2017 International Bionic Innovation Competition

Process Parameter Optimization of Extrusion-Based Metal Printing Biomimetic parts Utilizing PW–LDPE–SA Binder System

Abstract

An emerging process is applicable for the fabrication of metal parts into biomimetic products. Some critical parameters of extrusion-based 3D printing processes were optimized by a series of experiments with a melting extrusion printer. The raw materials were copper powder and a thermoplastic organic binder system and the system included paraffin wax, low density polyethylene, and stearic acid. The extrusion-based printing process for producing metal materials is a promising strategy because it has some advantages over traditional approaches for cost, efficiency, and simplicity.

Methods

Raw Materials Preparation. The composition of the raw materials was listed in Table 1. First, the paraffin wax, low-density polyethylene, and stearic acid were mixed at 180 ℃ as an organic binder until the mixture was uniform. Then, Cu powders were added into the organic binder and the whole system was thoroughly mixed. Finally, the materials were crushed into particles smaller than 3 mm.

Table 1. Composition of the raw materials.

Raw Materials		Content vol %
Cu powders		65
Organic binder	74 wt % paraffin wax (PW) 23 wt % low-density polyethylene 3 wt % stearic acid (SA)	35

3D Printing Process.

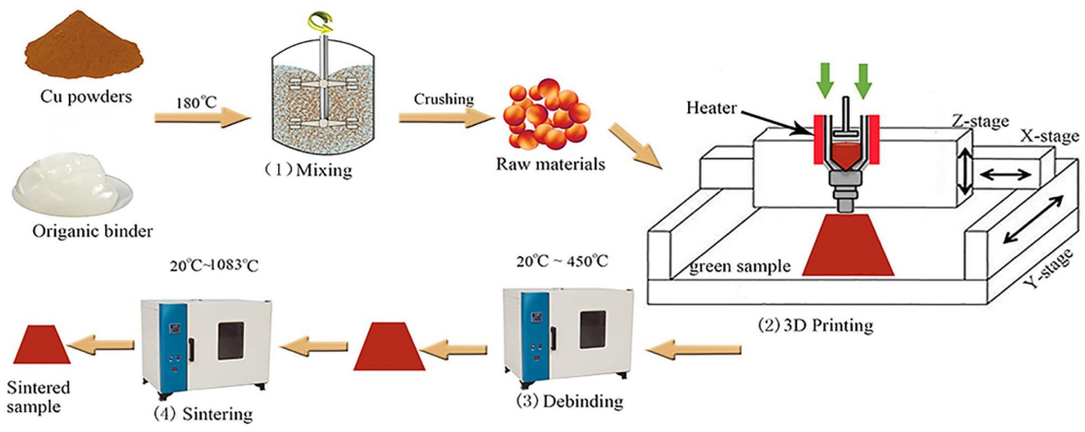


Figure 1. Schematic of the technological process.

