~~WHAT IS CLAIMED IS:~~CLAIMS

~~1. An amalgamation preform, comprising:~~

~~a base metal, and~~

~~a plurality of types of solid particles dispersed in the base metal, the base metal including one of a liquid base metal and a solid base metal,~~

~~wherein the plurality of types of solid particles at least includes:~~

~~non-reactive magnetic particles, responsive to a magnetic field for controllably dispersing the plurality of types of solid particles in the base metal, and~~

~~reactive particles, reactable with the base metal under the magnetic field.~~

~~2. The preform according to claim 1, wherein:~~

~~the base metal includes Ga, In, Sn, Bi, Pb, Cd, Hg, Rb, Zn, Bi, or a combination thereof.~~

~~3. The preform according to claim 1, wherein:~~

~~the reactive particle at least includes a reactive metal material, the reactive metal material including Fe, Ni, Cu, Ag, Au, In, Cu, Sn, Bi, Zn, Ti, V, Cr, Mo, Nb, Zr, Hf, Pt, Ir, or a combination thereof.~~

~~4. The preform according to claim 1, wherein:~~

~~a particle of the reactive particle includes a core-shell structure, wherein:~~

~~the core-shell structure includes a core material, and a shell material different than the core material and at least partially surrounding the core material, and~~

~~the core material has a reaction rate with the base metal different than the shell material.~~

~~5. The preform according to claim 4, wherein:~~

~~the shell material has a thickness ranging from a thickness of an atomic layer to a thickness of about 100 nm.~~

6. The preform according to claim 4, wherein:

the core material includes a reactive metal material, and

the shell material includes an oxide layer of the reactive metal material.

7. The preform according to claim 4, wherein:

the core-shell structure includes one or more of:

a core-shell structure having the shell material including an oxide of one or more of Fe and Ni, and the core material including the one or more of Fe and Ni;

a core-shell structure having the shell material including Cu, and the core material including Au;

a core-shell structure having the shell material including steel, and the core material including Cu;

a core-shell structure having the shell material including ZnO or TiO_2, and the core material including Cu, Ag, Ni, or a combination thereof; and

a core-shell structure having the shell material including Cu and copper oxide at least partially covering Cu, and the core material including Co, BeO, Si_3N_4, B_4C, WC, diamond, AlN, SiC, SiO_2, TiO_2, ZrO_2, Al_2O_3, or a combination thereof.

8. The preform according to claim 1, wherein:

the reactive particle includes a reactive magnetic particle, a reactive non-magnetic particle, or a combination thereof.

9. The preform according to claim 8, wherein:

the reactive magnetic particle includes one or more of Fe and Ni.

10. The preform according to claim 8, wherein:

the reactive magnetic particles have an average large size of more than about 50 microns.

~~11. The preform according to claim 8, wherein:~~

~~the reactive non-magnetic particle includes Cu, Ag, Au, In, Cu, Sn, Bi, Zn, Ti, V, Cr, Mo, Nb, Zr, Hf, Pt, Ir, or a combination thereof.~~

~~12. The preform according to claim 1, wherein:~~

~~a ratio of the base metal over the plurality of types of solid particles ranges from 4:1 to 1:4 by weight.~~

~~13. The preform according to claim 1, wherein:~~

~~the plurality of types of solid particles have an average size ranging from about 100 nm to about 100 μm.~~

~~14. The preform according to claim 1, wherein:~~

~~the reactive particles have an average size ranging from about 100 nm to about 50 μm.~~

~~15. The preform according to claim 1, wherein:~~

~~the non-reactive magnetic particles have an average size ranging from about 5 microns to about 100 microns.~~

~~16. The preform according to claim 1, wherein:~~

~~the non-reactive magnetic particles include Co-containing particles, Nd- containing particles, Cr-containing particles, or a combination thereof.~~

~~17. The preform according to claim 1, wherein:~~

~~the non-reactive magnetic particles include large-size magnetic particles having at least one dimension greater than 5 μm, and~~

~~the large-size magnetic particles include microwires, microfibers, or combination thereof.~~

~~18. The preform according to claim 1, wherein:~~

~~the plurality of types of solid particles further includes additives, including semiconductor particles, metal doped semiconductor particles, or combination thereof, and~~

