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(54) SOLDER COMPOSITION HAVING DISPERSOID PARTICLES FOR INCREASED CREEP RESISTANCE

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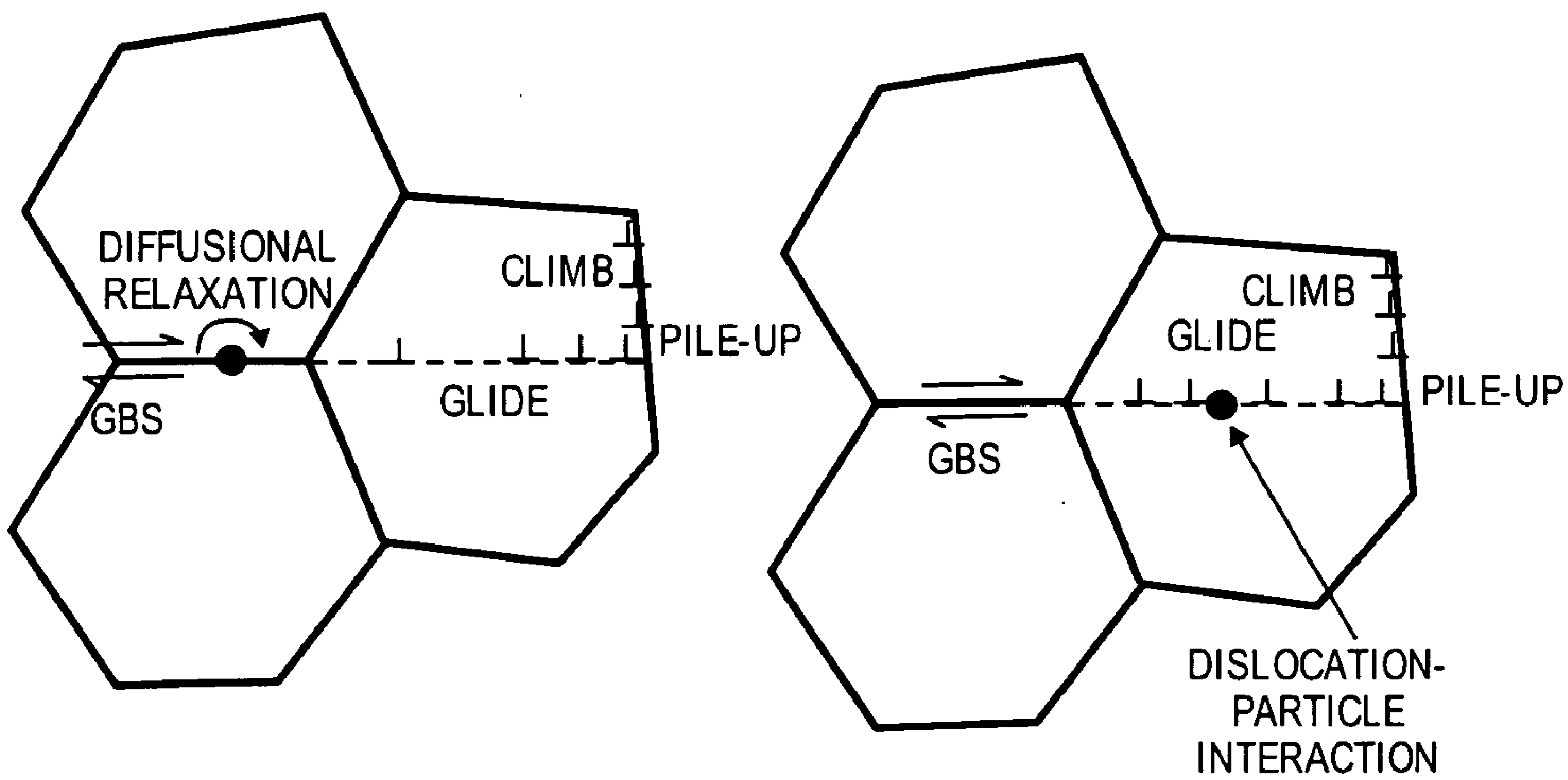
(57) ABSTRACT

A solder composition is provided. A solder composition has a solder matrix material and dispersoid particles in the solder matrix material. The solder matrix material has a relatively low melting temperature and the dispersoid particles have a relatively high melting temperature.