Results

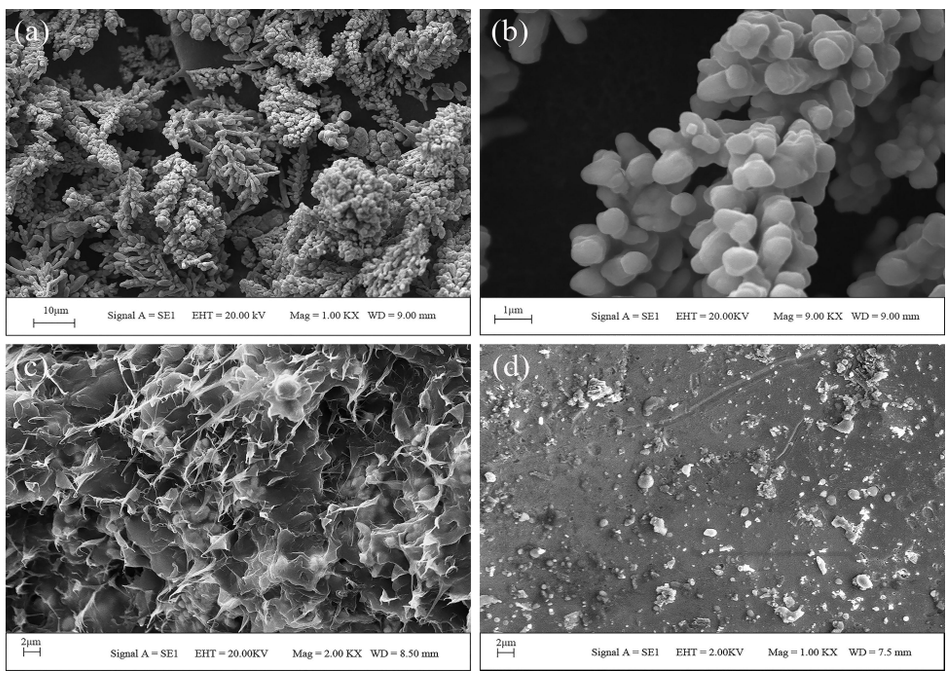


Figure 2. SEM image of the Cu powder with the magnifying power of 1 kx (a); the Cu powder with the magnifying power of 9 kx (b); cross section of the green body (c); surface of the sintered part with heating rate (3℃/min), highest temperature (1083 ℃), holding time (3 h) (d).

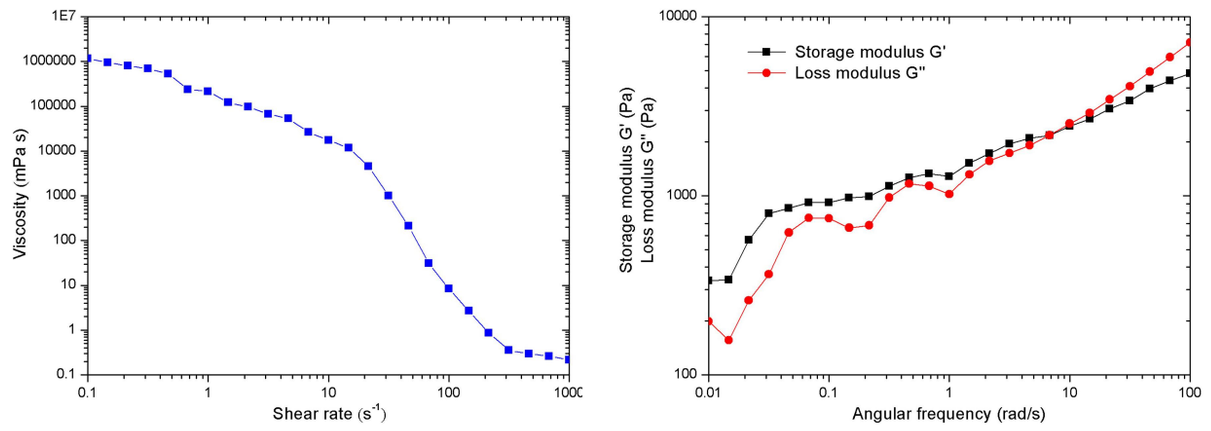
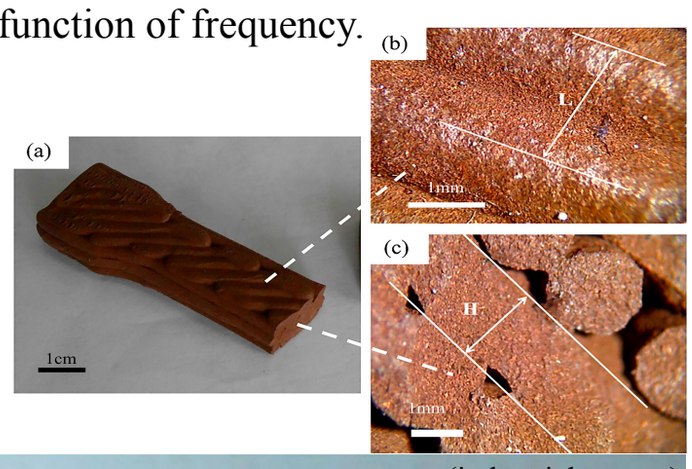


Figure 3. Rheological behaviour of the raw materials at 160 ℃: (a) the viscosity as a function of shear rate; (b) the storage modulus (G′) and loss modulus (G″) as a function of frequency.

