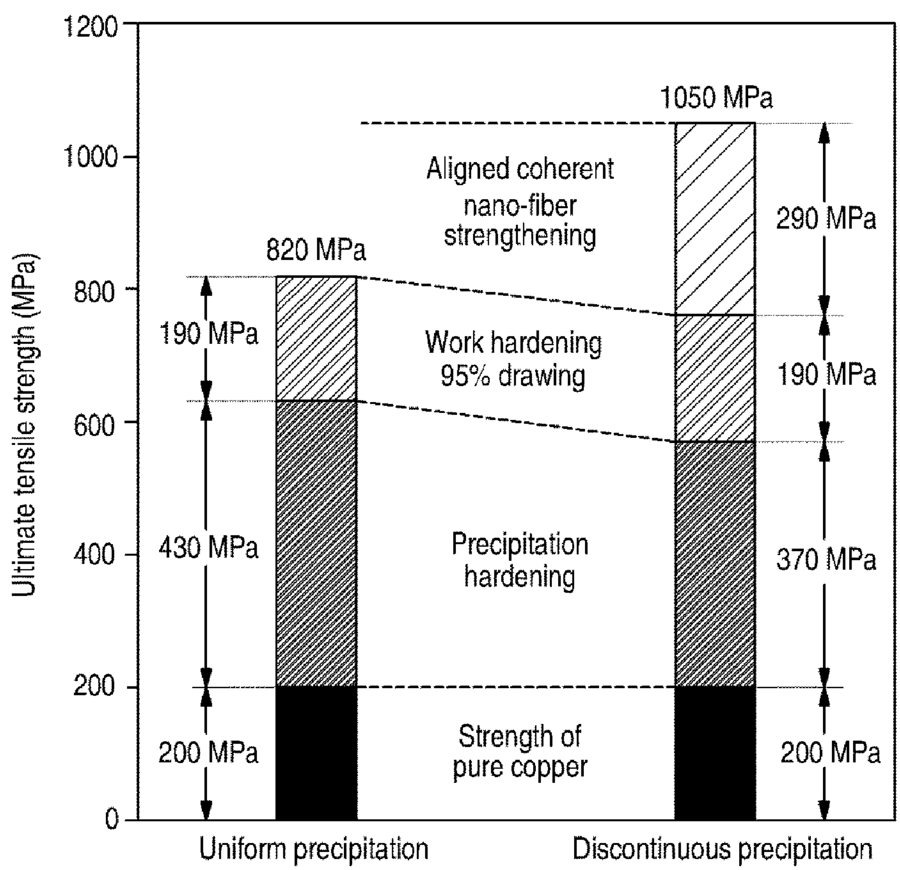

1000
800
600
400
200
0
Strength (MPa)
0
5
10
15
20
25
Strain (%)
Cold rolled (75%)
Uniformly distributed precipitate
Slowly cooled after S.H.T
Aged
Discontinuously distributed precipitate
Water quenched after S.H.T
Cu-Ni-Si

Figure 25


1200
1000
800
600
400
200
0
Ultimate tensile strength (MPa)
1050 MPa
820 MPa
Aligned coherent
nano-fiber
strengthening
290 MPa
190 MPa
Work hardening
95% drawing
190 MPa
430 MPa
Precipitation
hardening
370 MPa
200 MPa
Strength of
pure copper
200 MPa
Uniform precipitation
Discontinuous precipitation

METAL COMPOSITE COMPRISING ALIGNED PRECIPITATE AND PREPARATION METHOD THEREFOR

TECHNICAL FIELD

[0001] The present invention relates to a metal composite with an oriented precipitate and a method of manufacturing the same, and more particularly, to a metal composite with an oriented precipitate that has improved strength and electric conductivity by forcibly creating a precipitate through aging after creating a solid solution, which is created by selectively adding precipitation-promoting metal to an alloy and performing solution treatment or homogenization, and by orienting the forcibly created precipitate through plastic working, and a method of manufacturing the metal composite.

BACKGROUND ART

[0002] Due to high electric conductivity, copper is widely used in electric/electronic circuits, but as information communication parts have become highly integrated and reduced in weight, copper is exposed to high current and voltage when it is used in electric/electronic circuits.

[0003] Furthermore, when it is used as a conductive material, it is further exposed to a severe environment, so high strength and electric conductivity and excellent thermal stability are required.

