OSA Lasers in Manufacturing Technical Group

Newsletter

autumn 2017

Dear members of LiM technical group,

This is the third issue of the newsletter dedicated to the members of our Lasers in Manufacturing Technical Group.

In this issue we will cover laser assisted 3D printing and additive manufacturing. 3D printing is rapidly entering not only industrial environment but also becoming valuable tool for research activities. Apart from the list of selected publications I would also recommend reading nice review articles published in OPN related to 3D printing (**link**) and additive manufacturing (**link**).

Last month North America observed grand optical event – solar eclipse. We also invite to submit any pictures of this event that they have taken during the eclipse of August 21, 2017 over North America. The photographs will be featured in our LinkedIn group.

by Martynas Beresna, Chair

SELECTED PUBLICATIONS

The emerging requirements for advanced manufacturing lean towards *customization*, *high-quality/low-volume production*, and *high-precision manufacturing*.

Owing to their ability to focus irradiation at power densities as high as MW/cm^2, modern lasers have the potential to fulfil these requirements. While laser subtractive manufacturing was partly covered in the winter release of our newsletter, its additive counterpart is highlighted here.

The different laser additive manufacturing (LAM) processes share same material additive philosophy. However, each one of the different processes has its distinct characteristics. Depending on the type of application, its requirements and the materials to be used, a single LAM process or a combination of them, may be used for obtaining high-performance three-dimensional metallic or polymer components with tuneable properties.

LAM is strongly associated with metallic materials. The type of laser-powder interaction along with the metallurgical mechanism taking place define the LAM process. The prevailing LAM processes are three: laser sintering, laser melting, and laser-metal deposition. Interestingly, LAM is also emerging in polymers where with processes such as two-photon absorption functional devices have been demonstrated.

This recent attention in LAM is materialized with numerous interesting publications in the field, such as the ones highlighted bellow. Further advancement of these techniques, and additional *in-situ* monitoring within processes *per se* will onset the fabrication of even more sophisticated devices possible.

Looking forward, LAM is likely to become a dominant technology in various industries. In conjunction with laser subtractive technologies, lasers can provide a palette full of tools to fulfil the excessive needs of advanced manufacturing.

by Athanasiou Christos Edouardos, Committee Member

Three-dimensional printing of transparent fused silica glass

F. Kotz, K. Arnold, W. Bauer, D. Schild, N. Keller, K. Sachsenheimer, T. M. Nargang, C. Richter, D. Helmer, and B. E. Rapp

- Nature 554, 337-339 (2017)

Glass is one of the most important high-performance materials used for scientific research, in industry and in society, mainly owing to its unmatched optical transparency, outstanding mechanical, chemical and thermal resistance as well as its thermal and electrical insulating properties. However, glasses and especially high-purity glasses such as fused silica glass are notoriously difficult to shape, requiring high-temperature melting and casting processes for macroscopic objects or hazardous chemicals for microscopic features. These drawbacks have made glasses inaccessible to modern manufacturing technologies such as three-dimensional printing (3D printing). Using a casting nanocomposite, here we create transparent fused silica glass components using stereolithography 3D printers at resolutions of a few tens of micrometres. The process uses a photocurable silica nanocomposite that is 3D printed and converted to high-quality fused silica glass via heat treatment. The printed fused silica glass is non-porous, with the optical transparency of commercial fused silica glass, and has a smooth surface with a roughness of a few nanometres. By doping with metal salts, coloured glasses can be created. This work widens the choice of materials for 3D printing, enabling the creation of arbitrary macro- and microstructures in fused silica glass for many applications in both industry and academia.

Diode-based additive manufacturing of metals using an optically-addressable light valve

M. J. Matthews, G. Guss, D. R. Drachenberg, J. A. Demuth, J. E. Heebner, E. B. Duoss, J. D. Kuntz, and C. M. Spadaccini

- Optics Express 25, 11788-11800 (2017)

Selective Laser Melting (SLM) of metal powder bed layers, whereby 3D metal objects can be printed from a digital file with unprecedented design flexibility, is spurring manufacturing innovations in medical, automotive, aerospace and textile industries. Because SLM is based on raster-scanning a laser beam over each layer, the process is relatively slow compared to most traditional manufacturing methods (hours to days), thus limiting wider spread use. Here we demonstrate the use of a large area, photolithographic method for 3D metal printing, using an optically-addressable light valve (OALV) as the photomask, to print entire layers of metal powder at once. An optical sheet of multiplexed ~5 kW, 20 ms laser diode and ~1 MW, 7 ns Q-switched laser pulses are used to

selectively melt each layer. The patterning of near infrared light is accomplished by imaging 470 nm light onto the transmissive OALV, which consists of polarization-selective nematic liquid crystal sandwiched between a photoconductor and transparent conductor for switching.

Metal powder absorptivity: modeling and experiment

C. D. Boley, S. C. Mitchell, A. M. Rubenchik, and S. S. Q. Wu

Applied Optics 55, 6496-6500 (2016)

We present results of numerical modeling and direct calorimetric measurements of the powder absorptivity for a number of metals. The modeling results generally correlate well with experiment. We show that the powder absorptivity is determined, to a great extent, by the absorptivity of a flat surface at normal incidence. Our results allow the prediction of the powder absorptivity from normal flat-surface absorptivity measurements.

3D bioprinting of tissues and organs

S. V. Murphy and A. Atala

Nature Biotechnology 32, 773-785 (2014)

Additive manufacturing, otherwise known as three-dimensional (3D) printing, is driving major innovations in many areas, such as engineering, manufacturing, art, education and medicine. Recent advances have enabled 3D printing of biocompatible materials, cells and supporting components into complex 3D functional living tissues. 3D bioprinting is being applied to regenerative medicine to address the need for tissues and organs suitable for transplantation. Compared with non-biological printing, 3D bioprinting involves additional complexities, such as the choice of materials, cell types, growth and differentiation factors, and technical challenges related to the sensitivities of living cells and the construction of tissues. Addressing these complexities requires the integration of technologies from the fields of engineering, biomaterials science, cell biology, physics and medicine. 3D bioprinting has already been used for the generation and transplantation of several tissues, including multilayered skin, bone, vascular grafts, tracheal splints, heart tissue and cartilaginous structures. Other applications include developing high-throughput 3D-bioprinted tissue models for research, drug discovery and toxicology.

Printing of metallic 3D micro-objects by laser induced forward transfer

M. Zenou and Z. Kotler

Optics Express 24, 1431-1446 (2016)

Digital printing of 3D metal micro-structures by laser induced forward transfer under ambient conditions is reviewed. Recent progress has allowed drop on demand transfer of molten, femto-liter, metal droplets with a high jetting directionality. Such small volume droplets solidify instantly, on a nanosecond time scale, as they touch the substrate. This fast solidification limits their lateral spreading and allows the fabrication of high aspect ratio and complex 3D metal structures. Several

examples of micron-scale resolution metal objects printed using this method are presented and discussed.

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