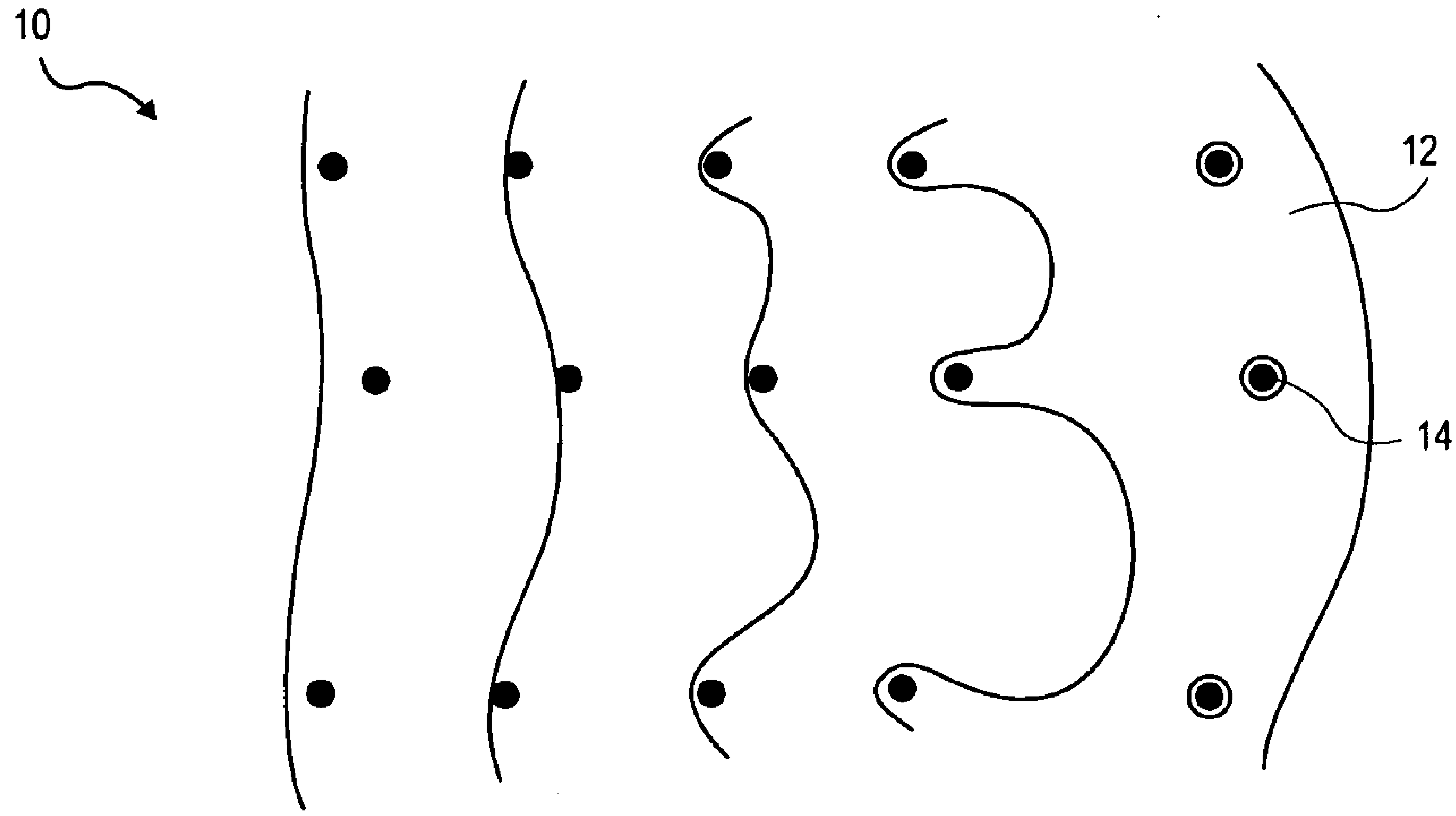


FIG. 1

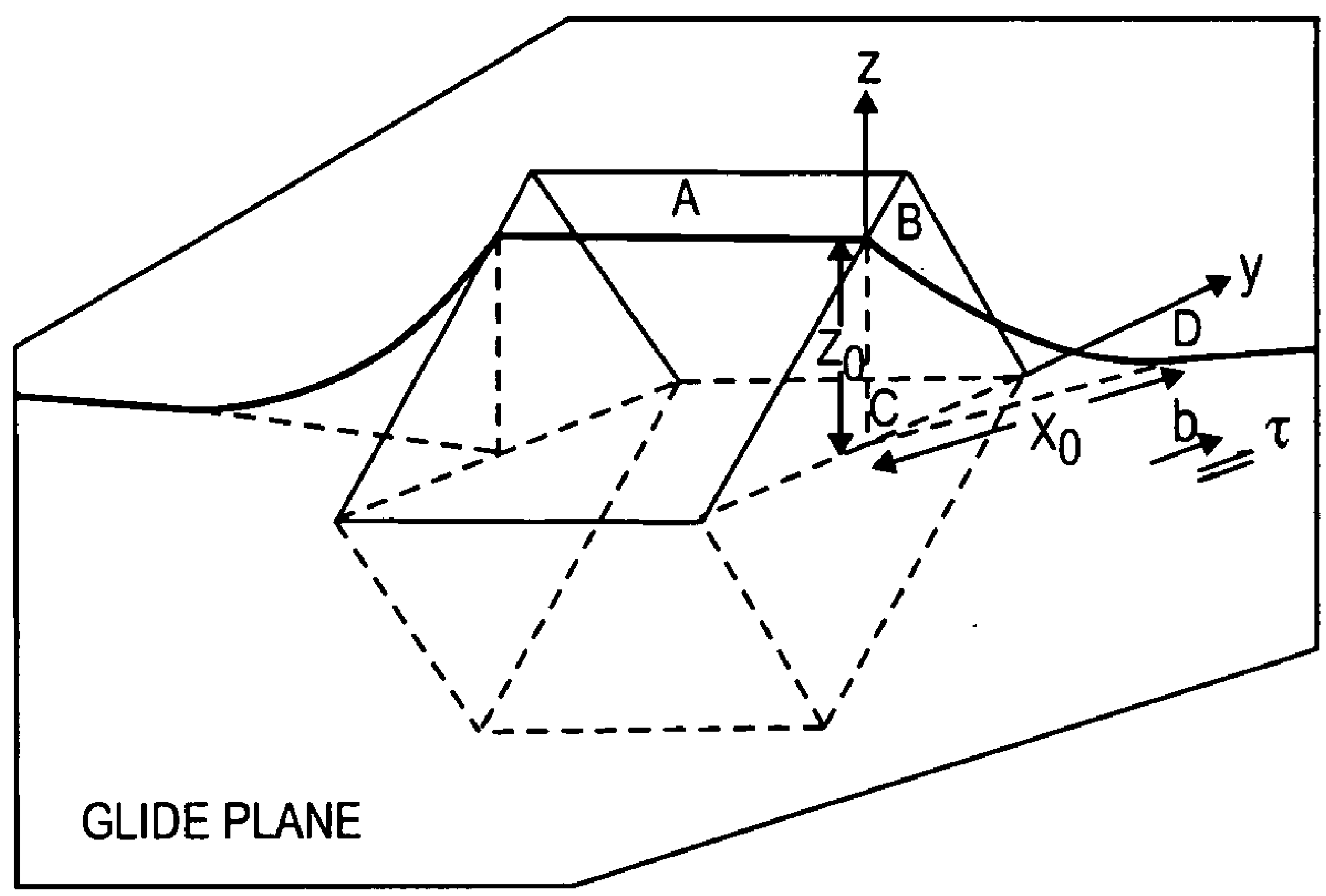


FIG. 2

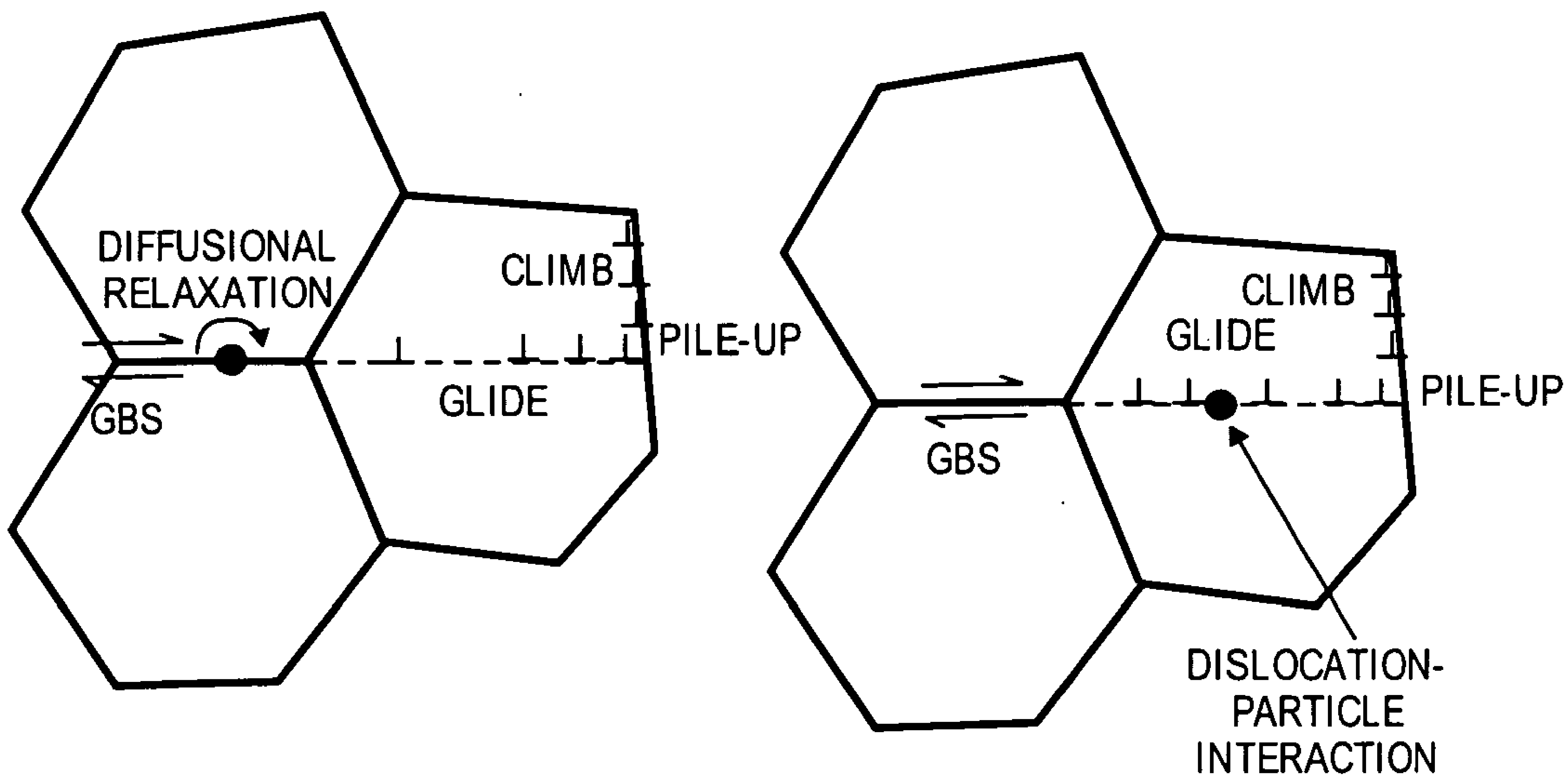

DIFFUSIONAL
RELAXATION
CLIMB
PILE-UP
GBS
GLIDE