[0004] That is, copper alloys are used for connectors, accumulators, or connectors for connecting a controller to various electric parts, actuators, and sensors in vehicles equipped with increased electric devices and it is strongly required to downsize these connectors.

[0005] In particular, connectors disposed close to an engine are exposed to the heat and vibration of the engine, and when a large amount of current is applied to the connectors, the connectors generate heat and increase the temperature to a high level. Accordingly, those connectors require high reliability under such environments.

[0006] Accordingly, as a material of copper alloy connectors used in common vehicles, a Cu—Fe—P alloy (Korean Patent No. 10-0997560) or a Cu—Mg—P alloy (Korean Patent No. 10-0417756) have been disclosed. The strength of the former alloy is improved by precipitating a Fe—P compound based on the addition of both of Fe and P.

[0007] Furthermore, there have been proposed an alloy of which mobility resistance is improved by adding Zn (Japanese Patent Application Publication No. 168830) and an alloy of which mitigation of stress resistance is improved by adding Mg (Japanese Patent Application Publication No. 358033).

[0008] The latter alloy is improved in tensile strength, electric conductivity, and mitigation of stress resistance by improving strength and creeping characteristic by adding Mg and P.

[0009] As described above, copper alloys can improve its electric conductivity, thermal stability, and strength by adding various components.

[0010] However, various components that are added to copper alloys make electric conductivity and strength opposite to each other.

[0011] That is, when the strength is increased, the electric conductivity is decreased, and when the electric conductivity is increased, a microstructure changes and strength decreases.

SUMMARY OF INVENTION

Technical Problem

[0012] An object of the present invention is to provide a metal composite with an oriented precipitate that has improved strength and electric conductivity by forcibly creating a precipitate through aging after creating a solid solution, which is created by selectively adding precipitation-promoting metal to an alloy and performing solution treatment or homogenization, and by orienting the forcibly created precipitate through plastic working, and a method of manufacturing the metal composite.

Solution to Problem

[0013] In order to achieve the object, the present invention provides a metal composite with an oriented precipitate, in which a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate of 40% or more per unit area of 500 μm×500 μm is forcibly created by aging, and the forcibly created precipitate is oriented by plastic working.

[0014] The present invention provides a metal composite with an oriented precipitate, in which a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate of 40% or more per unit area of 630 μm×480 μm is forcibly created by aging, and the forcibly created precipitate is oriented by plastic working.

[0015] The present invention provides a metal composite with an oriented precipitate, in which a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate is forcibly created by aging, and the forcibly created precipitate is oriented by plastic working to have a length of 2.0 μm or more per unit area of 3.5 μm×1.5 μm in a copper base.

[0016] The oriented precipitate has a length to diameter aspect ratio of 100 or more.

[0017] The alloy that became the solid solution is rapidly cooled by water quenching or cooled by air.

[0018] The aging is performed for three hours or more.

[0019] Precipitation-promoting metal is added in the solution treatment or homogenization process.

[0020] The precipitation-promoting metal includes any one of titanium (Ti) and vanadium (V).

[0021] The present invention provides a method of manufacturing a metal composite with an oriented precipitate which includes: a material preparing step of preparing a molded alloy; a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area; a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate of 40% or more per unit area of 500 μm×500 μm by aging the alloy containing the solid solution; and a precipitate orienting step of orienting the precipitate by performing plastic working on the alloy containing the precipitate.

[0022] The present invention provides a method of manufacturing a metal composite with an oriented precipitate which includes: a material preparing step of preparing a molded alloy; a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area; a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate of 40% or more per unit area of 630 μm×480 μm by aging the alloy containing the solid solution; and a precipitate orienting step of orienting the precipitate by performing plastic working on the alloy containing the precipitate.

[0023] The present invention provides a method of manufacturing a metal composite with an oriented precipitate which includes: a material preparing step of preparing a molded alloy; a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area; a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate of 40% or more per unit area of 630 μm×480 μm by aging the alloy containing the solid solution; and a precipitate orienting step of orienting the precipitate to have a length of 2.0 μm or more per unit area of 3.5 μm×**1.5** μm in a copper base by performing plastic working on the alloy containing the precipitate.

[0024] In the material preparing step, precipitation-promoting metal including any one of titanium (Ti) and vanadium (V) is added.

