Underwater femtosecond laser micromachining of porous transport layers for electrolysis applications

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Over the course of the last decades, the ongoing transition from fossil energy sources to renewable alternatives, such as solar and wind energy, has become the driving factor in the development of efficient short- and long-term energy storage solutions. Water electrolysis is one particularly promising process for reliable conversion of electrical energy with scalable storage capabilities. Due to significant energy losses during the production of hydrogen, various approaches for achieving enhanced conversion factors are subject to many studies that are aiming to improve the functionality of the inner layers in so-called electrolysis stacks. A central component of this stack is the porous transport layer (PTL), which has a significant impact on the overall efficiency. Typically made from sintered titanium powder, its electric conductivity and porous structure enable the flow of electric currents and process gases. To achieve better performances in terms of flow dynamics and electric contacting, laser-based micromachining of PTLs from thin titanium foils with a thickness of 25 µm was investigated. In this study, different technical approaches are combined for the generation of PTLs, which include femtosecond laser drilling under flowing water with MHz inter-burst modes and multi-beam process parallelization by a spatial light modulator. Successful fabrication of large PTLs for electrochemical testing purposes with dimensions of 50 mm × 50 mm and a total hole count of $2.25 \cdot 10^6$ are reported, corresponding to a hole density of roughly 900 / mm². With such densities and a minimal exit-hole diameter of around 8 µm, planar porosities over 16 % were achieved. Deionized water serves as the liquid medium during drilling, showing good results in terms of surface oxidation characteristics, as well as fast cooling and efficient removal of ablated particles. Figure 1 exemplary shows the homogenous transmission of light through the above-mentioned highly porous titanium foils and the magnified hole arrangement.

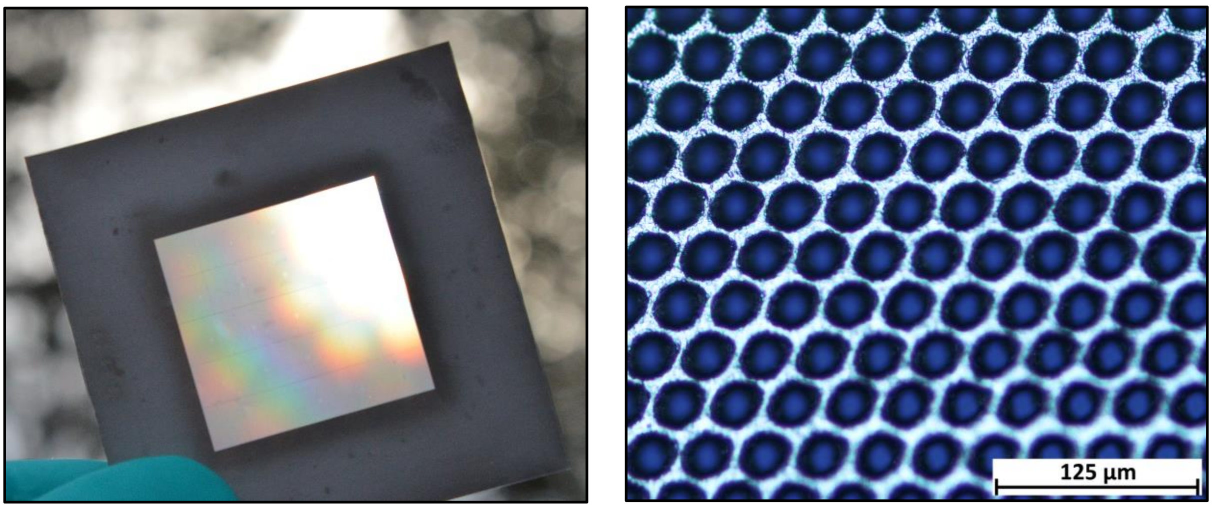

Figure 1: (left) Porous titanium foil with 571,320 laser drilled holes over 25 mm × 25 mm, used as test PTL. (right) Magnified front view of the hole pattern with Ø 8 µm exit hole diameter.