Study of the Pressure Effects on Emission Spectra, Band Gap Energy and Crystal Structure of Nd^{3+}-doped Garnets for Pressure Sensors

Matter under extreme pressure conditions is the subject of multidisciplinary studies that join diverse fields as physics, chemistry, geology, material science, microbiology, or food technology. The high pressure technique applied to rare earth ions in crystalline garnets provides a unique insight into the electronic structure and luminescence properties of the optically active ion. This study is focused on the possible applications of Nd^{3+} luminescence in garnets in optical pressure sensing.

Nd^{3+}-doped $RE_3(AlGa)_5O_{12}$ (RE=Gd,Y,and Lu) crystalline garnets have been synthesized by a μ-pulling technique [1]. With the decrease of the RE atom size and the relative concentrations of Al^{3+} and Ga^{3+} ions, the chemical pressure related to the decreasing volumes of the $(Al,Ga)O_4$ tetrahedral, $(Al,Ga)O_6$ octahedral and REO_8 dodecahedral units drive the garnets toward a more compacted structure, while changing the band gap structure.

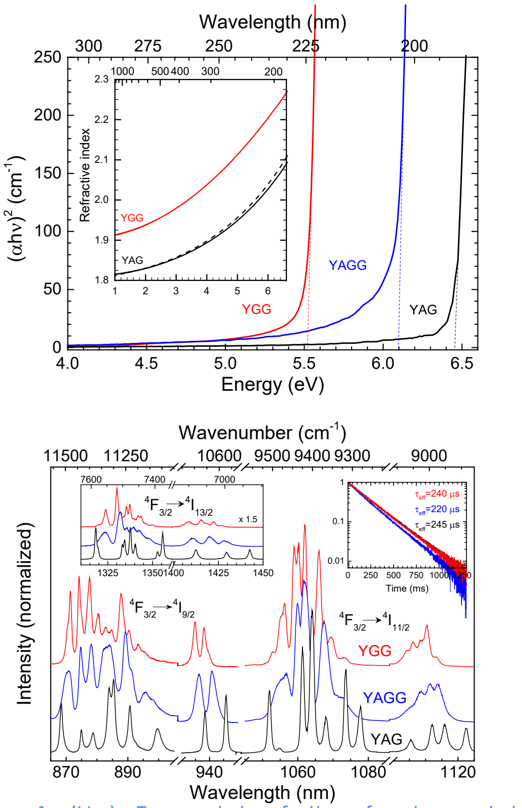

Fig. 1 (Up) Tauc-plot of the fundamental absorption edges of different garnets and (Bottom) emission spectra and lifetimes of YAG, YAGG and YGG garnets at ambient conditions.

The application of hydrostatic pressure in a diamond anvil cell (DAC) also increases the crystal-field strength felt by the RE^{3+} ions while decreases the orthorhombic distortionof the REO_8 local environment and varies the fundamental absorption edge of the crystals. These effects alter the absorption and emission properties of the Nd^{3+} ion measured in the near-infrared associated with the $^4F_{3/2}\rightarrow{}^4I_{9/2\text{-}13/2}$ transitions.

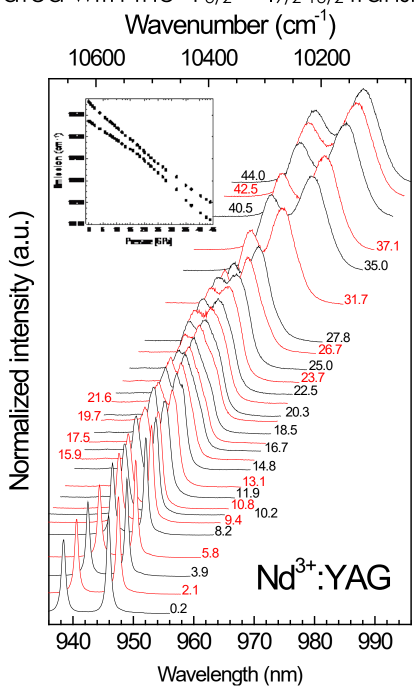

Fig. 2 $R_1,R_2\rightarrow Z_5$ emission spectra associated with the Nd^{3+} $^4F_{3/2}\rightarrow{}^4I_{9/2}$ transition as a function of pressure.

As an example, the pressure-induced shift of the emission spectrum corresponding to the near infrared $^4F_{3/2}\rightarrow{}^4I_{9/2}$ transition of Nd^{3+} ions in a YAG crystal was obtained from ambient conditions up to 44 GPa in order to test its suitability as an optical pressure sensor. The $R_1,R_2\rightarrow Z_5$ transitions are characterized and fit the requirements of an ideal optical pressure sensor.

References

[1] A. Yoshikawa, B.M. Epelbaum, K. Hasegawa, S.D. Durbin, T. Fukuda, J. Cryst. Growth 205, 305 (1999).

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