[0025] The solid solution creating step is a process of performing heating within a temperature range of above the lowermost temperature where a single phase is maintained in the state diagram and below the melting temperature−7.5×X (X is wt % of an added component other than copper base) of a copper base phase for two hours or more.

[0026] The precipitate forcible-creating step is performed at a temperature below 47×X (X is wt % of an added component other than copper base)+melting temperature of a copper base phase×0.4(K, absolute temperature).

[0027] The alloy is a copper alloy and (Ni+Si), which is X, is 4.8 to 7.5wt %.

Advantageous Effects of Invention

[0028] The present invention relates to a metal composite with an oriented precipitate that can function as a reinforcing material of a composite by artificially orienting an artificially created precipitate through plastic working.

[0029] Accordingly, electric conductivity and strength are improved.

[0030] Furthermore, it is possible to adjust the amount of precipitate by selectively adding precipitation-promoting metal.

BRIEF DESCRIPTION OF DRAWINGS

[0031] FIG. **1** is a picture of microstructures, obtained by an optical microscope, of a continuous precipitate and a discontinuous precipitate before plastic working in a metal composite with an oriented precipitate according to the present invention.

[0032] FIG. **2** is a picture of a microstructure obtained by a transmission electron microscope, enlarging the portion A of FIG. **1**.

[0033] FIG. **3** is a picture of a microstructure, obtained by a transmission electron microscope, of a metal composite with an oriented precipitate according to the present invention.

[0034] FIG. **4** is a diagram comparing changes in hardness and electric conductivity before/after aging in a metal composite with an oriented precipitate according to the present invention.

[0035] FIG. **5** is a flowchart illustrating a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0036] FIG. **6** is a schematic diagram illustrating a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0037] FIG. **7** is a Cu—Ni_2Si two-phase diagram for examining temperatures to be applied in a step of creating a solid solution and a step of forcibly creating a precipitate in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0038] FIG. **8** is a picture of a microstructure in a comparative example aged without a step of creating a solid solution in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0039] FIG. **9** is a picture of a microstructure after a step of creating a solid solution and a step of forcibly creating a precipitate in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0040] FIG. **10** is a picture of a microstructure in plastic working on a comparative example where slow cooling has been applied in a step of creating a solid solution in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0041] FIG. **11** is a picture of a microstructure in plastic working on an embodiment where rapid cooling has been applied in a step of creating a solid solution in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0042] FIG. **12** is a picture of a microstructure in a comparative example without a step of creating a solid solution in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0043] FIG. **13** is a picture of a microstructure in an embodiment with a step of creating a solid solution in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0044] FIG. **14** is a picture of a microstructure in a comparative example where slow cooling has been performed without precipitation-promoting metal in a step of creating a solid solution in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0045] FIG. **15** is a picture of a microstructure in an embodiment where rapid cooling has been performed with precipitation-promoting metal in a step of forcibly creating a precipitate in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0046] FIG. **16** is a picture of a microstructure in heat treatment at 500° C. after hot rolling on the comparative example of FIG. **14**.

[0047] FIG. **17** is a picture showing a change in the microstructure according to heat treatment temperature and time change in the embodiment of FIG. **15**.

[0048] FIGS. **18** and **19** are graphs showing changes in area ratios of discontinuous precipitation after a step of forcibly creating a precipitate in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0049] FIG. **20** is a picture of a microstructure, obtained by an electron microscope, in a preferred embodiment that has undergone a step of forcibly creating a precipitate in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0050] FIG. **21** is a picture of a microstructure when a step of forcibly creating a precipitate (up) and a step of orienting a precipitate (down) in a comparative example without a step of creating a solid solution.

[0051] FIG. **22** is a picture comparing microstructure before/after a step of orienting precipitate in a method of manufacturing a metal composite with an oriented precipitate according to the present invention.

[0052] FIG. **23** is a graph comparing mechanical properties before/after a step of orienting precipitates employing a drawing process in a comparative example and a preferred embodiment.

[0053] FIG. **24** is a graph comparing mechanical properties before/after a step of orienting precipitates employing a rolling process in a comparative example and a preferred embodiment.

[0054] FIG. **25** is a graph comparing the test results of FIG. **23** step by step.

DESCRIPTION OF EMBODIMENTS

[0055] A metal composite **20** with a discontinuous cellular precipitate or a lamellar precipitate according to the present invention is described hereafter with reference to FIGS. **1** to **3**.