CLIMB
GLIDE
PILE-UP
GBS
DISLOCATION-
PARTICLE
INTERACTION

FIG. 3

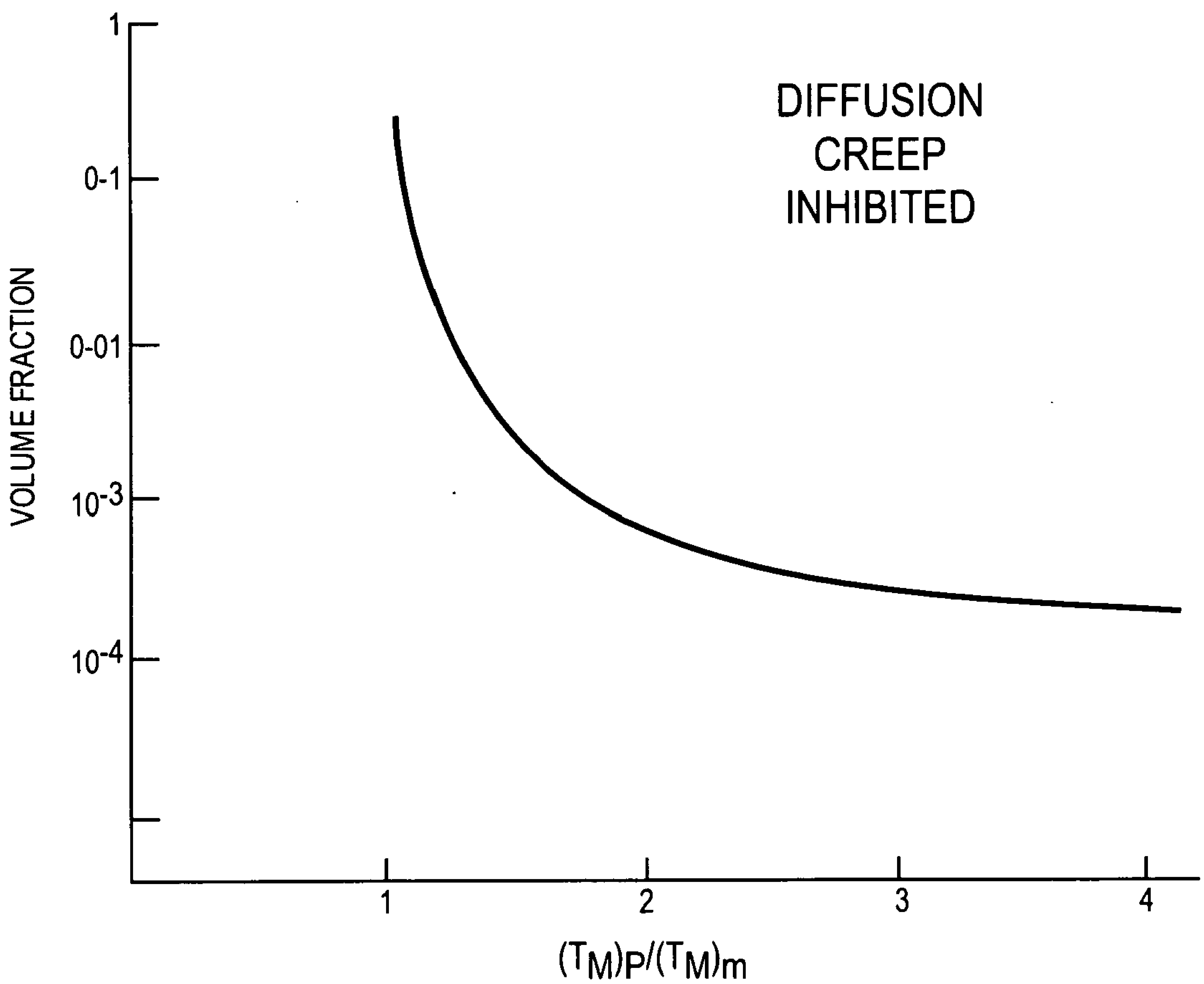
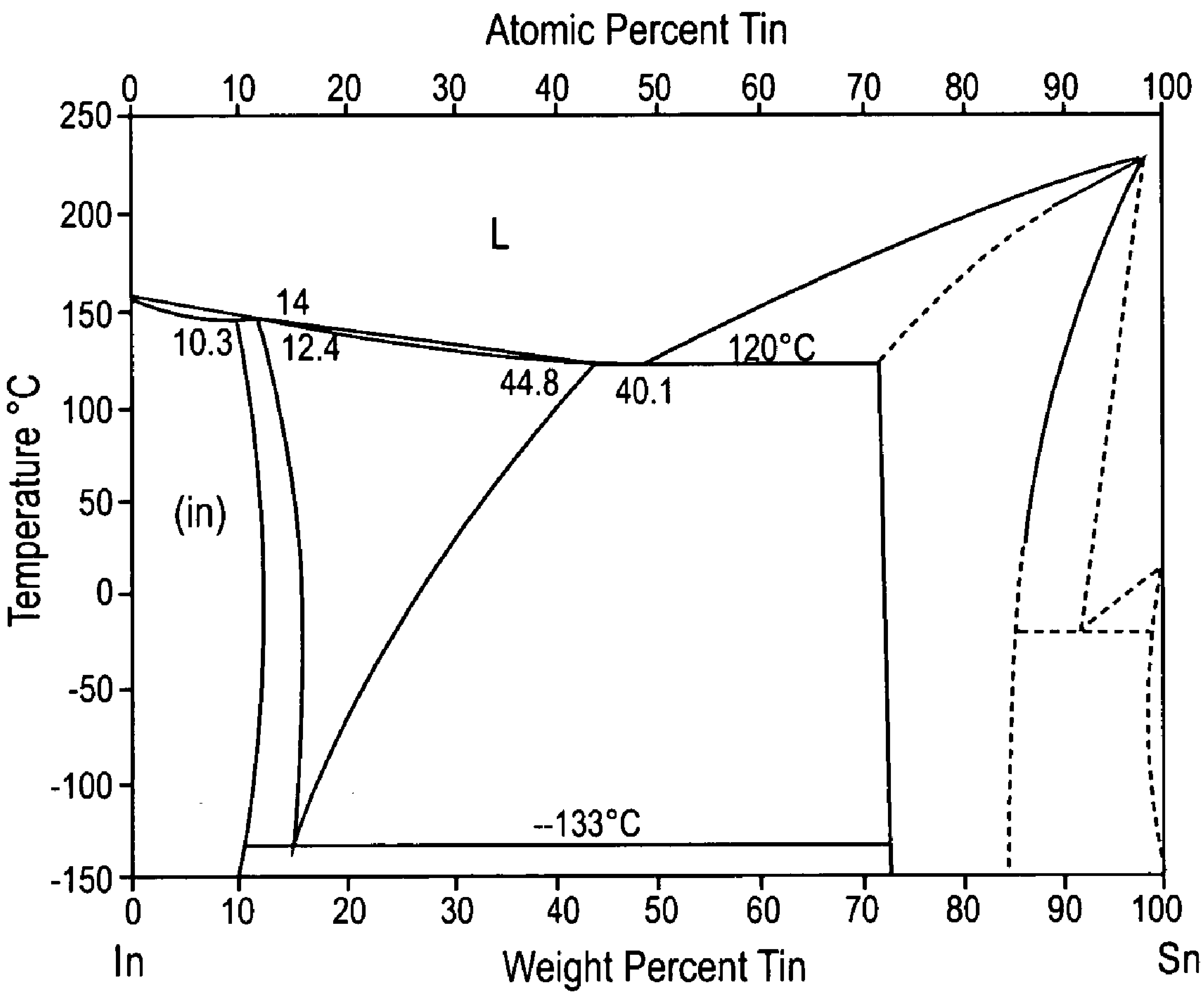
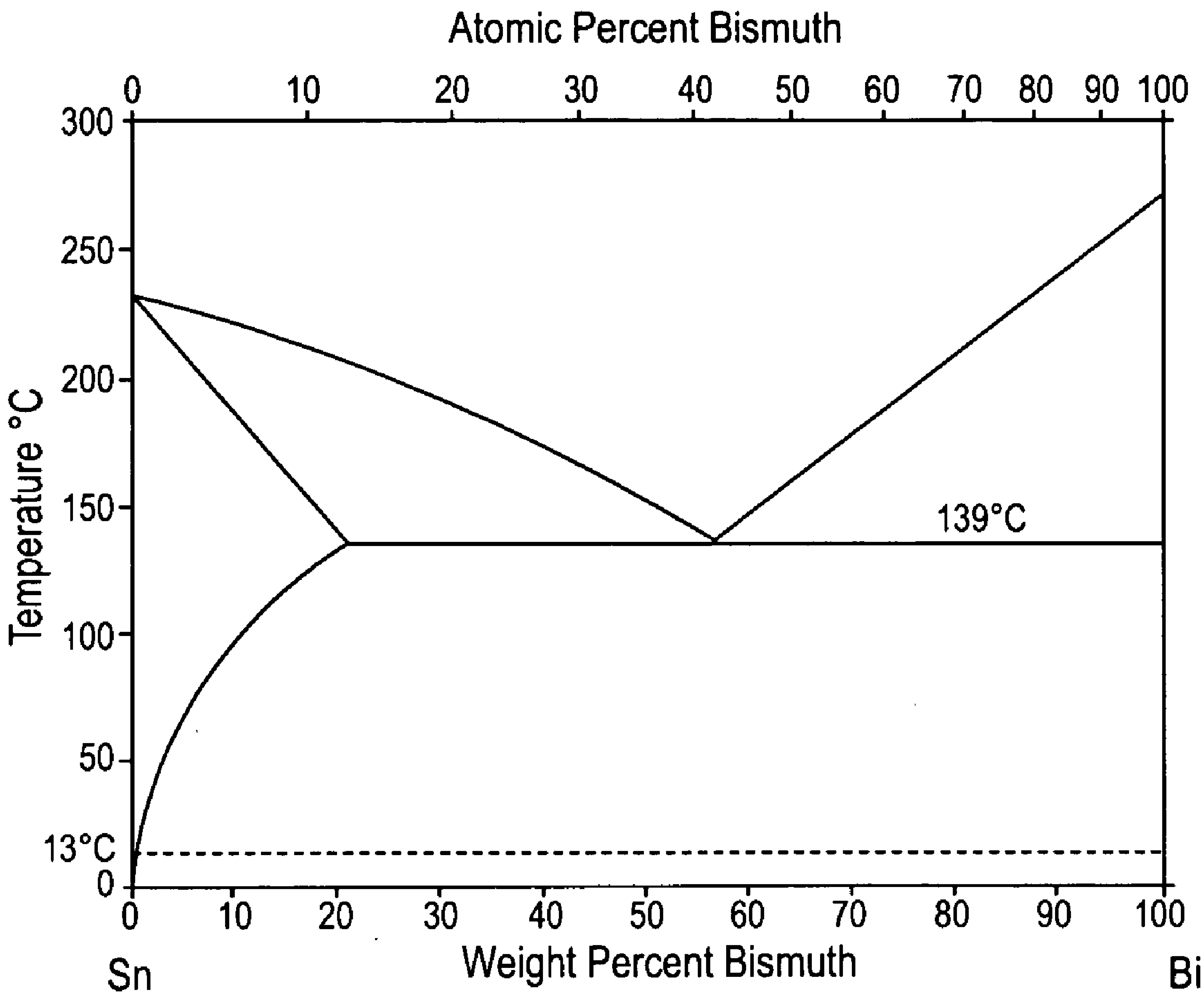