Figure 4. Green sample printed by this method: (a) overview; (b) the top surface of the green sample; (c) cross section of the green sample.



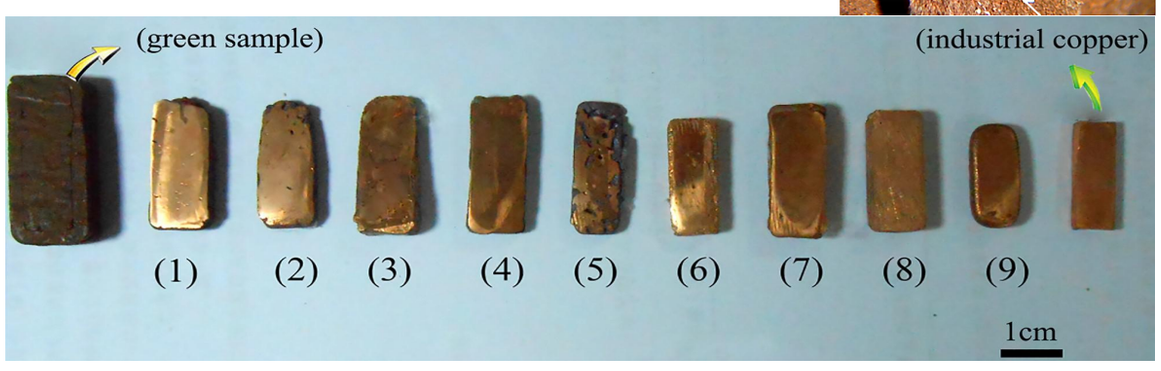


Figure 5. Sintered samples with different sintering parameters

Conclusions

We have demonstrated that metallic green samples can be produced through an extrusion-based printing process with the thermoplastic organic binder system. This article lays the foundation not only for expanding the variety of metals that can be additively manufactured, but also other particle-based materials.

(1) The raw materials with Cu particle content of 65 vol % can be prepared with the PW–LDPE–SA thermoplastic binder systems. The powder particles are homogeneously dispersed in the raw materials, and the rheological behaviour is fit for printing.

(2) During the printing process, the infill degree exerted the strongest effect on the ultimate tensile strength of the green sample, followed by the raster angle, and the layer thickness is the weakest.

(3) During the sintering process, the influence factors on the hardness of the sample can be described as follows: highest temperature > holding time > heating rate.

Publications/patents or rewards

Publications.

Process Parameter Optimization of Extrusion-Based 3D Metal Printing Utilizing PW–LDPE–SA Binder System. Materials 2017, 10(3), 305.

Patents.

(1)A 3DP printing method based on gelatin, ZL201510499628.5, Invention patents(Authorization)

(2)3D printing method for metal ceramic functionally gradient parts in alternating magnetic field,ZL201510990255.1,nvention patents (Authorization)

(3)3D printing forming method for metal material gradient parts, ZL201610218039, Invention patents (Authorization)

(4)3D printing material, printing method and printing device based on fused deposition manufacturing process, ZL201510530079.3 Invention patents (Authorization)

(5)3D printing method suitable for multi material, multi process and printing device used, 201610064285.4, Invention patents (Open)

(6) Powder material gradient laying method for 3D printing process and laying device used for the same，201610064298.1, Invention patents (Open)

(7) Multi material part 3D printing device and printing method，201510990147.4， Invention patents (Open)