~~the semiconductor particles include SiC particles, AlN particles, SiO_2 particles, or a combination thereof.~~

~~19. The preform according to claim 1, including:~~

~~a playdough-like amalgamation preform including the plurality of types of solid particles magnetically dispersed in the liquid base metal, wherein no reactions substantially occur between the reactive particles and the liquid base metal at a temperature of about 25 °C or less.~~

~~20. The preform according to claim 1, including:~~

~~a solid amalgamation preform including the plurality of types of solid particles magnetically dispersed in the solid base metal, wherein no reactions substantially occur between the reactive particles and the solid base metal at a temperature of about 25 °C or less.~~

~~21. A method of making an amalgamation preform, comprising:~~

~~providing a particle-liquid mixture containing a plurality of types of solid particles and a liquid base metal, wherein the plurality of types of solid particles at least includes:~~

~~reactive particles, reactable with the base metal, and~~

~~non-reactive magnetic particles;~~

~~applying a magnetic field to the particle-liquid mixture to magnetically disperse the plurality of types of solid particles in the liquid base metal to form a particle-liquid dispersion without substantially inducing a reaction between the reactive particles and the liquid base metal; and~~

preparing a playdough-like amalgamation preform based on the particle-liquid dispersion without solidifying the liquid base metal.

22. The method according to claim 21, wherein providing the particle-liquid mixture includes:

mixing the plurality of types of solid particles with base metal particles; and

melting the base metal particles into the liquid base metal by applying a magnetic field thereto, the liquid base metal being mixed with the plurality of types of solid particles.

23. The method according to claim 21, wherein providing the particle-liquid mixture includes:

liquefying a solid base metal by applying a magnetic field thereto, and

adding the plurality of types of solid particles into the liquefied base metal particles to provide the particle-liquid mixture.

24. The method according to claim 21, wherein preparing the playdough-like amalgamation preform based on the particle-liquid dispersion includes:

processing the particle-liquid dispersion by one or more of rolling, pressing, extruding, and casting of the particle-liquid dispersion to form the playdough-like amalgamation preform.

25. The method according to claim 21, further including:

preparing the playdough-like amalgamation preform by rolling the particle-liquid dispersion, wherein the playdough-like amalgamation preform has a thickness ranging from about 5 microns to about 500 microns.

26. The method according to claim 21, further including:

forming a solid amalgamation preform by solidifying the playdough-like amalgamation preform without substantially inducing a reaction in the solid amalgamation preform; and

processing the solid amalgamation preform by one or more of rolling, pressing, extruding, and casting of the solid amalgamation preform.

~~27. The method according to claim 21, further including:~~

~~providing the particle-liquid mixture in a container, wherein the container includes a plastic surface made of a material including polytetrafluoroethylene (PTFE), high-density polyethylene (HDPE), low-density polyethylene (LDPE), or a combination thereof.~~

~~28. The method according to claim 21, wherein applying the magnetic field to the particle-liquid mixture includes:~~

~~placing a container containing the particle-liquid mixture in a magnetic processing device, wherein the magnetic processing device includes coils winding around the container, and~~

~~controlling a current or a current change in the coils by a controller to modulate one or more of polarity, strength, localization, motion, orientation, and rotation of the magnetic field applied to a portion or a whole of the particle-liquid mixture.~~

~~29. The method according to claim 21, further including:~~

~~moving the particle-liquid mixture from one position to another, along an inner wall of the container by applying the magnetic field, when forming the particle-liquid dispersion.~~

~~30. The method according to claim 21, wherein applying the magnetic field to the particle-liquid mixture includes:~~

~~modulating the magnetic field changing in one or more angles to move the plurality of types of solid particles through a cross-section of the particle-liquid mixture and drag the plurality of types of solid particles along a surface of a container containing the particle-liquid mixture.~~

~~31. The method according to claim 21, wherein applying the magnetic field to the particle-liquid mixture further includes:~~

applying a gradient static magnetic field to controllably align the plurality of types of solid particles in the particle-liquid mixture to provide one or more of an anisotropic thermal conductivity and an anisotropic mechanical strength.