DIFFUSION
CREEP
INHIBITED
VOLUME FRACTION
1
0-1
0-01
10-3
10-4
1
2
3
4
(TM)P/(TM)m

FIG. 4



Atomic Percent Tin
0
10
20
30
40
50
60
70
80
90
100
250
200
150
100
50
0
-50
-100
-150
Temperature °C
L
14
10.3
12.4
44.8
40.1
120°C
(in)
--133°C
0
10
20
30
40
50
60
70
80
90
100
In
Weight Percent Tin
Sn

FIG. 5


Atomic Percent Bismuth
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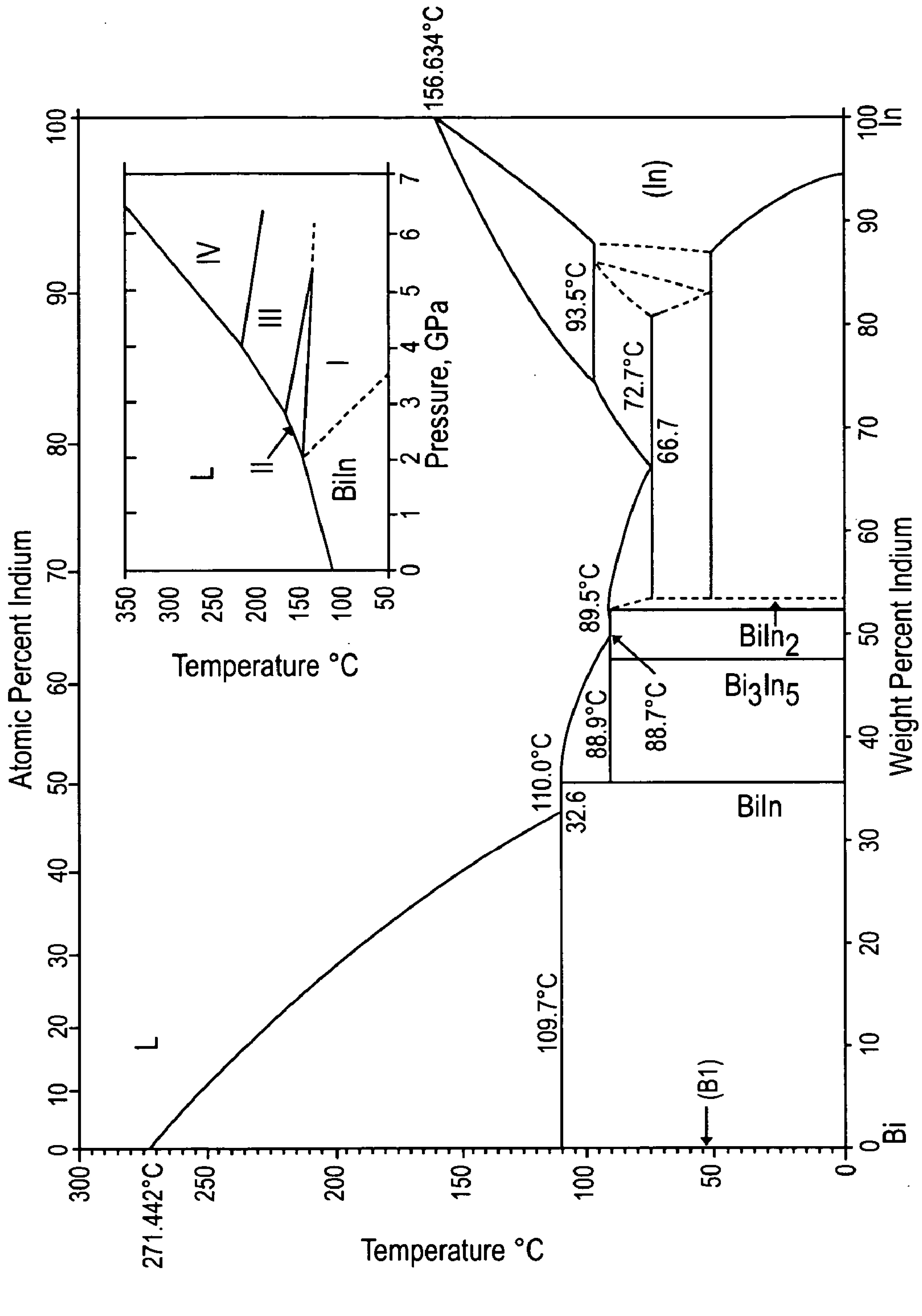
10
20
30
40
50
60
70
80
90
100
300
250
200
150
100
50
13°C
0
Temperature °C
139°C
0
10
20
30
40
50
60
70
80
90
100
Weight Percent Bismuth
Sn
Bi

FIG. 6


Atomic Percent Indium
Weight Percent Indium
Temperature °C
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156.634°C
L
(In)
109.7°C
110.0°C
32.6
88.9°C
88.7°C
89.5°C
66.7
72.7°C
93.5°C
BiIn
Bi3In5
BiIn2
Bi
In
(B1)
Pressure, GPa
IV
III
II
I