[0056] The terms and words used in the present specification and claims should not be interpreted as being limited to typical meanings or dictionary definitions, but should be interpreted as having meanings and concepts relevant to the technical scope of the present invention based on the rule according to which an inventor can appropriately define the concept of the term to describe most appropriately the best method he or she knows for carrying out the invention.

[0057] Therefore, the configurations described in the embodiments and drawings of the present invention are merely the most preferable embodiments and do not represent all of the technical spirit of the present invention. Thus, the present invention should be construed as including all the changes, equivalents, and substitutions included in the spirit and scope of the present invention at the time of filing this application.

[0058] FIGS. **1** and **2** are pictures of microstructures, obtained by an optical microscope, of a continuous precipitate and a discontinuous precipitate before plastic working, with FIG. **2** being the enlarged picture of portion A in FIG. **1**, in a metal composite with an oriented precipitate according to the present invention and FIG. **3** is a picture of a microstructure, obtained by a transmission electron microscope, of a metal composite **20** with an oriented precipitate according to the present invention.

[0059] The present invention provides a metal composite **20** that has improved strength and electric conductivity by providing a composite type strengthening effect by creating and artificially orienting a precipitate of a cellular or lamellar structure that reduces mechanical strength in metal.

[0060] That is, the metal composite **20** of the present invention was achieved by artificially creating a precipitate in an alloy **10**, as in FIGS. **1** and **2**, and artificially orienting the precipitate, as in FIG. **3**.

[0061] The precipitate may be a discontinuous cellular precipitate or a continuous lamellar precipitate and, for the plastic working, various processes such as drawing, rolling, and extruding may be selected.

[0062] FIG. **4** is a chart comparing changes in hardness and electric conductivity before/after aging in the metal composite **20** with an oriented precipitate according to the present invention.

[0063] As shown in the figure, precipitation-promoting metal **10** for increasing the amount of a precipitation may be added to the alloy in the process of manufacturing the metal composite **20**.

[0064] The precipitation-promoting metal is titanium (Ti) or vanadium (V) and a copper alloy was selected in a preferred embodiment of the present invention.

[0065] Since the precipitation-promoting metal is selectively added, electric conductivity or strength can be artificially adjusted.

[0066] The length to diameter aspect ratio of a precipitate, artificially created by aging for more than three hours before plastic working, is 100 or more and a discontinuous precipitate area of 40% or more of the entire area of the alloy **10** is formed, so as to improve strength and electric conductivity.

[0067] According to the present invention, it is possible to forcibly create a discontinuous cellular precipitate or lamellar precipitate of 40% or more per unit area of 500 μm×500 μm through aging after creating a solid solution by performing solution treatment or homogenization on the alloy **10** and it is also possible to create a discontinuous cellular precipitate or a continuous lamellar precipitate of 40% or more per unit area of 630 μm×480 μm.

[0068] Furthermore, it is possible to orient the forcibly created precipitate to have a length of 2.0 μm or more per unit area of 3.5 μm×1.5 μm in a copper base through plastic working.

[0069] A method of manufacturing the metal composite **20** is described hereafter with reference to FIG. **5**.

[0070] FIG. **5** is a flowchart illustrating a method of manufacturing the metal composite **20** with an oriented precipitate according to the present invention.

[0071] As shown in the figure, the method of manufacturing the metal composite **20** of the present invention includes a material preparing step (S**100**) of preparing a molded alloy **10**, a solid solution creating step (S**200**) of creating a solid solution by thermally treating the alloy **10** in a one phase area, a precipitate forcible-creating step (S**300**) of creating a cellular precipitate or a lamellar precipitate by aging the alloy **10** containing the solid solution, and a precipitate orienting step (S**400**) of orienting the precipitate by performing plastic working on the alloy **10** containing the precipitate.

[0072] The material preparing step (S**100**) is a process of preparing an alloy (see FIGS. **5** and **6**), in which the precipitation-promoting metal described above may be selectively prepared.

[0073] In detail, the alloy **10**, which is a copper alloy containing Ni—Si in an embodiment of the present invention, is a mold formed by any one of rolling, drawing, and extruding and contains a residual precipitate.

[0074] The precipitation-promoting metal includes any one of titanium (Ti) and vanadium (V).

[0075] The weight percent (wt %) of (Ni+Si), which is the sum of nickel (Ni) and silicon (Si), is limited to 81% or more of the highest solid solubility to the entire weight of the alloy **10**, that is, 4.8 to 7.5wt % and the balance is copper (Cu) and other unavoidable impurities.

