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## Synthesis of advanced nanomaterials for Energy Applications by Laser Pyrolysis

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Laser pyrolysis is an effective method to synthesize a variety of oxide and non-oxide nanoparticles such as SiC, Si, TiO<sub>2</sub>, etc. This paper will present one example each of oxide and non-oxide materials being studied in our labs, describing both their synthesis methods and applications. First, we will discuss silicon and silicon alloy core-shell nanoparticles and their performance as anode materials in Li-ion batteries. Next we will cover TiO<sub>2</sub>-carbon nanocomposites as active materials in perovskite solar cells.

Due to increasing demand in energy storage, much attention has been paid to Si as an anode material in Li-Ion batteries because of its theoretical capacity (3579 mAh/g in the Li<sub>15</sub>Si<sub>4</sub> alloy vs 372 mAh/g for graphitic carbon). However, silicon suffers several drawbacks, including rapid pulverization and continuous ripening of the solid-electrolyte interphase, limiting its use. Nanostructuring and protection of silicon by a carbon coating are proven methods to improve the behavior of the silicon-based anodes [1]. We will present the development of a two stage laser pyrolysis reactor, wherein the continuous synthesis of silicon-carbon core-shell nanoparticles was achieved. That is, there are no intermediate manipulations between the synthesis of the core (from silane precursor) and the shell (from ethylene) [2]. The protective influence of the carbon coating is clearly seen by impedance spectroscopy. Another strategy to enhance the performance and lifetime of Si-based anode materials is the use of Si alloys. By adding germane in the reaction zone, we were able to synthesize nanoparticles of Si<sub>x</sub>Ge<sub>1-x</sub> with x in the range 20-80. These particles also present a core@shell organization with a silicon shell at the surface of the alloy particle. Li-ion coin cells incorporating these materials demonstrate improved coulombic efficiency and stability [3].

In the context of transitioning to renewable energy sources, the development of efficient and cost-effective solar cells is a major objective in establishing an optimal energy mix. The 3<sup>rd</sup> generation of photovoltaic cells, which is now emergent, holds the promise of achieving higher efficiencies using earth abundant materials and facile processing techniques. Among them, perovskites present several significant advantages, including demonstrated power conversion efficiencies up to 25.2 % [4]. Titanium dioxide mesoporous layers play a crucial role as the significant light absorbing component in “sensitized” versions of these high efficiency devices. However, these layers are also responsible for charge trapping and recombination, representing two major loss mechanisms. As carbon nanostructures are good electron transporters, the use of TiO<sub>2</sub>/graphene nanocomposites with a clean interface between carbon and TiO<sub>2</sub> seems to be a promising strategy to reduce recombination phenomena and improve electron collection [5]. By using a mixture of graphene dispersed in the titania precursor (titaniumtetraisopropoxide), it was possible to obtain TiO<sub>2</sub>/graphene nanocomposites

where TiO<sub>2</sub> is strongly attached to the surface of graphene. Tests were conducted with a chlorine-doped methylammonium lead iodide (MAPI-Cl) reference perovskite deposited in a single-step, on TiO<sub>2</sub> porous electrodes composed of laser pyrolysis derived materials. The results show a better electron injection efficiency from the perovskite layer to the mesoporous graphene-doped TiO<sub>2</sub>. Larger photocurrents and smaller series resistances are also observed for these devices, under standard illumination in the presence of graphene. An increase in power conversion efficiency from 13,8 % à 15,3 % is achieved for perovskite solar cells containing graphene in the mesoporous layer, demonstrating the benefit of the laser pyrolysis process for the production of high quality electron transport layers [6].

[1] M.N. Obrovac, V.L. Chevrier. *Chem. Rev.*, **2014**, 114.

[2] J. Sourice, et al, *ACS Applied Materials and Interfaces* **2015**, 7(12), 6637-6644

[3] A. Desrues et al, batteries and super cap, accepted...

[4] [www.nrel.gov/ncpv/](http://www.nrel.gov/ncpv/)

[5] J. Wang, et al., *ACS Applied Materials & Interfaces* **2015**, 7, 51-56

[6] Belchi et al, *ACS omega*, **2019**, 4, 11906-11913