FIG. 7

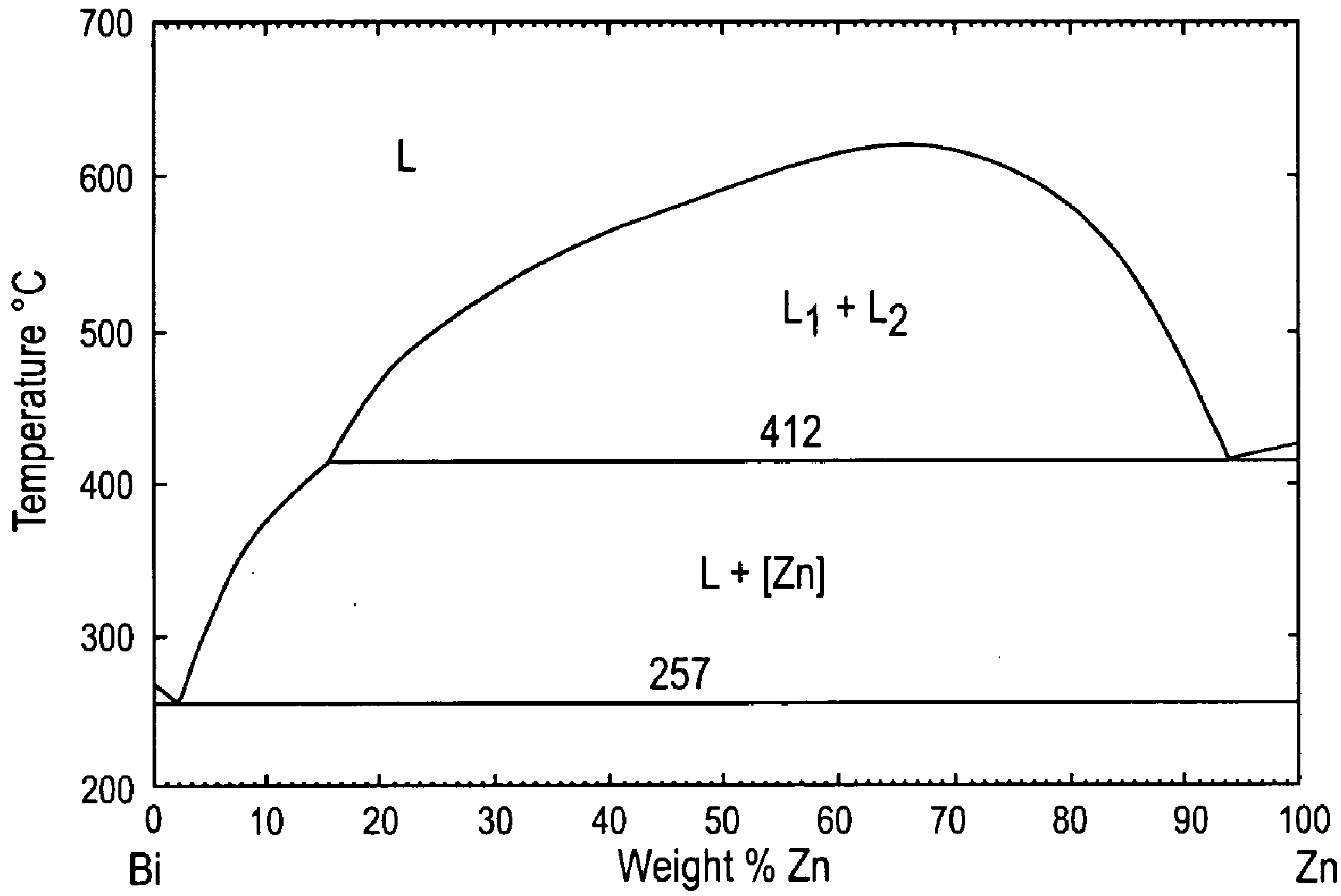
700
600
500
400
300
200
Temperature °C
L
$L_1 + L_2$
412
L + [Zn]
257
0
10
20
30
40
50
60
70
80
90
100
Bi
Weight % Zn
Zn

