Efficient manufacturing of undercut or vaulted nano-scaled surfaces

Presented here is a very simple process of manufacturing undercut respectively vaulted surfaces with nano-scaled structures. Especially for cell culture and implantologic purposes those structures are of great interest. Compared to conventional techniques like two-photon polymerization, this present invention enables the rapid processing of large surface areas.

Challenge

Micro- and nano-scaled surface structures are usually produced by excavating, constructing or transforming methods. Excavating methods include laser ablation and variations of etching techniques, while constructing methods comprise all sorts of (laser-aided) deposition or polymerization techniques (e.g. two-photon polymerization). Transforming methods include nanoimprinting as well as laser assisted direct imprint techniques.
Most of these methods are not capable of producing defined undercut or excavated structures. Even though undercut structures can be realized by lithographic techniques the process itself is very time consuming and labor-intensive. Although two-photon polymerization can be used for manufacturing a huge variety of structures (including excavated or undercut surface structures), the process can not be parallelized easily, thus limiting its process speed.
An easy, cost-effective and rapid way of producing net-like or undercut structures on biocompatible surfaces is especially interesting for cell culture or implantological purposes since different surface topologies can enhance or reduce cell proliferation, cell growth and cell adhesion. Regarding cell growth, it is well known that undercut (mushroom-shaped) surface structures are beneficial for the growth of neurons.

Our Solution

The presented technique for producing a nano-scaled periodic structure comprises a first step during which a "hard layer" is deposited on a substrate-like fused silica. This layer can for example be an oxide layer like SiOx. In a second step, a "soft layer" is applied on top of this first layer in the form of a polymer layer or a liquid film. This so-called Confinement calms down the surface during the actual treatment.
In order to actually produce the nanostructures the hard layer is illuminated by a pulsed laser. The laser has a wavelength for which the hard layer is absorbing and an intensity profile which is spacially modulated. This causes the ablation threshold of the hard layer to be exceeded at well defined areas and therefore its local separation from the substrate, thus creating the desired undercut structure. If the ablation threshold is not exceeded, no separation occurs.
Finally, the soft layer can be removed and an aftertreatment of the surface (e.g. tempering) can be conducted. Selection of illumination parameters allows realization of various structures, such as nets or bubble-like cavities.

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Advantages

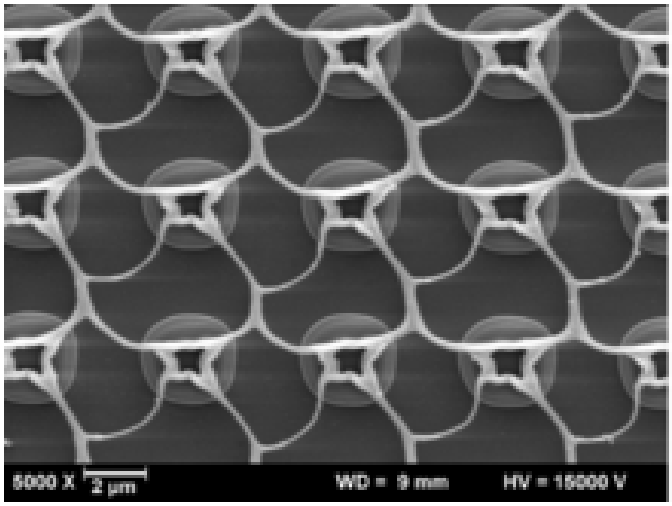
- Efficient method
  - Large-scale application
  - High throughput
  - Easy implementation
- Simple adjustment and control of the parameters
- Structuring of
  - transparent substrates (e.g. fused silica), or
  - opaque substrates (e.g. stainless steel, titanium), possible
- Various structures (bubbles, grids, ...) with different periodicities possible
- Proven significant impact on cell growth and adhesion

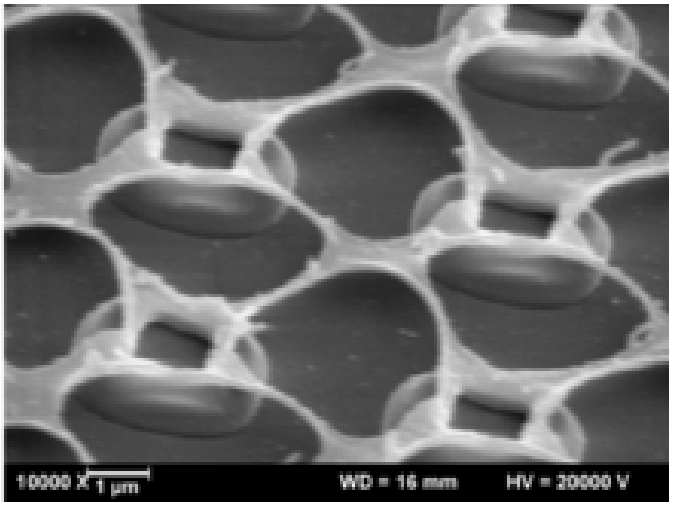
Applications

- Substrates for controlling cell growth and adhesion
- Micro- and nano fluidics (e.g. quartz nanochannels)
- Production of hydrophilic / hydrophobic surfaces
- Substrates for field amplification e.g. for surface-enhanced Raman spectroscopy (SERS)
- Templates for neuron-chip-interfaces
- Photonic chips
- Optical fibers with sub-wavelength diameter
- Silicon nano wires
- Ring resonators
- Photocatalysis

Development Status

A variety of different structures (among others on fused silica) has been produced. The surface structures itself can be controlled by a variety of parameters and include bubble- or tube-like cavities as well as self-supporting mesh wires and even nets that are completely detached from the substrate.





Example of a net-like surface with periodic structures under two different angles. At locations that hat been irradiated with lower laser intensity, the structure stays bonded to the substrate while at locations of high laser intensity it is burst open and separated. For the shown structure, the period length is approximately five micrometers. (Source: Weichenhain-Schriever, Ihlemann)

Patent Status

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