[0076] The precipitation-promoting metal is selectively included, and titanium (Ti) of 0.025 to 0.24wt % or vanadium (V) of 0.028 to 0.086wt % may be included.

[0077] After the material preparing step (S**100**), the solid solution creating step (S**200**) is performed. The solid solution creating step (S**200**) is a process for removing a residual precipitation, and when precipitation-promoting metal is included in the material preparing step (S**100**), the solution solubility may be low.

[0078] The solid solution creating step (S**200**) is a process of heating the alloy **10** and the precipitation-promoting metal at a predetermined temperature or more and the preferred temperature in the solid solution creating step (S**200**) is preferably 950° C. or more for the copper-based alloy and under 1084 (melting point of pure copper)−7.5×X.

[0079] X is the weight percent (wt %) of (Ni+Si) described above, 1084−7.5×X where a liquid state is not produced and 950° C. or more that is the highest solid solution limit temperature where a solid solution can be produced are preferable for the Cu—Ni—Si, Cu—Ni—Si—Ti, Cu—Ni—Si—V alloy **10** that is an embodiment of the present invention.

[0080] That is, referring to FIG. **7**, in the Cu—Ni—Si, Cu—Ni—Si—Ti, or Cu—Ni—Si—V alloy **10** that is an embodiment, not a single phase, but a multiple phase is produced 950° C. or less, so a discontinuous precipitate is not created.

[0081] After the solid solution creating step (S**200**), the discontinuous precipitate forcible-creating step (S**300**) is performed.

[0082] The precipitate forcible-creating step (S**300**) is a process of creating a discontinuous cellular precipitate or a discontinuous lamellar precipitate in the alloy **10**, and in an embodiment of the present invention, when water quenching or air cooling is performed and precipitation-promoting metal was added after the solid solution creating step (S**200**), aging was performed for two or more hours, and when precipitation-promoting metal was not added, aging was performed for five or more hours, thereby forcibly creating a discontinuous precipitate.

[0083] That is, FIGS. **8** and **9** are pictures of microstructures in a comparative example and an embodiment employing different ways of cooling in the solid solution creating step (S**200**). It was slowly cooled in a furnace in the comparative example, whereas it was rapidly cooled in the embodiment.

[0084] Accordingly, it can be seen that a precipitate having a normal shape was created in the comparative example, but a discontinuous precipitate was created in the embodiment.

[0085] FIG. **10** is a picture of a microstructure in plastic working on a comparative example in which slow cooling was performed in the solid solution creating step (S**200**) in the method of manufacturing the metal composite with an oriented precipitate according to the present invention and FIG. **11** is a picture of a microstructure in plastic working on an embodiment in which rapid cooling was performed in the solid solution creating step (S**200**) in the method of manufacturing the metal composite with an oriented precipitate according to the present invention.

[0086] As in these figures, a precipitate was not oriented in the comparative example in which slow cooling was performed in a furnace, but in the embodiment in which rapid cooling was performed in the solid solution creating step (S**200**), it can be seen that the precipitate was oriented in the processing direction in the precipitate orienting step (S**400**).

[0087] Accordingly, it is preferable to perform rapid cooling using water quenching or air cooling in the solid solution creating step (S**200**).

[0088] After the solid solution creating step (S**200**), the precipitate forcible-creating step (S**300**) is performed. The precipitate forcible-creating step (S**300**) is a step for increasing the amount of a precipitate formed in the alloy **10** in the solid solution creating step (S**200**), and aging was performed in an embodiment of the present invention.

[0089] Microstructures before/after the precipitate forcible-creating step (S**300**) are comparatively described with reference to FIGS. **12** to **19**.

[0090] First, as in FIGS. **12** and **13**, a small area of discontinuous precipitate area was created in a comparative example in which slow cooling was performed in a furnace in the solid solution creating step (S**200**), but in an embodiment where the solid solution creating step (S**200**) was preferably performed, it can be seen that the area of a discontinuous precipitate expanded even if the precipitate forcible-creating step (S**300**) was performed for the same amount of time as the comparative example.

[0091] The contents of components in the comparative example and the embodiments were as in the following Table 1.

