CLAIMS:

1. A heat exchanger for transferring heat from a first material to a second material, comprising

a structural heat transfer member having a first surface in contact with the first material and a second surface in contact with the second material; and

a coating disposed on the first surface or the second surface, or disposed on the first and second surfaces, the coating comprising rod, tubule, fiber, or platelet filler particles that are nanoscopic in at least one dimension dispersed in a polymer resin matrix and characterized in that the filler particles are aligned in a direction of heat flow across the coating.

2. The heat exchanger of claim 1, wherein the interfacial thermal resistance between the individual filler particles and the polymer resin matrix is less than or equal to 7×10^{-7} m^2-K/W, preferably less than or equat to 7×10^{-8} m^2-K/W, and more preferably less than or equal to $7 \times 10^{-9} m^2$-K/W.

3. The heat exchanger of claims 1 or 2, wherein the thermal conductivity of the individual filler particles is at least 30 W/m-K, preferably at least 300 W/m-K, and more preferably at least 3000 W/m-K.

4. The heat exchanger of any of claims 1-3, wherein the filler particles have at least one dimension less than or equal to 500 nm, preferably less than or equal to 100nm.

5. The heat exchanger of any of claims 1-4, wherein the surface of the coating is hydrophobic.

6. The heat exchanger of any of claims 1-5, wherein the filler particles have an orientation ratio $\phi_{p,p}$ of greater than 0.

7. The heat exchanger of any of claims 1-6, wherein the filler particles comprise carbon nanotubes, carbon nanoplatelets, graphene, boron nitride nanotubes, or boron nanoplatelets.

8. The heat exchanger of any of claims 1-7, wherein the polymer resin comprises π orbital electrons.

9. The heat exchanger of claim 8, wherein the polymer resin comprises phenyl or phenylene groups.

10. The heat exchanger of claim 9, wherein the polymer resin comprises polyphenylene sulfide, polyarylether ketone, poly(p-phenylene), polyphenylene oxide.

11. The heat exchanger of any of claims 8-10, wherein the filler particles are functionalized with carboxylic acid groups, hydroxide, oxide, or amine.

12. The heat exchanger of any of claims 1-11 wherein the coating has a hierarchical surface roughness with microscale and nanoscale roughness.

13. A heat transfer system comprising a heat transfer fluid circulation loop, including the heat exchanger of any of claims 1-12 disposed in the heat transfer fluid circulation loop.

14. The heat transfer system of claim 13 that is a vapor compression heat transfer system that comprises an evaporator heat exchanger, a compressor that receives heat transfer fluid from the evaporator heat exchanger, a condenser heat exchanger that receives heat transfer fluid from the condenser, an expansion device that receives heat transfer fluid from the condenser heat exchanger and provides heat transfer fluid to the evaporator heat exchanger, wherein the heat exchanger of any of claims 1-12 is the evaporator heat exchanger or the condenser heat exchanger.

15. A method of operating the heat transfer system of claims 13 or 14, comprising circulating the heat transfer fluid through the heat transfer fluid circulation loop to transfer heat from the first material to the second material, wherein the coated surface of the heat exchanger of any of claims 1-12 is subjected to a temperature below the freezing point of water.