Remarkable Nonlinear Optical Response of non van der Waals 2D Hematene and Magnetene Nanoplatelets Exfoliated from Mineral Ores Using a Green Synthesis Method for Ultrafast Photonic Applications

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Ultra-thin two-dimensional (2D) nanostructures, traditionally obtained from the cleavage of the weak interlayer van der Waals (vdW) forces, have been spotlighted over the last two decades, sparking a rapidly growing research interest for their potential applications. However, the application of vdW 2D materials in nanotechnology is hampered, inevitably, due to the lack of their stability under ambient conditions. As a result, the perspective to synthesize ultra-thin 2D sheets from non vdW bulk materials and study their physicochemical properties became very challenging, given their stability, easy processing, and abundance on earth. Until now, the preparation of non vdW 2D materials was regarded inaccessible due to the high surface energies and the lack of anisotropy in the 3D bonding network. [1] Unexpectedly, the recent progress in liquid phase exfoliation of covalent/ionic crystals has led to the exfoliation of a series of atomically thin non vdW layered nanostructures from naturally grown bulk metal minerals.

The 2D analogs of hematite and magnetite, called hematene and magnetene, constitute the two archetype 2D iron-ore non-vdW materials. [2,3] These nanostructures display exceptional magnetic and photo/electrocatalytic properties which are superior to those of their bulk counterparts due to quantum confinement and surface effects. [2,3] In addition, because of their interesting optoelectronic features, it is speculated that hematene and magnetene could be used for innovative photonic and optoelectronic devices. [2,3] However, such studies are still in their early stages, as investigations pertaining to the ultrafast nonlinear optical (NLO) properties of non-van der Waals 2D materials are rather scarce.

In this context, the present work constitutes the first systematic investigation, to the best of our knowledge, of the ultrafast NLO response (NLO absorption and refraction) and its temporal evolution in hematene and magnetene 2D nanostructures prepared via a green synthesis method and dispersed in water. More specifically, for the assessment of their ultrafast NLO response and its dynamics, Z-scan and optical Kerr effect (OKE) measurements were performed using 50 fs, 400 nm laser pulses. The results of the present work strongly suggest that hematene and magnetene can have applications in a wide range of photonic and optoelectronic applications.

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