TABLE 1

Item	Cooling type	Cu	Ni	Si
Comparative example	Slow cooling	Bal.	5.98 wt %	1.43 wt %
Embodiment	Rapid cooling	Bal.	5.98 wt %	1.43 wt %

[0092] As in FIGS. **14** and **15**, it can be seen that the discontinuous precipitate area was wider when precipitation-promoting metal was included than when precipitation-promoting metal was not included, even if the precipitate forcible-creating step (S**300**) was performed for the same amount of time.

[0093] FIG. **14** is a picture of a microstructure in a comparative example in which precipitation-promoting metal was not added and slow cooling was performed in the solid solution creating step (S**200**) in the method of manufacturing a metal composite **20** with an oriented precipitate according to the present invention and FIG. **15** is a picture of a microstructure in an embodiment in which precipitation-promoting metal was added and rapid cooling was performed in the solid solution creating step (S**200**) in the method of manufacturing a metal composite **20** with an oriented precipitate according to the present invention, in which microstructures after the solid solution creating step (S**200**) and the precipitate forcible-creating step (S**300**) was finished, when vanadium (V) was added in the material preparing step (S**100**) are shown, and it could be seen that formation of a discontinuous precipitate was promoted in the same way as titanium (Ti).

[0094] FIG. **16** is a picture of a microstructure in a heat treatment of 500° C. after hot rolling in the comparative example of FIG. **14**, and FIG. **17** is a picture showing changes in a microstructure according to changes in heat treatment temperature and length of time in the embodiment of FIG. **15**.

[0095] When heating was performed at 400° C. in the precipitate forcible-creating step (S**300**), as in FIG. **17**, a discontinuous precipitate was not created even though six hours passed, but when heating was performed at 450° C. and 500° C., a precipitate began to increase from the point of time when one hour passed.

[0096] On the other hand, in the comparative example, a precipitate was not created even though heating was performed at 500° C. for seven hours, as in FIG. **16**.

[0097] The microstructure did not show a large change in the comparative example before the precipitate forcible-creating step (S**300**), as in FIGS. **14** and **16**, but in the embodiment, it could be seen that the discontinuous precipitate increased with the lapse of time, as in FIGS. **15** and **17**.

[0098] In the comparative example, when vanadium (V) or titanium (Ti) not added, a small amount of discontinuous precipitate was formed even though the precipitate forcible-creating step (S**300**) was performed for a long time, the result being opposite to the preferred embodiment.

[0099] FIGS. **18** and **19** are graphs showing changes in area ratios in discontinuous precipitation after the precipitate forcible-creating step (S**300**) in the method of manufacturing a metal composite **20** with an oriented precipitate according to the present invention.

[0100] That is, the figures provide graphs for analyzing the amount of creation of a precipitate when X, which is weight percent (wt %) of (Ni+Si), was changed, in which it can be seen that when X, which is the weight percent (wt %) of (Ni+Si), is included over 4.81wt % to the entire weight of the alloy **10**, a discontinuous precipitate or a lamellar precipitate occupied an area of 40% or more.

[0101] However, when X, which is the weight percent (wt %) of (Ni+Si), is less than 4.81wt %, a discontinuous precipitate having an area of 40% or more was not created.

[0102] Accordingly, it is preferable that X, which is the weight percent (wt %) of (Ni+Si), is in the range of 4.8 to 7.5wt % in the state diagram shown in FIG. **7**. Furthermore, it is possible to estimate from the state diagram that all of precipitated alloys show the same phenomenon, so the same phenomenon occurs in an alloy containing 81% of the highest solution solubility.

[0103] Based on the embodiment described above, as the result of performing the precipitate forcible-creating step (S**300**) at 500° C., as in FIG. **20**, a discontinuous cellular precipitate was created and the length to diameter aspect ratio of the lamellar precipitate was 100 or more.

[0104] Based on the test result described above, the temperature (° C.) for the discontinuous forcible creating step (S**300**) is 47×X+260° C(533K) or less and has this relationship.

[0105] Furthermore, the temperature (° C.) for the solid solution creating step (S**200**) is 1084−7.5×X and 950° C. or more, which is the highest soluble limit where a solid solution can be created and has this relationship.

[0106] The discontinuous precipitate is created from 0.4× the melting point (K, absolute temperature) of copper-based metal or more where dispersion starts, so a discontinuous precipitate is forcibly created in the area in the state diagram shown in FIG. **7** from the relationship with additional components other than the base metal proposed in the present invention.

