Photocatalytic Lithography with Atomic Layer Deposited TiO_2 Films to Tailor Biointerface Properties

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Heterogeneous substrates with different functionalities are key for the production of micro- and nanostructures in various applications. For instance, the biointerface in biosensors and lab-on-a-chip devices comprise bioreceptor molecules specifically bound to the biosensor areas to enable analyte detection, while an antifouling layer is deposited onto all other parts to prevent loss of the analyte by non-specific adsorption. Patterns of self-assembled monolayers (SAMs) are often used for these purposes, but a high-throughput production process that enables patterning on a large scale is not available.

In this work, direct photocatalytic lithography is used to generate a spatial pattern of an azido-containing SAM (N_3-SAM) for the specific binding of biomolecules, and a polyethylene glycol SAM (PEG-SAM) in other areas to avoid non-specific binding. First, the degradation of N_3-SAM is monitored as a function of UV exposure time for three different thicknesses. The 10 nm and 20 nm thick ALD TiO_2 films are found to remove the hydrophobic C-chains and azido groups already after 3 min of UV exposure time, while the 5 nm thick films present very limited photocatalytic activity. X-ray diffraction measurements and a wet etching procedure shows that the activity is related to the crystallinity of the material as-deposited.

Next, a biofunctional pattern is successfully created using thin ALD TiO_2 films (≤ 20 nm) that are anatase-rich as-deposited, a conventional lithography mask and a short exposure time up to 5 min to a simple 308 nm UV-lamp. The effectiveness of this approach is visualized by coupling fluorescently labelled antibodies to the patterns. A schematic illustration of the patterning procedure and the resulting patterns can be seen in figure 1. It is found that the technique is very sensitive to the exposure time. An exposure time of 3 min leads to printed features that are comparable to their actual size on the photomask, but an incomplete removal of the N_3-SAM in the exposed areas due to the influence of the soda lime glass mask on the irradiation. A longer exposure time of 5 min on the other hand, can successfully remove all N_3-SAM from the exposed areas but results in some broadening of the printed features.

The patterning technique offers the opportunity to use such TiO_2 coatings for patterning inside the microfluidic channels of a lab-on-a-chip device as ALD is known for the uniform and conformal coating in high-aspect ratio features. In addition, the technique can be implemented in a high-throughput production environment as additional processing steps are limited and short UV exposure times can be used.