32. A method of making an amalgamation preform, comprising:

providing a particle-liquid mixture containing a plurality of types of solid particles and a liquid base metal, wherein the plurality of types of solid particles at least includes:

reactive particles, reactable with the base metal, and

non-reactive magnetic particles;

applying a magnetic field to the particle-liquid mixture to magnetically disperse the plurality of types of solid particles in the liquid base metal to form a particle-liquid dispersion without substantially inducing a reaction between the reactive particles and the liquid base metal;

solidifying the liquid base metal to disperse the plurality of types of solid particles in a solidified base metal without substantially inducing a reaction between the reactive particles and the solid base metal; and

preparing a solid amalgamation preform including the plurality of types of solid particles and the solidified base metal.

33. The method according to claim 32, wherein solidifying the liquid base metal includes:

a rapid quenching process, including a liquid cooling and a Peltier cooling.

34. The method according to claim 32, wherein:

the solid amalgamation preform has a thickness ranging from 25 microns to 10 mm.

35. A method of using an amalgamation preform, comprising:

providing mating bonding surfaces;

placing a particle-liquid mixture corresponding to the amalgamation preform between the mating bonding surfaces, wherein:

~~the particle-liquid mixture contains a plurality of types of solid particles and a base metal in a liquid form, and the plurality of types of solid particles at least includes reactive particles reactable with the base metal and non-reactive magnetic particles;~~

~~applying a first magnetic field to the particle-liquid mixture to magnetically disperse the plurality of types of solid particles in the liquid base metal to form a particle-liquid dispersion; and~~

~~applying a second magnetic field to cure the particle-liquid dispersion to allow reactions between the reactive particles and the base metal.~~

~~36. The method according to claim 35, wherein:~~

~~when placing the particle-liquid mixture, a gap is formed between each mating bonding surface and an adjacent side of the particle-liquid mixture.~~

~~37. The method according to claim 35, further including:~~

~~placing a physical spacer between the particle-liquid mixture and each mating bonding surface to maintain a gap there-between.~~

~~38. The method according to claim 35, wherein the mating bonding surfaces are provided by two mating substrates, and each of the two mating substrates includes one or more of an engineering metal, a face-centered cubic (FCC) metal, a ceramic, and an insulator.~~

~~39. The method according to claim 35, prior to providing the mating bonding surfaces, further including:~~

~~solvent cleaning the mating bonding surfaces; and/or~~

~~removing excessive oxide from one or more of the mating bonding surfaces.~~

~~40. The method according to claim 35, wherein one or more of the mating bonding surfaces have a surface roughness ranging from 1 nm to 100 microns.~~

41. The method according to claim 35, prior to placing the particle-liquid mixture between the mating bonding surfaces, further including:

providing the particle-liquid mixture by one or more of following operations including:

mixing the plurality of types of solid particles with base metal particles; and melting the base-metal particles into the liquid base metal;

liquefying base-metal particles to form a liquefied base metal, and adding the plurality of types of solid particles into the liquefied base metal; and

liquefying a playdough-like amalgamation preform and/or a solid amalgamation preform to provide the particle-liquid mixture.

42. The method according to claim 35, wherein placing the particle-liquid mixture between the mating bonding surfaces includes:

placing the amalgamation preform between the mating bonding surfaces, wherein the amalgamation preform includes a playdough-like amalgamation preform and/or a solid amalgamation preform; and

forming the particle-liquid mixture by liquefying the amalgamation preform placed between the mating bonding surfaces.

43. The method according to claim 35, wherein applying the first magnetic field and/or applying the second magnetic field include:

placing the mating bonding surfaces in a magnetic processing device, wherein the magnetic processing device includes coils winding around the mating bonding surfaces, and

controlling a current or a current change in the coils to modulate one or more of polarity, strength, localization, motion, orientation, and rotation of a magnetic field applied to a portion or a whole of the particle-liquid mixture or the particle-liquid dispersion.

44. The method according to claim 35, further including:

moving the particle-liquid mixture from one position to another, along one or more of the mating bonding surfaces by applying the first magnetic field, for forming the particle-liquid dispersion.

