Ultrafast laser spectroscopy and composite materials for advanced photovoltaic and photonic applications

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ABSTRACT

Among other aspects the charge conversion efficiency and stability of energy harvesting materials is strongly related to the photo-induced processes that are responsible for the electric charge generation and transfer. For the development of efficient materials, devices, and operations, the most critical photo-induced processes are the charge carrier lifetimes (free electrons and holes), and the recombination losses (electron/hole recombination, exciton dissociation etc.). Namely, for achieving optimum performance, it remains a continuous scientific challenge to maximize the free charge carrier lifetimes, while reducing the recombination losses. In the ULMNP laboratory of IESL we employ ultrafast laser time-resolved transient absorption spectroscopy (TAS) in order to study these ultrafast relaxation phenomena on a temporal femtosecond (fs) to nanosecond (ns) scale, and provide valuable insights on the aforementioned critical parameters and the physical mechanisms of charge generation and transfer. Herein we present indicative findings on the improved carrier transport in perovskite solar cells (PSCs) as monitored by TAS [1]. In particular TAS relaxation times and decay dynamics are correlated with the structure and crystalline quality of the fabricated perovskite films, as well as, with the morphology of the employed hole transport layer (HTL) polymers. In addition, we demonstrate the development of perovskite films by means of laser-assisted crystallization, while correlating the charge carrier dynamics with the employed crystallization conditions [2]. It is concluded that TAS is a benchmark technique for the understanding of charge carrier transport mechanisms in PSCs and constitutes a figure-of-merit tool towards their efficiency enhancement.

We present also recent developments on the synthesis and characterization of novel composite silver-based phosphate glasses for potential use in advanced photonic applications. At first, nonlinear laser imaging microscopy is employed in order to study the dynamics of second harmonic generation (SHG) in a series of silver iodide phosphate glasses [3]. Furthermore, we demonstrate the incorporation of all-inorganic lead halide perovskite patterns within phosphate glasses by means of simple and low-cost fabrication protocols. The resulted composite perovskite-glasses exhibit remarkably efficient and stable luminescent properties that render them suitable for state-of-the-art optoelectronic devices. Finally, on a similar manner, we encapsulate two dimensional (2D) structures of molybdenum disulfide (MoS_2) within silver-containing phosphate glasses. It is found that the interaction of MoS_2 phases with the silver nanoparticles of the glass results to the manipulation and significant enhancement of the excitonic emission of the developed 2D material heterojunctions. Based on these findings, these novel MoS_2 composite phosphate glasses are highly promising for being the main component of efficient light emitting diodes and light tuning photonic applications.

REFERENCES

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