Photonic Sintering of Nanoparticle Inks: Experimental Characterization, Computational Modeling and System Design for Additive Manufacturing

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Abstract:

Photonic sintering of nanoparticles is a relatively new process for sintering of nanoparticles, deposited on a substrate, into functional solid structures. The working principle of this process is the incidence of large-area broad-spectrum light onto deposited nanoparticles, which results in heat generation in the nanoparticles and their subsequent densification. Key advantages of photonic sintering include rapid, scalable and ambient condition operation. For these reasons there is significant interest in using this process as a manufacturing solution for nanoparticle sintering in emerging applications like RFID tags, flexible electronics, solar cells, and sensors. Despite preliminary demonstrations of photonic sintering, there is little knowledge on the underlying process physics, which results in limited physics-based control of the process.

The goals of this work are to (1) expand the state of knowledge on the physics of photonic sintering; and (2) develop a system that can leverage the advantages of photonic sintering for low-cost additive manufacturing using nanoparticle building blocks.

Four key topics are investigated. First, the effects of nanoparticle size on densification and temperature (of nanomaterial and substrate) are experimentally characterized and found to be highly dependent on the nanoparticle size used. Secondly, a multiphysical model of photonic sintering is developed to link particle size, optically-induced heat generation, resulting temperature rise and consequent interparticle necking. In addition to reflecting experimentally observed trends, this model also provides an improved insight into the physics of photonic sintering. Thirdly, densification and temperature evolution in photonic sintering of non-metallic nanoparticles is characterized. Lastly, a prototype system is designed and fabricated to demonstrate the potential of photonic sintering in low-cost, multi-material, desktop additive manufacturing. With further development and greater understanding of photonic sintering, the developed additive manufacturing system can be further refined. When fully developed this system has the potential to increase accessibility of low-cost, multi-material additive manufacturing, similar to the current widespread accessibility of polymer 3D printing.

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