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Laser 3D Manufacturing II

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Introduction

At the second meeting of the Laser 3D Manufacturing conference, the following topical areas were addressed:

- manufacturing of metal structures
- mechanical metamaterials
- materials and device fabrication
- process design and certification
- micro-engineering
- process control and monitoring.

The formal portion of the conference comprised two full days, with an additional day to hold a joint session with the *Laser Applications in Microelectronic and Optoelectronic Manufacturing* (LAMOM) conference, which addressed the topic of Laser Induced Forward Transfer (LIFT) as it applies to 3D manufacturing. The goal of the conference remained the assembling of experts in topical areas pertinent to advancing 3D manufacturing. In our opinion, this includes not only addressing issues with regards to the manufacturing technique, but also those of process design, control, and monitoring. In the 2015 event, there was an increased focus in process control and monitoring to address industrial criticisms regarding process repeatability and reliability. The 3D manufacturing technique—whether it is by sintering (as for metals), or single photon or its high-finesse "cousin" two-photon polymerization for plastics—has already proven the complexity of shapes that can be realized (with feature sizes now measured down to tens of nanometers for polymers).

However, there were several industrial "concerns" that were voiced at the meeting.

1) How do we address the formation of imperceptible defects formed during manufacturing that render the part valueless upon an *ex situ* inspection?
2) How do we increase the poor surface finish of a 3D-formed metal part?
3) For high-precision 3D manufacturing (i.e., two-photon polymerization), how can we increase the fabrication throughput?

Various approaches to address these issues were presented: with process control and monitoring offering a means to solve the defect problem; the use of a high-power fs laser for 3D manufacturing to mitigate the surface finish issue and the use of specialty materials; oxygen quenching; and parallel light projection to enhance the speed of two-photon polymerization.

While the conference did address practical or industrial concerns, there were also new capabilities made possible by laser 3D processing. A few examples were described only to showcase the extent. Due to the high temperatures required, fusing tungsten powder/metal is difficult to accomplish with CW fiber lasers. Consequently, 3D metal parts made out of tungsten have not been demonstrated. However, the process becomes amenable when a high-power fs laser is used. Also, it is clear that nature applies hierarchical approaches to form structures. Several presentations addressed the development of high strength and lightweight hierarchical materials based on laser 3D manufacturing that could be applied to photonics and biomimetics; and many of the structures also have mechanical metamaterial properties. Finally, while it is the hardware and the techniques that continue to fascinate with the types of 3D structures that can be fabricated, it is the software logic, the CADCAM, and the simulations that permit the design of the complex shapes. Presentations addressed architecture for multiscale simulation and strategies for reliable selective melting.

3D manufacturing promises much, and many of these promises remain to be demonstrated. It is only through forums such as this conference where technical exchanges among the laser users, the materials developers, the tool manufacturers, and the software (CADCAM) and controls experts will decide what is of value. The Chairs thank our conference sponsor, PolarOnyx, Inc. of San Jose, California for their generous support and look forward to *3D Manufacturing III*, one year hence.

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Bo Gu