FIG. 8

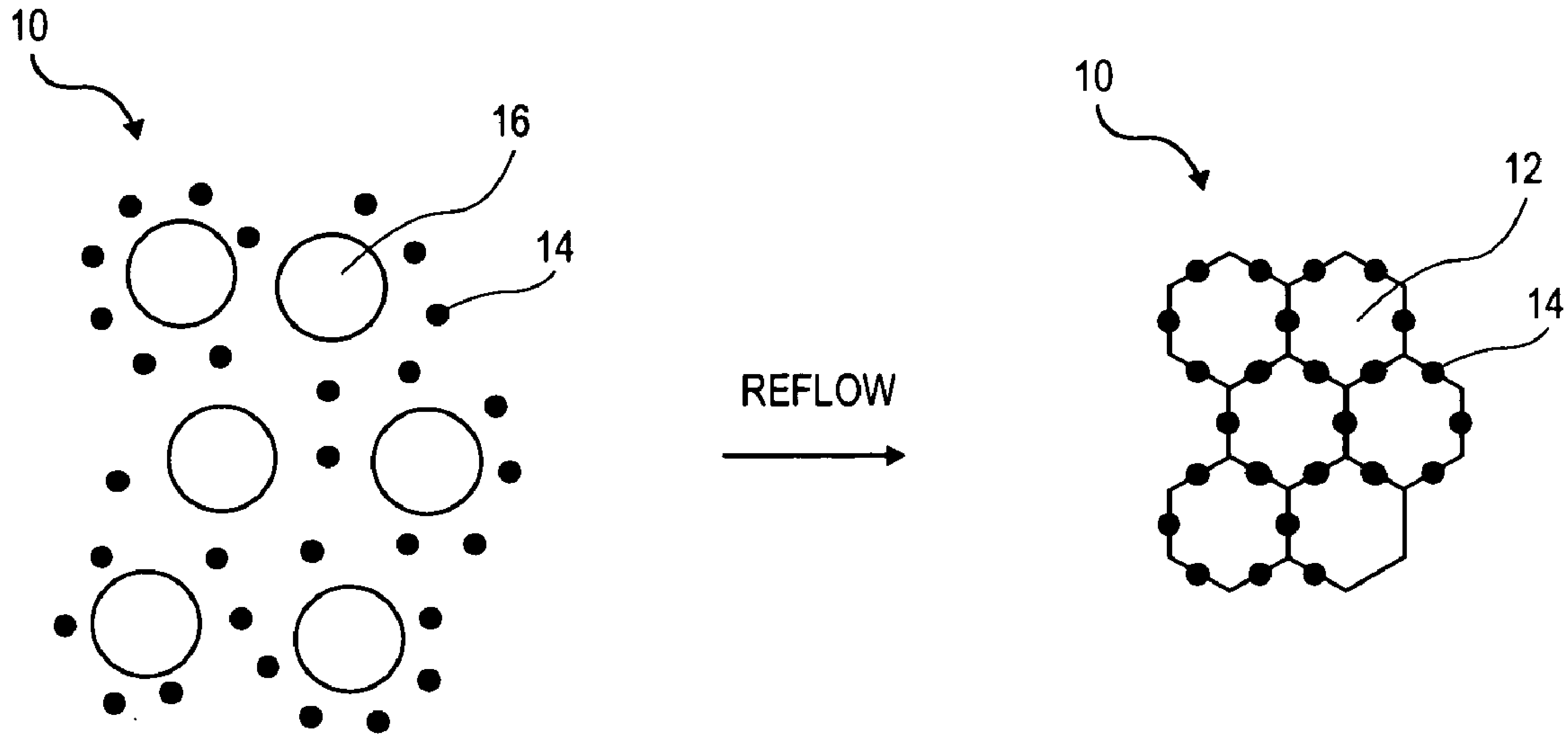

FIG. 9

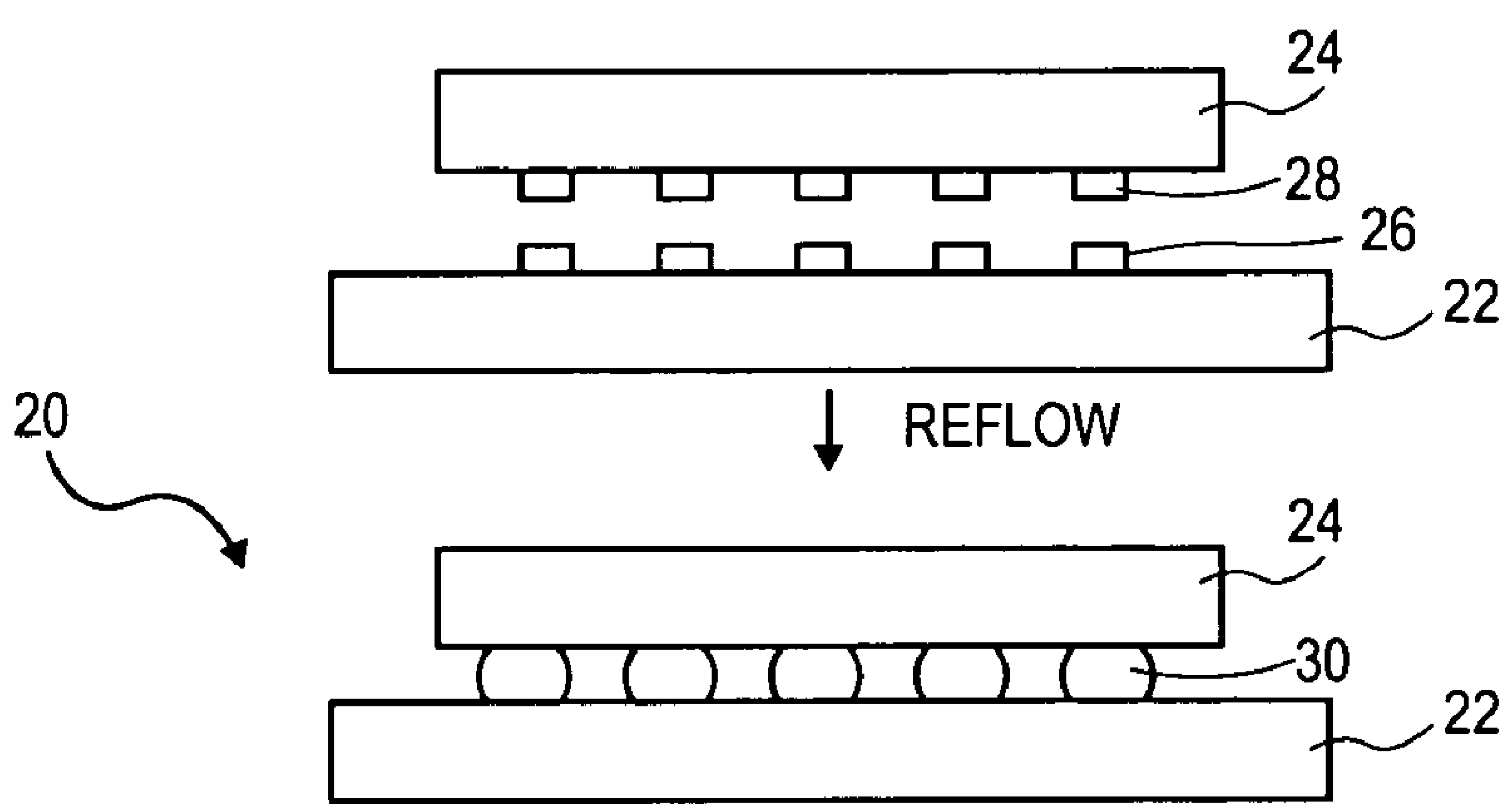

FIG. 10

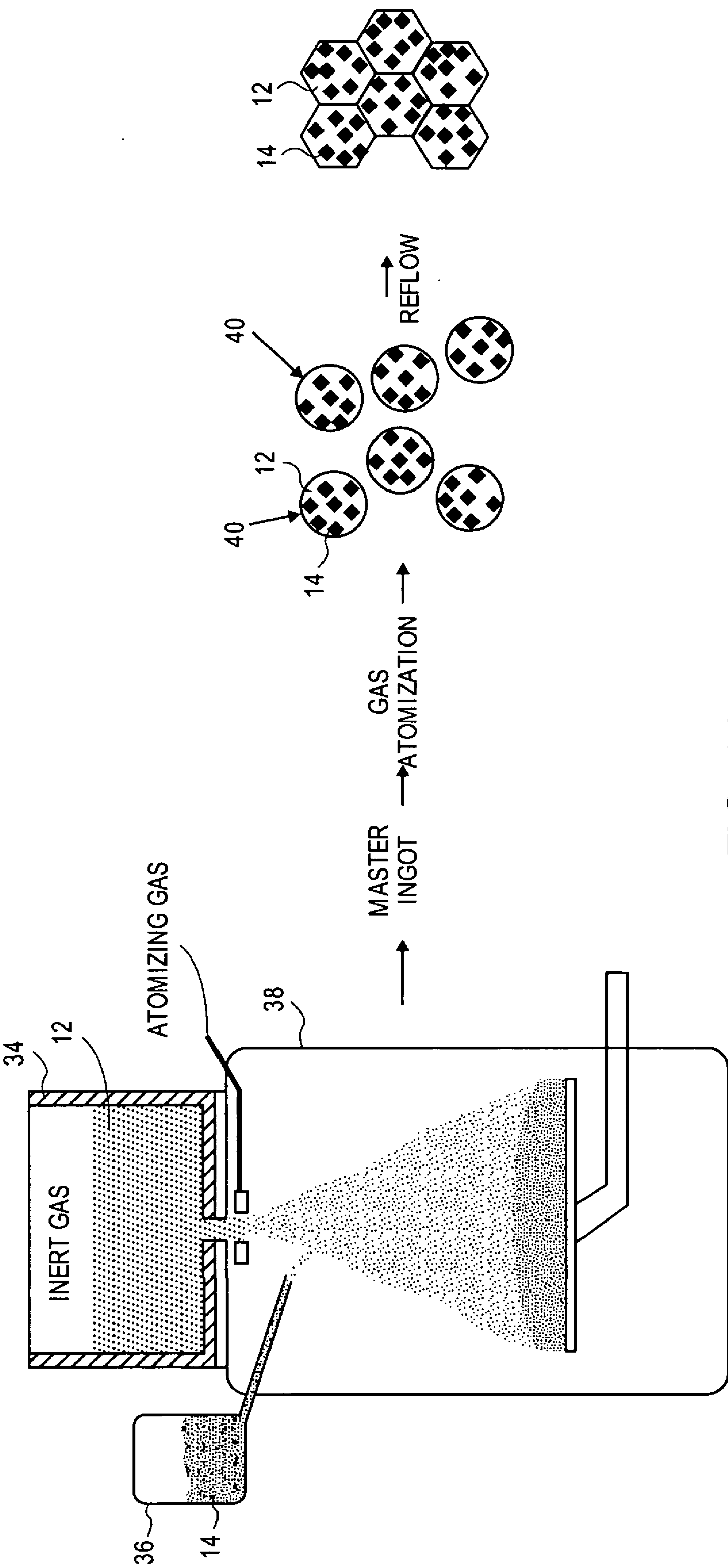
INERT GAS
34
12
ATOMIZING GAS
38
36
14
MASTER
INGOT
GAS
ATOMIZATION
40
12
40
14
REFLOW
12
14

FIG. 11

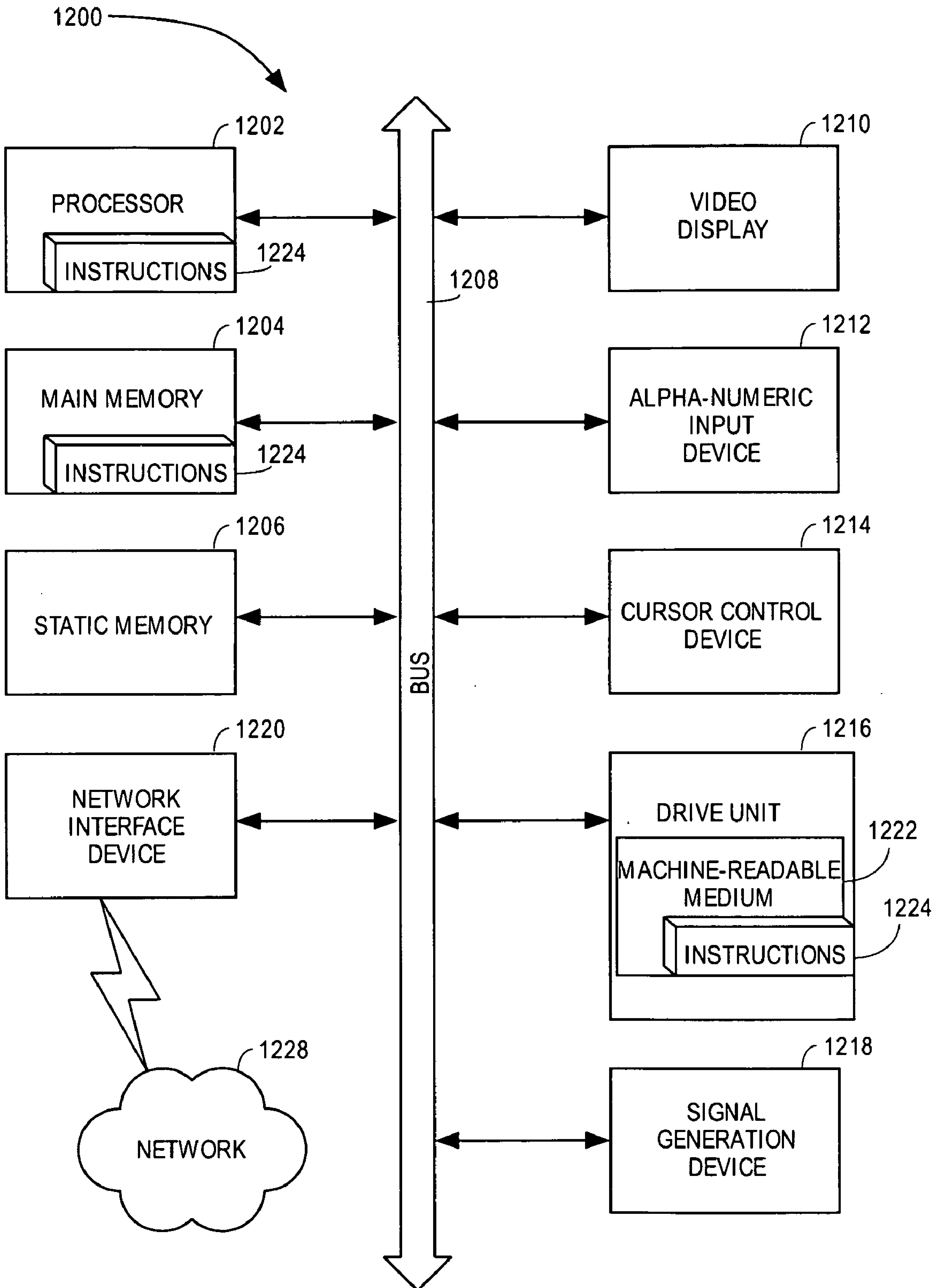
1200
1202
PROCESSOR
INSTRUCTIONS
1224
1204
MAIN MEMORY
INSTRUCTIONS
1224
1206
STATIC MEMORY
1220
NETWORK INTERFACE DEVICE
1228
NETWORK
1208
BUS
1210
VIDEO DISPLAY
1212
ALPHA-NUMERIC INPUT DEVICE
1214
CURSOR CONTROL DEVICE
1216
DRIVE UNIT
1222
MACHINE-READABLE MEDIUM
1224
INSTRUCTIONS
1218
SIGNAL GENERATION DEVICE

