Laser micro processing of polymeric devices – structuring, surface modification and bonding

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Polymeric devices are of high interest for lab-on-a-chip devices due to their disposability and inexpensiveness allowing the use as disposable parts. Laser processing can be applied at many steps of the production process of a polymeric device, e.g. laser micromilling can be used for the rapid and cost-efficient manufacturing of metallic mould inserts for micro replication techniques. However, the focus of this study is on direct laser treatment and functionalization of polymers and their surfaces. Three different laser-based processes are discussed, the first being laser microstructuring, where defined surface geometries such as microfluidic channels or micro-sized holes are directly generated via CO_2- or excimer laser ablation. The capabilities of different laser processes with respect to achievable structure sizes, aspect ratios and processing speeds are discussed. The second process is laser-assisted surface modification allowing the formation of chemical patterns on polymeric surfaces, thereby modifying the wettability as well as enabling localized protein and cell adhesion. As third laser-based process laser transmission welding of microstructured and transparent polymeric devices and its technical capabilities are discussed. It is shown that the combination of these three laser process technologies can be applied for the flexible fabrication of functional micro devices.

Laser structuring

For the manufacturing of 3D shapes, pockets, holes, and channels in transparent polymeric materials two different laser sources were applied. The first one based on a CO_2 laser system leads to rounded structures as a result of the Gaussian intensity distribution of the laser beam. Due to the laser wavelength of 10.6 µm this was a thermal process leading to the formation of a melt buldge. As second laser source an excimer laser with a wavelength of 193 nm was applied. The high photon energy of the UV laser source is capable of directly breaking the bonds of the polymeric chains. This process can therefore be described as cold ablation. The generated channel structures therefore show sharp edges.

Figure 1 schematically shows the intensity distribution and shape of structures manufactured using the two laser sources.

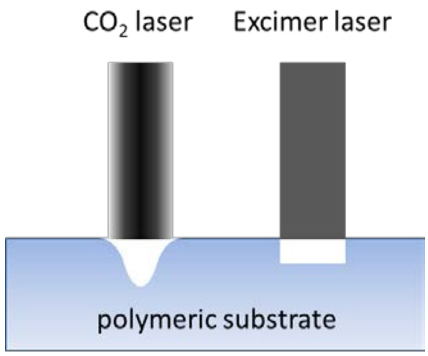

Figure 1. Scematic representation of different laser structuring processes for polymers.

Laser surface modification

UV excimer laser radiation below the ablation threshold can be applied to chemically modify the surface. This allows an adjustment of the wettability of different polymeric materials ranging from superhydophobic to superhydrophilic behaviour. This chemical modification can also be used to locally modify cell adhesion properties.

Laser transmission welding

Typically, as final step in the production of microfluidic devices, an air-tight sealing is required. For the bonding of two transparent polymers a laser transmission welding technique has been developed based on using an laser absorption layer such as a carbon layer with a thickness in the range of 1 – 10 nm. This leads to localised energy absorption allowing high bonding temperatures and therefore enabling high bonding strengths.

As an example to demonstrate the capabilities of the different laser processes a complete capillary electrophoresis (CE) microchip using contactless conductivity detection was manufactured applying different laser technologies. The channel structures were cut using a high speed CO_2 laser system. In addition, the influence of a excimer laser-based surface modification on the analytical performance of the microchip system was analysed. For sealing of the microfluidic structures high power diode laser transmission welding was used. The influence of different channel geometries was investigated for PMMA microchips.

Presenter

Robert Kohler is currently working on his PhD thesis on laser processes for electrode materials for lithium-ion batteries. His master thesis was focussed on the development of laser processing of polymeric microfluidic devices.

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Short Abstract:

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Abstract: Polymeric devices are of high interest for lab-on-a-chip devices due to their disposability and inexpensiveness allowing the use as disposable parts. Laser processing can be applied at many steps of the production process of a polymeric device, e.g. laser microcaving can be used for the rapid and cost-efficient manufacturing of metallic mould inserts for micro replication techniques. However, the focus of this study is on direct laser treatment and functionalization of polymers and their surfaces. Three different laser-based processes are discussed, the first being laser microstructuring, where defined surface geometries such as microfluidic channels or micro-sized holes are directly generated via CO2- or excimer laser radiation. The capabilities of different laser ablation processes with respect to achievable structure sizes, aspect ratios and processing speeds are discussed. The second process is laser-assisted surface modification allowing the formation of chemical patterns on polymeric surfaces, thereby modifying the wettability as well as enabling localized protein and cell adhesion. As third laser-based process laser transmission welding of microstructured and transparent polymeric devices and its technical capabilities are discussed. It is shown that the combination of these three laser process technologies can be applied for the flexible fabrication of functional micro devices.