CLAIMS

1. A method for 3-D printing a metal object having a density at least 95% that of pure metal, the method comprising:

forming a series of layers comprising the metal object, each layer formed from a metal filament, wherein forming each layer comprises:

forming a series of voxels from the metal filament via application of ultrasonic energy to a print tool in contact with the metal filament,

wherein a portion of the print tool in contact with the metal filament vibrates with an amplitude of between 0.9 microns and 1.1 microns responsive to the ultrasonic energy,

wherein each voxel in the series of voxels is coupled via mass transport to adjacent voxels in the layer and to adjacent voxels in the prior layer,

wherein, during formation of a voxel, the temperature of the metal filament increases by less than 6 degrees Celsius,

wherein each voxel is formed via application of ultrasonic energy for a period of between 200 microseconds and 400 microseconds,

wherein forming the series of voxels is conducted at nominal pressure applied to the metal filament, and

wherein the forming a series of voxels is conducted at room temperature and in ambient atmosphere.

2. The method of claim 1, wherein the metal filament comprises at least one of aluminum, titanium, gold, silver, copper, or a steel alloy.

3. The method of claim 1, further comprising varying an intensity of the applied ultrasonic energy between formation of voxels to alter the microstructure of the metal.

4. The method of claim 1, wherein the print tool comprises a tungsten carbide bar, and wherein the print tool is coupled to a piezoelectric crystal operative at between 40 kHz and 200 kHz.

5. The method of claim 1, wherein the print tool comprises a tungsten carbide bar having a thickness of between 2 mm and 3 mm and a length of between 12 mm and 25 mm.

6. A method for additive manufacturing, the method comprising:

contacting a first length of metal wire with a metal substrate;

inducing, via application of ultrasonic energy, materials flow and solid-state diffusion in the first length of metal wire in a first target area to bond a portion of the first target area to the metal substrate; and

inducing, via application of ultrasonic energy, materials flow and solid-state diffusion in the first length of metal wire in a second target area at least partially overlapping the first target area to bond a portion of the second target area to the metal substrate,

wherein nominal pressure is applied to the first length of metal wire during the inducing the materials flow and solid-state diffusion in the first length of metal wire.

7. The method of claim 6, further comprising:

contacting a second length of metal wire to the first target area and the second target area; and

inducing, via application of ultrasonic energy, materials flow and solid-state diffusion in the second length of metal wire in a third target area to bond a portion of the third target area to at least one of the first target area or the second target area.

8. The method of claim 6, wherein the ultrasonic energy is applied to the first length of metal wire via a print tool comprising a tungsten carbide bar having a thickness of between 2 mm and 3 mm and a length of between 12 mm and 25 mm.

9. The method of claim 6, wherein the source of the ultrasonic energy is a piezoelectric crystal operating at a frequency of about 60 kHz, and wherein the piezoelectric crystal and the print tool are coupled via a steel horn.

10. The method of claim 6, wherein the materials flow and solid-state diffusion in the first length of metal wire in the first target area occurs with a temperature rise in the wire of less than 6 degrees Celsius.

11. The method of claim 7, wherein the combined density of the first target area, the second target area, and the third target area exceeds 95% of the density of the pure metal.

12. The method of claim 6, wherein the portion of the first target area bonded to the substrate forms a voxel.

13. The method of claim 12, further comprising repeatedly forming a series of voxels to form a desired structure.

14. The method of claim 13, further comprising varying the amount of ultrasonic energy applied to a set of voxels in the series of voxels to control a microstructure of the metal grain in the desired structure.

15. The method of claim 6, wherein the metal comprises at least one of aluminum, titanium, gold, silver, copper, or a steel alloy.

16. The method of claim 6, wherein the method is performed at room temperature and in ambient atmosphere.

17. The method of claim 8, wherein, responsive to the ultrasonic energy, a free end of the print tool vibrates with an amplitude of between 0.9 microns and 1.1 microns.

18. The method of claim 6, wherein the ultrasonic energy is applied for a period of between 200 microseconds and 400 microseconds.

19. The method of claim 6, further comprising removing at least a portion of the first target area, the second target area, or the third area to form a desired structure.