FIG. 12

SOLDER COMPOSITION HAVING DISPERSOID PARTICLES FOR INCREASED CREEP RESISTANCE

BACKGROUND OF THE INVENTION

[0001] 1). Field of the Invention

[0002] Embodiments of this invention relate to a solder composition that may be used in the construction of electronic assemblies.

[0003] 2). Discussion of Related Art

[0004] Solder compositions are used for attaching pieces to one another. In the manufacture of electronics works, for example, solder compensations can be used for attaching contacts of a die having a microelectronic circuit formed therein to contacts of a substrate. A solder composition may also be used for attaching a heat spreader or a heat sink to a surface of a microelectronic die. A solder composition typically has to have a relatively low melting temperature, so that the pieces can be attached to one another at a relatively low temperature. Most solder compositions are relatively weak. An electronic assembly that is subjected to thermal stresses may fracture at the locations of the solder compositions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] An embodiment of the invention is described by way of example with reference to the accompanying drawings, wherein:

[0006] FIG. **1** is a cross-sectional view of a solder composition according to an embodiment of the invention;

[0007] FIG. **2** is a perspective view illustrating the direction of forces on a dispersoid particle in a solder matrix material;

[0008] FIG. **3** is a cross-sectional view illustrating how shear can be reduced by the inclusion of dispersoid particle;

[0009] FIG. **4** is a graph illustrating the effect of temperatures and volume fraction on creep innovation;

[0010] FIGS. **5** to **8** are phase diagrams of solder matrix materials that may find applications in the embodiments of the present invention;

[0011] FIG. **9** are cross-sectional views illustrating one manner of forming a solder composition;

[0012] FIG. **10** are side views of an electronic assembly that is manufactured utilizing the solder composition of FIG. **9**;

[0013] FIG. **11** is a diagram illustrating the manufacture of a solder composition according to an alternative embodiment of the invention; and

[0014] FIG. **12** is a block diagram illustrating a computer system or machine in which the electronic assembly of FIG. **10** may find application.

DETAILED DESCRIPTION OF THE INVENTION

[0015] FIG. **1** of the accompanying drawings illustrates a solder composition **10**, according to an embodiment of the invention, including a solder matrix material **12** and dispersoid particles **14** in the solder matrix material **12**. The solder matrix material **14** has a relatively low melting temperature and the dispersoid particles **14** have a relatively high melting temperature. The relatively low melting temperature of the solder matrix material allows the bulk of the solder composition **10** to be melted and again be solidified at a relatively low temperature to secure first and second pieces to one another. The relatively high melting temperature of the dispersoid particles **14** provide dislocations in a final crystal structure of the solder matrix material **12** after solidification. The dislocations reduce creep and enhance the strength of the solder matrix material **12** and the solder composition **10** as a whole.

[0016] Dislocation climb/ detachment and Orowan bowing are among key mechanisms identified as direct interaction that can impede dislocation glide and climb. According to the Orowan model, bowing and dislocation climbs/detachment is proportional to:

$$\tau_{Orow} = \frac{Gb\sqrt{f}}{\langle r \rangle}$$

[0017] The variables used in formula (1) are shown in FIG. **2**. As can be seen from the above model, the fine and uniform distribution of hard and thermally-stable dispersoid can substantially strengthen the bulk material. If particle size is an order of microns, the direct interaction between dislocation and dispersoid becomes ineffective. Larger particles are associated with a lower Orowan stress for a given volume fraction depending on loading conditions and k value, (r/b) of 10 to 100 can typically be obtained and therefore nano-size particles are key to the success of dispersion strengthening.

[0018] FIG. **3** illustrates the effect of a dispersoid particle where the dispersoid particle is on a grain boundary or entirely within a granular crystal. In both cases, glide is reduced in a plane of the grain boundary. In both cases, there is also a corresponding reduction in climb for pile up.

[0019] FIG. **4** illustrates the effect of volume fraction and melting temperature on diffusion creep. The higher the melting temperature of the dispersoids $(T_M)_P$ relative to the melting temperature of solder matrix material $(T_M)_P$, the more inhibition of diffusion creep is achieved. A higher volume fracture of dispersoid particles within the solder composition also results in a greater inhibition of diffusion creep. The volume fraction of the dispersoid particle may, for example, be between 1% and 20%.

[0020] FIGS. **5**, **6**, **7** and **8** and In-Ss, Sn—Bi, Bi—In and Bi—Zn phase diagram. The solder matrix material is preferably selected from table 1.

TABLE 1

Composition range of "non-eutectic" Sn—In—Bi—Zn alloys

Sn (wt. %)	In	Bi	Zn	Liquidus range (C.)
42-19	0-25	58-56	0	138-79
48-20	52-48	0-32	0	118-59
0-19	33-25	67-56	0	110-79
0-20	67-48	33-32	0	72-59

TABLE 1-continued

Composition range of "non-eutectic" Sn—In—Bi—Zn alloys				
Sn (wt. %)	In	Bi	Zn	Liquidus range (C.)
48-46	52-52	0	0-2	118-107
0	33-33	67-66	0-1	110-108
0	33.4-52.2	66.3-47.4	0.3-0.4	108-86
0	52.2-66.8	47.4-32.7	0.4-0.5	86-68
0	66-66.8	34-32.7	0-0.5	72-68

Note:
you will get 100 wt. % by adding each element's composition in sequence (e.g., 1st row, Sn(42) + In(0) + Bi(58) + Zn(0) = 100, Sn(19) + In(25) + Bi(56) + Zn(0) = 100, etc.)

[0021] Ideally, the solder matrix material is a eutectic because of the lower melting temperature of a eutectic. A eutectic composition may be selected from table 2.

TABLE 2

Compositions of "eutectic" Sn—In—Zn alloys		
Lowt Tm Interlayer (wt. %)	Eutectic Melting temp. (C.)	Example of bonding temp (10 C. above Tm.) (C.)
In—48Sn	118	128
Bi—22In	110	120
Bi—33In—0.3Zn	108	118
In—46Sn—1.5Zn	107	118
In—47Bi—0.4Zn	86	96
Bi—25In—19Sn	79	89
In—34Bi	72	82
In—33Bi—0.5Zn	68	78
In—32Bi—20Sn	59	69
In—35Bi—16Sn—0.4Zn	58	68

[0022] As can be seen from the above tables, the solder matrix material may have a melting temperature below 150° C., more preferably below 125° C.

[0023] Optionally, the composition may have a small amount of precipitation-forming alloying elements so that after reflow, fine precipitation will be formed throughout the baseline alloy matrix. For precipitation, alloying elements should form an intermetallic compound with the baseline constituents at room temperature. Based on the binary phase diagrams in FIGS. **5**, **6**, **7** and **8**, the following elements can be added for precipitation: Cu, Ni, Ag, Ti, Mn, Co, Au or Fe. The weight percentage of the precipitation-forming alloying elements is preferably between 0.1% and 10% of the composition.

[0024] The dispersoid particles should preferably have a high melting temperature, typically above 1000° C., be non-shearable, and should preferably be non-soluble in the solder matrix material. Based on the above criteria, the oxides and carbides in table 3 may be used as dispersoid particles.

TABLE 3

Dispersoid	Tm (C.)	Dispersoid	Tm (C.)
SiC	>2700	In2O3	1920
W2C	>2800	Yb2O3	2315-2413
WC	>3000	Y2O3	2356-2453
ZrC	3540	TiO2	1830-1850

TABLE 3-continued

Dispersoid	Tm (C.)	Dispersoid	Tm (C.)
TiC	3170	ZrO2	2700
B4C	2450-2723	Cr2O3	2300
Cr3C2	1250	MgO	2800
Cr7C3	1665	SiO2	
Cr3C6	1890	WO3	1473
Al2O3	2000		

[0025] Optimum sizes for dispersoid particles are 10 to a few hundred nm, e.g. 200 nm. The larger the sizes of the dispersoid particles, the weaker the strengthening effects. The higher the volume fraction of the dispersoid particles in the composition, the higher the strengthening effects.

