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Additive manufacturing of magnetic parts by laser powder bed fusion of iron oxide nanoadditivated polyamide powders

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Abstract

Laser powder bed fusion (LPBF) allows the processing of polymer powders with design freedom achieving highly complex geometries that are relevant for medical and aerospace applications. The characteristics of the generated parts as well as the processability by LPBF depends on the initial polymer powder properties. A route to achieve a controlled modification of the polymer powders and adapt the properties of the final parts to the desired application is the nanoparticle-additivation of the powders. The generation of superparamagnetic iron oxide nanoparticles by laser fragmentation and supporting on polyamide (PA12) is shown to transfer the magnetic response of the nanoparticles to the resulting nanoadditivated powder even when the nanoparticle loading is only 0.1 wt%. The characterization of the as-built parts confirms that the saturation magnetization and structure of the iron oxide nanoparticles are not influenced by LPBF processing, proving the successful transfer of the initial nanoparticle properties to the 3D-printed part.

Keywords: Laser powder bed fusion, Laser fragmentation in liquids, Magnetic Nanoparticles, Selective laser melting, Iron oxide.

1. Introduction

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One of the main methods in additive manufacturing (AM) of polymers is laser powder bed fusion (LPBF). However, LPBF is limited to only few polymer powder materials available for complex processing tasks, dominated by the standard material polyamide 12 (PA12).[1] Expanding the material portfolio beyond PA12 towards other engineering and high performance polymers and modifying the properties of the generated structures is still challenging.[2] A profound understanding of the relationships between the powder and the process parameters on one side, and the resulting microstructure as well as the final part properties on the other side is required.

To achieve this goal, the controlled addition of nanoparticles to the polymer powders has been shown to allow the modification of the optical properties with loadings as low as 0.1 wt%.[3] To optimize the properties transfer to the polymer powders, the nanoparticles should be well dispersed, avoiding agglomeration. A method for homogeneous surface decoration of particles is colloidal additivation, which is used for pH-controlled adsorption of colloidal nanoparticles on inorganic powders.[4] This method appears ideal to modify other material characteristics as providing magnetic properties.

2. Results and conclusions

Iron oxide nanopowders (γ-Fe_2O_3) are irradiated with a 10 ps laser, wavelength of 355 nm and a repetition rate of 80 kHz. The TEM analysis of the generated colloids shows the size reduction of the Fe_2O_3 nanoparticles to a monomodal size distribution with a hydrodynamic mean size of 11 nm. PA12 powders at a concentration of 50 mg/l are added to the generated colloid and the pH-driven dielectrophoretic deposition process leads, as confirmed by SEM, to a homogeneous supporting of the nanoparticles on the surface of the PA12 microparticles. The nanoadditivated powder is dried and characterized by reflectance measurements and Mössbauer spectroscopy to find an increased absorption and new magnetic properties due to the FeO_x nanoparticles presence. Finally, the powder is employed for LPBF, and the feasibility of producing parts from this powder is proved. The overall process is depicted in Fig 1 showing the innovative approach to generate nanoadditivated polymer powders with enhanced properties suitable for LPBF.[5]

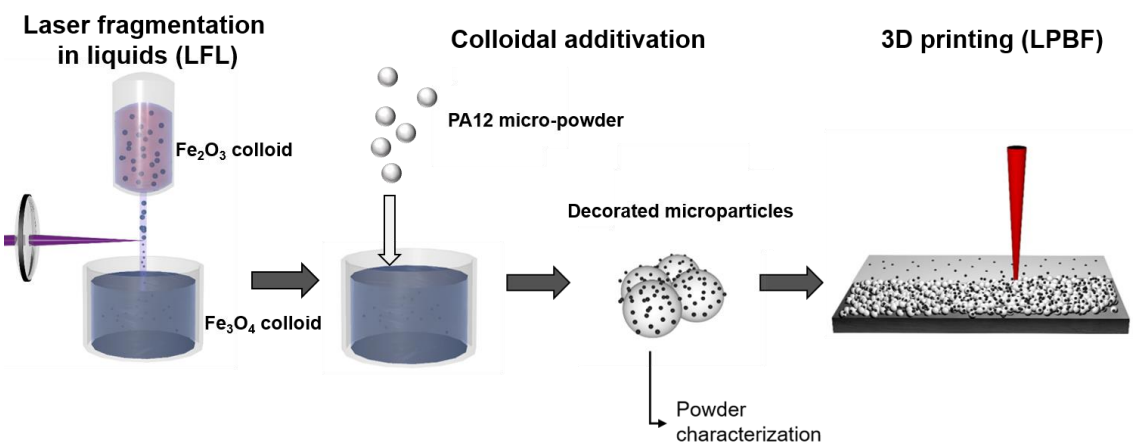

Fig. 1. Fragmentation in a liquid jet configuration (LFL) of iron oxide nanoparticles. Irradiation employing 355 nm ps pulses. After fragmentation of the iron oxide nanoparticles the polymer powder is added to the colloid to achieve additivation. The nanoadditivated powder is dried and parts are built by LPBF.

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