Characterization of enzymatically synthesized mesoporous TiO_2 thin films for low-cost photovoltaic cells by positron annihilation spectroscopy

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A new method is developed to produce mesoporous titania thin films at room temperature using the enzyme papain in a dip-coating procedure, providing low-cost TiO_2 thin films in a sustainable manner. Quartz crystal microbalance, positron annihilation Doppler broadening and lifetime spectroscopy, scanning electron microscopy, and X-ray diffraction are used to determine the deposition and structural properties of the films. As-deposited films have low densities of ~0.6 g/cm^3, contain small micropores and proteins, and exhibit corrugated surfaces [1]. Annealing at temperatures of 300 °C or higher for 4 h leads to the destruction and evaporation of most of the organic remains in the films, a thickness decrease of 50–60%, an increase in density, and a titania film of higher purity. Furthermore, thermal annealing leads to an increase in micropore size and a decrease in the concentration and size of vacancies [1], as deduced from positron annihilation lifetime spectroscopy (PALS) using the PLEPS spectrometer (NEPOMUC) and from 3γ-annihilation (ortho-Positronium, o-Ps) and Doppler broadening positron annihilation spectroscopy (DB-PAS) using the VEP facility.

Based on these mesoporous TiO_2 films, first test devices consisting of natural dye-sensitized solar cells are produced, that show photovoltaic activity and indicate possibilities for low-cost, accessible, organic production of solar cells.

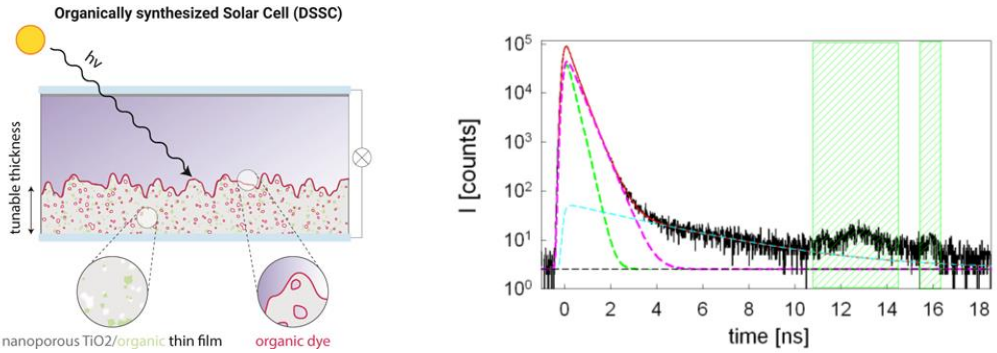

Fig.1. *Left*: Mesoporous titania thin films synthesized by biomineralization show high potential for application in Dye-Sensitized Solar Cells (DSSC) [1]. *Right*: PALS spectrum collected at 1 keV of a mesoporous TiO_2/papain nona-layer synthesized using papain and annealed at 450 °C for 4 h [1].

[1] E.F. van Amelrooij, H. Schut, W. Egger, M. Dickmann, C. Hugenschmidt, L. Mallée, U. Hanefeld, D.G.G. McMillan, S.W.H. Eijt, Advanced Sustainable Systems **4**, 2000003 (2020).