45. The method according to claim 35, wherein:

the first magnetic field is applied in a manner such that the plurality of types of solid particles is pulled to move in the liquid base metal toward an interface with each mating bonding surface, wherein:

the plurality of types of solid particles, under the first magnetic field, breaks an oxide layer formed at an outermost layer of the particle-liquid mixture, to improve surface wetting of the mating bonding surfaces to eliminant a need for a fluxing agent.

46. The method according to claim 35, wherein:

the second magnetic field is applied in a manner such that the plurality of types of solid particles is alloyed with the base metal at a temperature of 250 °C or less.

47. The method according to claim 35, wherein:

the plurality of types of solid particles is alloyed with the base metal at a temperature of 50 °C or less under the second magnetic field.

48. The method according to claim 35, wherein applying the first magnetic field includes:

applying a gradient static magnetic field to controllably align the plurality of types of solid particles in the particle-liquid mixture to provide one or more of an anisotropic thermal conductivity and an anisotropic mechanical strength of the cured particle-liquid dispersion.

49. A method of using an amalgamation preform, comprising:

providing mating bonding surfaces;

placing the amalgamation preform between the mating bonding surfaces, wherein:

~~the amalgamation preform contains a plurality of types of solid particles and a base metal, and the plurality of types of solid particles at least includes reactive particles and non-reactive magnetic particles;~~

~~heating the amalgamation preform at a temperature over a low melting temperature of the base metal to provide a particle-liquid mixture, containing the plurality of types of solid particles in a liquid base metal; and~~

~~while heating, applying a magnetic field to magnetically disperse the plurality of types of solid particles in the liquid base metal and to allow reactions between the reactive particles and the base metal.~~

~~50. The method according to claim 49, wherein:~~

~~a gap between the particle-liquid mixture and each mating bonding surface has a thickness maintained when heating the amalgamation preform.~~

~~51. The method according to claim 49, wherein the amalgamation preform includes a playdough-like amalgamation preform and/or a solid amalgamation preform.~~

~~52. The method according to claim 49, further including:~~

~~under the magnetic field, moving the particle-liquid mixture from one position to another, along one or more of the mating bonding surfaces to magnetically disperse the plurality of types of solid particles in the liquid base metal.~~

~~53. The method according to claim 49, wherein:~~

~~when applying the magnetic field, the plurality of types of solid particles is pulled to move in the liquid base metal toward an interface with each mating bonding surface, wherein:~~

~~the plurality of types of solid particles breaks an oxide layer formed at an outermost layer of the particle-liquid mixture, to improve surface wetting of the mating bonding surfaces to eliminant a need for a fluxing agent.~~

~~54. The method according to claim 49, wherein:~~

~~the magnetic field is applied to allow the reactions between the reactive particles and the base metal under at a temperature of 150 °C or less.~~

1. An amalgamation preform, comprising:

a base metal, and

a plurality of types of solid particles dispersed in the base metal, the base metal including one of a liquid base metal and a solid base metal,

wherein the plurality of types of solid particles at least includes:

non-reactive magnetic particles, responsive to a magnetic field for controllably dispersing the plurality of types of solid particles in the base metal, and

reactive particles, capable of being reactive with the base metal under the magnetic field for amalgamation; and

wherein the plurality of types of solid particles are together solely located in one or more regions that are proximal to an outermost surface of the amalgamation preform.

2. The preform according to claim 1, wherein:

the base metal includes Ga, In, Sn, Bi, Pb, Cd, Hg, Rb, Zn, Bi, or a combination thereof; and/or

the reactive particle at least includes a reactive metal material, the reactive metal material including Fe, Ni, Cu, Ag, Au, In, Cu, Sn, Bi, Zn, Ti, V, Cr, Mo, Nb, Zr, Hf, Pt, Ir, or a combination thereof.

3. The preform according to claim 1, wherein:

a particle of the reactive particles includes a core-shell structure, wherein:

the core-shell structure includes a core material, and a shell material different than the core material and at least partially surrounding the core material, and

the core material has a reaction rate with the base metal different than the shell material.