[0026] FIG. **9** illustrates one method of making the solder composition. Solder particles **16** are mixed with the dispersoid particles **14**. The composition **10** is then reflowed. During reflow, the composition **10** is heated to a temperature above the melting temperature of the solder particles **16**, so that the solder particles **16** melt, and the composition **10** is then allowed to cool so that the material of the solder particles **16** form the solder matrix material **12**. The dispersoid particles **14** are located between portions of the solder matrix material **12** that formed the original solder particles **16**.

[0027] FIG. **10** illustrates how the composition **10** can be used in the construction of an electronic assembly **20**. The electronic assembly **20** includes a substrate **22** and a die **24** having a microelectronic circuit formed therein. Contacts **26** and **28** are formed on the substrate **22** and the die **24** respectively. Either the contacts **26** or the contacts **28**, or all the contacts **26** and **28** can be formed from the composition **10** on the left in FIG. **9**. The contacts **26** and **28** are then brought together. During reflow, the contacts **26** and **28** combine with one another to form interconnects **30** between the substrate **22** and the die **24**.

[0028] What should be noted from FIG. **9** is that the dispersoid particles **14** are not located within the volumes of the original solder particles **16**, so that these volumes are not strengthened. Referring now to FIG. **11**, another process is shown for the manufacture of a solder composition having superior strength to the solder composition of FIG. **9**. The solder matrix material **12** is held as a liquid metal in a first container **34** and the dispersoid particles **14** are held in a second container **36**. The solder matrix material **12** and the dispersoid particles **14** are then mixed in a third chamber **38**. Because the solder matrix material **12** is in liquid form, the dispersoid particles **14** become embedded within the crystals of the solder matrix material **14**. The solder composition that results is then allowed to cool. A master ingot is then manufactured utilizing conventional milling and extrusion processes. The master ingot is then subjected to gas atomization, which breaks the master ingot into powder particles **40**. Each powder particle may for example be about 1000 nm across. Each powder particle **40** includes some of the metal matrix material and some of the dispersoid particles **14** within the metal matrix material **12**. It is the metal matrix material that includes the powder particles **40** that is applied to form the contacts **26** and/or **28** in FIG. **10**. Following reflow, the dispersoid particles **14** are held within the original volumes of the powder particles **40**. Embedding of the dispersoid particles **14** into the crystal structures of the particles **40** in this manner substantially enhances their strengthening effect.

[**0029**] FIG. **12** shows a diagrammatic representation of a machine in the exemplary form of a computer system **1200** within which a set of instructions, for causing the machine to perform any one or more methodologies may be executed. In alternative embodiments, the machine operates as a stand alone device or may be connected (e.g., network) to other networks. In a network deployment, the machine may operate in the capacity of a server or a client machine in a server-client network environment, or as peer machine in a peer-to-peer (or distributed) network environment. The machine may be a Personal Computer (PC), a tablet PC, a Set-Top Box (STB), a Personal Digital Assistant (PDA), a cellular telephone, a web appliance, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term (machine) shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

[**0030**] The exemplary computer system **1200** includes a processor **1202** (e.g., a Central Processing Unit (CPU), a Graphics Processing Unit (GPU) or both), a main memory **1204** (e.g., Read Only Memory (ROM), flash memory, Dynamic Random Access Memory (DRAM) such as Synchronous DRAM (SDRAM) or Rambus DRAM (RDRAM), etc.), and a static memory **1206** (e.g., flash memory, Static Random Access Memory (SRAM), etc.), which communicate with each other via a bus **1208**. The electronic assembly **20** shown in FIG. **10** may be any one of the components **1202**, **1204** or **1206**.

[**0031**] The computer system **1200** may further include a video display **1210** (e.g. Liquid Crystal Display (LCD) or a Cathode Ray Tube (CRT)). The computer system **1200** also includes an alphanumeric input device **1212** (e.g., a keyboard), a cursor control device **1214** (e.g., a mouse), a disk drive unit **1216**, a signal generation device **1218** (e.g. a speaker), and a network interface device **1220**.

[**0032**] The disk drive unit **1216** includes a machine-readable medium **1222** on which is stored one or more sets of instructions **1224** (e.g. software) embodying any one or more methodologies or functions. The software may also reside, completely or at least partially, within the main memory **1204** and/or within the processor **1202** during execution thereof by the computer system **1200**, the main memory **1204**, and the processor **1202** also constituting machine-readable media.

[**0033**] The software may further be transmitted or received over a network **1228** via the network interface device **1220**.

[**0034**] While the machine-readable medium **1224** is shown in an exemplary embodiment to be a single medium, the term "machine-readable medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The term "machine-readable medium" shall also be taken to include any medium that is capable of storing, encoding or carrying a set of instructions for execution by the machine and that cause the machine to perform one or more methodologies. The term "machine-readable medium" shall accordingly be taken to include, but not be limited to, solid-state memories, optical and magnetic media, and carrier wave signals.

[**0035**] While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative and not restrictive of the current invention, that this invention is not restricted to the specific instructions and arrangements shown and described since modifications may occur to those ordinarily skilled in the art.

What is claimed:

1. A solder composition comprising:

a solder matrix material having a relatively low melting temperature; and

dispersoid particles in the solder matrix material having a relatively high melting temperature.

2. The solder composition of claim 1, wherein the solder matrix material is a eutectic of first and second different components.

3. The solder composition of claim 1, wherein the solder matrix material includes first and second different components, each component including at least one of In, Sn, Bi, and Zn.

4. The solder composition of claim 1, wherein the solder matrix material is one of In-48Sn, Bi-33In, Bi-33In-0.3Zn, In-46Sn-1.5Zn, In-47Bi-0.4Zn, Bi-25In-19Sn, In-34Bi, In-33Bi-0.5Zn, In-32Bi-20Sn, and In-35Bi-16Sn-0.4Zn.

5. The solder composition of claim 1, wherein the melting temperature of the solder matrix material is below 150° C.

6. The solder composition of claim 5, wherein the melting temperature of solder matrix material is below 125° C.

7. The solder composition of claim 1, wherein the melting temperature of the dispersoid particles is above 1000° C.

8. The solder composition of claim 1, wherein the dispersoid particles are between 10 and 200 nm across.

9. The solder composition of claim 1, wherein the dispersoid particles make up between 1% and 20% of the composition by volume.

10. The solder composition of claim 1, wherein the dispersoid particles are made of at least one of SiC, W_2C, WC, ZrC, TiC, B_4C, Cr_3, C_2, Cr_7C_3, Cr_3C_6, and Al_2O_3.

11. The solder composition of claim 1, further comprising precipitation forming alloying elements.

12. The solder composition of claim 11, wherein the precipitation forming alloying elements include at least one of Cu, Ni, Ag, Ti, Mn, Co, Au, and Fe.

13. The solder composition of claim 11, wherein the precipitation forming alloying elements comprise between 1 and 10% of the composition by weight.

14. An electronic assembly comprising:

a first piece including a microelectronic circuit;

a second piece; and

a solder composition attaching the first and second pieces to one another, including a solder matrix material having a relatively low melting temperature, and dispersoid particles in the solder matrix material having a relatively high melting temperature.

15. The electronic assembly of claim 14, wherein the melting temperature of the solder matrix material is below 150° C. and the melting temperature of the dispersoid particles is above 1000° C.

16. The electronic assembly of claim 14, wherein the solder matrix material includes first and second different components, each component including at least one of In, Sn, Bi, and Zn.

17. The electronic assembly of claim 14, wherein the dispersoid particles include at least one of the SiC, W_2C, WC, ZrC, TiC, B_4C, Cr_3, C_2, Cr_7C_3, Cr_3C_6, and Al_2O_3.

18. A method of making a solder composition, comprising:

mixing a solder matrix material with dispersoid particles of the solder matrix material having a relatively low melting temperature and the dispersoid particles having a relatively high melting temperature.

19. The method of claim 18, wherein the solder matrix material include particles, the method further comprising heating the particles so that they melt and reflow so that they attach to one another, and cooling the material of the particles attaching first and second pieces to one another.

20. The method of claim 18, further comprising manufacturing a master ingot that includes the solder matrix material and the dispersoid particles, and breaking the master ingot into solder particles.

* * * * *