[0107] The precipitate orienting step (S**400**) is performed after the discontinuous precipitate forcible-creating step (S**300**). The precipitate orienting step (S**400**) is a process for artificially orienting a discontinuous precipitate or a discontinuous lamellar precipitate formed inside in accordance with the embodiment described above.

[0108] That is, in an embodiment of the present invention, rolling, drawing, or extruding was employed in the precipitate orienting step (S**400**), FIG. **11** is a picture of a microstructure of the metal composite **20** manufactured by rolling (upper) and drawing (lower) in FIG. **11**, and it can be seen that discontinuous precipitates are arranged in parallel in the metal composite **20** manufactured in accordance with a preferred embodiment of the present invention.

[0109] Microstructures of a comparative example and an embodiment are compared hereafter with reference to FIGS. **21** and **22**.

[0110] FIG. **21** is a picture of a microstructure when a precipitate orienting step was performed in a comparative example without the solid solution creating step (S**200**) and FIG. **22** is a picture comparing microstructures before/after the precipitate orienting step (S**400**) in the method of manufacturing the metal composite **20** with an oriented precipitate according to the present invention.

[0111] In the comparative example shown in FIG. **21**, the precipitate orienting step (S**400**) was performed on an alloy where a precipitate was not created in the precipitate forcible-creating step (S**300**) since the solid solution creating step (S**200**) was not performed. Thus, it can be seen that the orientation of the microstructure is very different from the embodiment (the lower picture in FIG. **22**) where the precipitate orienting step (S**400**) was performed after a solid solution was created (the upper picture in FIG. **22**).

[0112] The difference in whether there is orientation of microstructures considerably depends on mechanical properties, as in FIGS. **23** and **24**.

[0113] FIG. **23** is a graph comparing mechanical properties before/after the precipitate orienting step (S**400**) where drawing was employed in a comparative example and a preferred embodiment, and FIG. **24** is a graph comparing mechanical properties before/after the precipitate orienting step (S**400**) where rolling was employed in a comparative example and a preferred embodiment.

[0114] First, referring to FIG. **23**, in the embodiment where aging was finished, it shows strength of 500 MPa or less, which is lower than 600 MPa, which is the strength of the comparative example.

[0115] However, it can be seen that the increases in strength are very different in the comparative example and the embodiment employing drawing in the precipitate orienting step (S**400**).

[0116] That is, the strength was 600 MPa before drawing, but it slightly increased to 800 MPa after drawing in the comparative example, but in the embodiment, the strength was about 500 MPa before drawing, but it increased close to 1100 MPa after drawing. Accordingly, it can be seen that the strength of the alloy **10** is higher in the embodiment than the comparative example after the precipitate orienting step (S**400**).

[0117] Accordingly, it can be seen that a precipitate can function as a reinforcing material by forcibly creating a precipitate through the precipitate forcible-creating step (S**300**) and then forcibly orienting the precipitate.

[0118] FIG. **24** shows an example when rolling was used in the precipitate forcible-creating step (S**400**), in which the strength was 600 MPa before rolling in the comparative example, which is higher than 550 MPa, which is the strength in the embodiment, but after the precipitate forcible-creating step (S**400**) was performed, the strength was less than 800 MPa in the comparative example, but the strength in the preferred embodiment of the present invention was 900 MPa, so an effect of increasing strength according to orientation of a precipitate could be seen.

[0119] FIG. **25** is a graph comparing the test result of FIG. **23** in each stage, in which effects of increasing strength in each process are shown sequentially in the upward direction starting from the bottom.

[0120] As in the figure, the comparative example and the embodiment show the same strength of 200 MPa in the state of the alloy **10**, but the strength of the comparative example increased to 430 MPa, which is higher than the strength of the embodiment, after the solid solution creating step (S**200**) and the precipitate forcible-creating step (S**300**).

[0121] However, after the precipitate forcible-creating step (S**400**), the strength increased by 190 MPa in the comparative example, the strength in the embodiment increased by 480 MPa, which shows an effect of increasing strength of 290 MPa in comparison to the comparative example.

[0122] That is, since discontinuous precipitates are arranged in parallel in the metal composite **20** manufactured in accordance with a preferred embodiment of the present invention, it can be seen that the mechanical properties were considerably increased in comparison to the mechanical properties of the metal composite **20** manufactured in accordance with a common manufacturing method.

