Pressure-Modulated Luminescence and Phase Transitions in Functional Materials

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The continuous advancement of luminescent materials underpins innovation across fields such as photonics, optoelectronics, bioimaging, and sensing. In particular, lanthanide ions (e.g., Nd^{3+}, Eu^{3+}, Ho^{3+}) exhibit well-defined emission features, including hypersensitive transitions, which are highly responsive to variations in local symmetry and crystal field strength. This sensitivity makes them effective probes for tracking subtle structural modifications within a material's lattice [1].

The objective of this work is to establish a novel approach for identifying phase transformations based on intrinsic optical responses, eliminating the need for direct contact or invasive techniques. The method relies on luminescence signals from lanthanide dopants or changes in optical characteristics of the host matrix as indicators of structural transformation.

Experimental studies are performed under high-pressure conditions using a Diamond Anvil Cell (DAC), enabling access to pressure up to ~100 GPa. Owing to the optical transparency of diamond across a broad spectral range, in situ spectroscopic techniques, such as absorption, photoluminescence, excitation, and Raman measurements can be applied to monitor pressure-induced changes in real time [2,3]. Mechanical compression alters key structural parameters, including interatomic distances and lattice geometry, which may ultimately trigger phase transitions. Both reversible and irreversible transformations can occur, offering distinct functional opportunities. Reversible changes may be exploited for pressure sensing applications (e.g., optical manometry), whereas irreversible transitions can yield new material phases with enhanced luminescent efficiency or improved performance characteristics.

In addition, high-pressure synthesis routes based on hydraulic pressing (up to ~30 GPa) allow for the production of bulk materials stabilized under extreme conditions. Such approaches expand the accessible materials space and support the development of advanced luminescent systems with potential utility in photonics, next-generation optoelectronic technologies, and sensing platforms.

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