CLAIMS

1. An adhesive additive for magnetically curing an adhesive, the adhesive additive comprising:

a magnetic nanoparticle comprising

(i) more than one metal, wherein the more than one metal comprises iron, manganese, cobalt, nickel, and/or zinc, or

(ii) a metal oxide, wherein the metal oxide contains more than one metal which comprises iron, manganese, cobalt, nickel, and/or zinc;

a coating on the magnetic nanoparticle, wherein the coating comprises

(a) a surfactant; and

(b) a monomer or a polymer which is miscible with an adhesive substrate which the adhesive additive is incorporable to,

wherein the magnetic nanoparticle produces thermal energy in response to an alternating magnetic field applied thereto for the adhesive substrate to form cross-linkages.

2. The adhesive additive of claim 1,

wherein the magnetic nanoparticle is represented by a formula of $A_xZn_{1-x}Fe_2O_4$;

wherein A is cobalt, manganese, or nickel; and

x has a value in the range of 0.4 to 0.9.

3. The adhesive additive of claim 1 or 2, wherein the surfactant is formed as an organic coating, wherein the organic coating comprises a fatty acid having 15 to 20 carbon atoms.

4. The adhesive additive of any one of claims 1 to 3, wherein the surfactant comprises oleic acid.

5. The adhesive additive of any one of claims 1 to 4, wherein the surfactant is covalently bonded to the magnetic nanoparticle.

6. The adhesive additive of any one of claims 1 to 5, wherein the coating comprises an epoxy as the polymer.

7. The adhesive additive of any one of claims 1 to 6, wherein the monomer comprises bisphenol A diglycidyl ether and/or glycerol diglycidyl ether.

8. The adhesive additive of claim 6 or 7, wherein the monomer further comprises a hardener, wherein the hardener comprises a dicyandiamide.

9. The adhesive additive of any one of claims 1 to 5, wherein the polymer comprises polycaprolactone.

10. The adhesive additive of any one of claims 1 to 9, further comprising a carbon allotrope.

11. The adhesive additive of any one of claims 1 to 10, wherein the alternating magnetic field comprises a frequency of 100 kHz to 1 MHz and/or a magnetic field strength of 50 Oe to 140 Oe.

12. An adhesive which is magnetically curable, the adhesive comprising:
the adhesive additive of any one of claims 1 to 11; and
an adhesive substrate.

13. The adhesive of claim 12, wherein the adhesive substrate is:

(i) a resin comprising a thermoset which is activated to form cross-linkages by the thermal energy produced from a magnetic nanoparticle in the adhesive additive of any one of claims 1 to 11, wherein the thermoset comprises epoxy and diazirine; or

(ii) a resin comprising a thermoplastic, wherein the thermoplastic comprises polycaprolactone.

14. The adhesive of claim 12 or 13, wherein the adhesive substrate is a resin absent of a hardener.

15. The adhesive of any one of claims 12 to 14, wherein the adhesive additive and the adhesive substrate are present in a weight ratio of 1:100 to 50:100.

16. A method of forming the adhesive additive of claim 1, the method comprising:

providing a magnetic nanoparticle comprising

(i) more than one metal, wherein the more than one metal comprises iron, manganese, cobalt, nickel, and/or zinc, or

(ii) a metal oxide, wherein the metal oxide contains more than one metal which comprises iron, manganese, cobalt, nickel, and/or zinc;

mixing an aqueous solution comprising the magnetic nanoparticle with a surfactant; and

mixing an organic solution comprising the magnetic nanoparticle coated with the surfactant with (i) a monomer or (ii) a polymer which is miscible with an adhesive substrate which the adhesive additive is incorporable to.

17. The method of claim 16, wherein providing the magnetic nanoparticle comprises:

mixing an alkaline solution with two precursor solutions to form an alkaline mixture, wherein the alkaline solution contains a first metal precursor, wherein each of the two precursor solutions contains a second metal precursor and a third metal precursor, respectively, wherein the first metal precursor, the second metal precursor, and the third metal precursor form different metals in the magnetic nanoparticle; and

hydrothermally treating the alkaline mixture to form the magnetic nanoparticle.

18. The method of claim 16 or 17, wherein mixing the aqueous solution comprising the magnetic nanoparticle with the surfactant comprises:

dispersing the magnetic nanoparticle in an aqueous medium; and

mixing the aqueous medium with the surfactant.

19. The method of any one of claims 16 to 18, wherein the surfactant comprises a fatty acid having 15 to 20 carbon atoms.

20. The method of any one of claims 16 to 19, wherein mixing the organic solution comprising the magnetic nanoparticle coated with the surfactant with (i) the monomer or (ii) the polymer comprises:

dispersing the magnetic nanoparticle coated with the surfactant in an organic medium;

dissolving the monomer or the polymer in an organic solvent to form a monomer solution or a polymer solution, respectively; and

mixing the monomer solution or the polymer solution with the organic medium containing the magnetic nanoparticle coated with the surfactant.

21. The method of any one of claims 16 to 20, further comprising:

adding the adhesive additive in a further resin; and

mixing a carbon allotrope with the further resin containing the adhesive additive.