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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_2, 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_2-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 $Li_{15}Si_4$ 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. Nanostructuration 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 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_xGe_{1-x} 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 3rd 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_2/graphene nanocomposites with a clean interface between carbon and TiO_2 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_2/graphene nanocomposites where TiO_2 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_2 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_2. 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].

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