Sol-gel/ALD low temperature process : study of Al2O3 and codoped TiO2 nanostructures for photovoltaic applications

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Abstract: Solar energy remains one of the most common renewable energy sources. Using photovoltaic cells, the energy of sunlight can be converted into electricity. Unfortunately, one of the main drawbacks of Si solar cells is their limited efficiency absorption of long wavelength sunlight. To address this issue, special attention is given to the upconversion luminescence process in which the sequential absorption of two or more photons leads to the emission of light at shorter wavelength (Visible) than the excitation wavelength (Near Infra Red) that can be reabsorbed by the cell. In this context, the work of this PhD thesis aims to develop coated upconversion nanopowder based thin films to extend the spectral sensitivity of solar cells to the NIR (Near Infra Red) spectrum.
The idea is to investigate the efficiency of a low temperature procedure to get an efficient upconversion emission that can be used to improve the performance of Si solar cells. The structural, morphological and composition properties after every step of the proposed approach are examined in details. For the nanopowder based thin film, TiO2 is chosen as host material and Er3+/Yb3+, embedded as activator/sensitizer, to play the role of spectrum modifier. This nanopowder based thin film is formed through an optimization of the dispersion (pH, ultrasonication) and deposition (spin coating parameters) steps of the elaborated upconversion nanopowder. The Atomic Layer Deposition (ALD) layer of Al2O3 material followed by thermal treatment is used as an important tool for Si passivation through defects reducing. In addition, its potential application as a barrier from the surrounding environment helps to avoid the supressing of luminescence. The influence of thickness layer and thermal treatment on upconversion luminescence and structural properties of the nanopowder-based films are studied. It is concluded that ALD reinforced nanopowder thin films retained the original functionality of the nanopowder related to upconversion phenomenon. Interestingly, by tuning the thickness of the coating layer, enhancement by 98% of the green upconversion emission can be obtained, it is proved that Al2O3 acts as a barrier to decrease the quenching of luminescence and promote the light absorption. Furthermore, the effect of ALD coating and thermal treatment on adhesion and hardness of the coated nanopowder based films is investigated. The combination of the

common steps used for enhancing electrical properties with good luminescence and mechanical properties makes these films more attractive.