4. The preform according to claim 3, wherein:

the shell material has a thickness ranging from a thickness of an atomic layer to a thickness of about 100 nm,

the core material includes a reactive metal material, and

the shell material includes an oxide layer of the reactive metal material.

5. The preform according to claim 3, wherein:

the core-shell structure includes one or more of:

a core-shell structure having the shell material including an oxide of one or more of Fe and Ni, and the core material including the one or more of Fe and Ni;

a core-shell structure having the shell material including Cu, and the core material including Au;

a core-shell structure having the shell material including steel, and the core material including Cu;

a core-shell structure having the shell material including ZnO or TiO_2, and the core material including Cu, Ag, Ni, or a combination thereof; and

a core-shell structure having the shell material including Cu and copper oxide at least partially covering Cu, and the core material including Co, BeO, Si_3N_4, B_4C, WC, diamond, AlN, SiC, SiO_2, TiO_2, ZrO_2, Al_2O_3, or a combination thereof.

6. The preform according to claim 1, wherein:

the reactive particle includes a reactive magnetic particle, a reactive non-magnetic particle, or a combination thereof.

7. The preform according to claim 6, wherein:

the reactive magnetic particle includes one or more of Fe and Ni,

the reactive magnetic particles have an average size of more than about 50 microns, and/or

the reactive non-magnetic particle includes Cu, Ag, Au, In, Cu, Sn, Bi, Zn, Ti, V, Cr, Mo, Nb, Zr, Hf, Pt, Ir, or a combination thereof.

8. The preform according to claim 1, wherein:

a ratio of the base metal over the plurality of types of solid particles ranges from 4:1 to 1:4 by weight.

9. The preform according to claim 1, wherein:

the plurality of types of solid particles have an average size ranging from about 100 nm to about 100 μm,

the reactive particles have an average size ranging from about 100 nm to about 50 μm, and/or

the non-reactive magnetic particles have an average size ranging from about 5 microns to about 100 microns.

10. The preform according to claim 1, wherein:

the non-reactive magnetic particles include Co-containing particles, Nd- containing particles, Cr-containing particles, or a combination thereof.

11. The preform according to claim 1, wherein:

the non-reactive magnetic particles include large-size magnetic particles having at least one dimension greater than 5 μm, and

the large-size magnetic particles include microwires, microfibers, or combination thereof, and a length direction of the microwires and the microfibers is aligned, in parallel with a direction along the outermost surface of the amalgamation preform.

12. The preform according to claim 1, wherein:

the plurality of types of solid particles further includes additives, including semiconductor particles, metal doped semiconductor particles, or combination thereof, and

the semiconductor particles include SiC particles, AlN particles, SiO_2 particles, or a combination thereof.

13. A amalgamation preform, comprising:

a liquid base metal, and

a plurality of types of solid particles magnetically dispersed in the liquid base metal without solidifying the liquid base metal,

wherein

the plurality of types of solid particles at least includes:

non-reactive magnetic particles, responsive to a magnetic field for controllably dispersing the plurality of types of solid particles in the liquid base metal, and

reactive particles, wherein

the plurality of types of solid particles are together solely located in one or more regions that are proximal to an outermost surface of the amalgamation preform,

the reactive particles are capable of being reactive with the liquid base metal under the magnetic field for amalgamation, and

no reactions occur between the reactive particles and the liquid base metal at a temperature of about 25 °C or less.

14. A method of making the amalgamation preform according to claim 1 or claim 13, comprising:

providing a particle-liquid mixture containing the plurality of types of solid particles and the liquid base metal, wherein the plurality of types of solid particles at least includes the reactive particles and the non-reactive magnetic particles;

applying a magnetic field to the particle-liquid mixture to magnetically disperse the plurality of types of solid particles in the liquid base metal to form a particle-liquid dispersion without substantially inducing a reaction between the reactive particles and the liquid base metal, and

preparing the amalgamation preform including the plurality of types of solid particles and the base metal.

15. A method of using the amalgamation preform the amalgamation preform according to claim 1 or claim 13, comprising:

providing mating bonding surfaces;

placing a particle-liquid mixture corresponding to the amalgamation preform between the mating bonding surfaces; and

applying a magnetic field to the particle-liquid mixture.