[0123] The scope of the present invention is not limited to the embodiments described above and many other modifications based on the present invention may be achieved by those skilled in the art within the scope of the present invention.

[0124] For example, titanium was used as precipitation-promoting metal in an embodiment of the present invention, but vanadium may also be used.

INDUSTRIAL APPLICABILITY

[0125] The present invention relates to a metal composite with an oriented precipitate functioning as a reinforcing material for a composite by artificially orienting a precipitate, which is artificially created, through plastic working, and a method of manufacturing the metal composite, so electric conductivity and strength are improved. Furthermore, if necessary, it is possible to artificially adjust the amount of precipitate by selectively adding precipitation-promoting metal, so it can be used in various fields by adjusting electrical and mechanical properties.

1. A metal composite with an oriented precipitate, wherein a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate of 40% or more per unit area of 500 μm×500 μm is forcibly created by aging, and the forcibly created precipitate is oriented by plastic working.

2. A metal composite with an oriented precipitate, wherein a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate of 40% or more per unit area of 630 μm×480 μm is forcibly created by aging, and the forcibly created precipitate is oriented by plastic working.

3. A metal composite with an oriented precipitate, wherein a solid solution is created by performing solution treatment or homogenization on an alloy, a discontinuous cellular precipitate or lamellar precipitate is forcibly created by aging, and the forcibly created precipitate is oriented by plastic working to have a length of 2.01 μm or more per unit area of 3.5 μm×1.5 μm in a copper base.

4. The metal composite of claim **1**, wherein the oriented precipitate has a length to diameter aspect ratio of 100 or more.

5. The metal composite of claim **4**, wherein the alloy that became the solid solution is rapidly cooled by water quenching or cooled by air.

6. The metal composite of claim **5**, wherein the aging is performed for three hours or more.

7. The metal composite of claim **6**, wherein precipitation-promoting metal is added in the solution treatment or homogenization process.

8. The metal composite of claim **7**, wherein the precipitation-promoting metal includes any one of titanium (Ti) or vanadium (V).

9. A method of manufacturing a metal composite with an oriented precipitate, the method comprising:

a material preparing step of preparing a molded alloy;/a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area;

a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate of 40% or more per unit area of 500 μm×500 μm by aging the alloy containing the solid solution; and

a precipitate orienting step of orienting the precipitate by performing plastic working on the alloy containing the precipitate.

10. A method of manufacturing a metal composite with an oriented precipitate, the method comprising:

a material preparing step of preparing a molded alloy;

a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area;

a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate of 40% or more per unit area of 630 μm×480 μm by aging the alloy containing the solid solution; and

a precipitate orienting step of orienting the precipitate by performing plastic working on the alloy containing the precipitate.

11. A method of manufacturing a metal composite with an oriented precipitate, the method comprising:

a material preparing step of preparing a molded alloy;

a solid solution creating step of creating a solid solution by performing heat treatment on the alloy in a single phase area;

a precipitate forcible-creating step of creating a cellular precipitate or a lamellar precipitate by aging the alloy containing the solid solution; and

a precipitate orienting step of orienting the precipitate to have a length of 2.0 μm or more per unit area of 3.5 μm×1.5 μm in a copper base by performing plastic working on the alloy containing the precipitate.

12. The method of any one of claim **9** wherein precipitation-promoting metal including any one of titanium (Ti) and vanadium (V) is added in the material preparing step.

13. The method of claim **12**, wherein the solid solution creating step is a process of performing heating within a temperature range of above the lowermost temperature where a single phase is maintained in the state diagram and below the melting temperature−7.5×X (X is wt % of an added component other than copper base) of a copper base phase for two hours or more.

14. The method of claim **12**, wherein the solid solution creating step is a process of performing heating within a temperature range of above the lowermost temperature where a single phase is maintained in the state diagram and below the melting temperature−7.5 ×X (X is wt % of an added component other than copper base) of a copper base phase for two hours or more.

15. The method of claim **14**, wherein the alloy is a copper alloy and (Ni+Si), which is X, is 4.8 to 7.5 wt %.

16. The metal composite of claim **2**, wherein the oriented precipitate has a length to diameter aspect ratio of 100 or more.

17. The metal composite of claim **3**, wherein the oriented precipitate has a length to diameter aspect ratio of 100 or more.

18. The method of claim **10** wherein precipitation-promoting metal including any one of titanium (Ti) and vanadium (V) is added in the material preparing step.

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