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High pressure Raman and photoluminescence studies of $In_xAl_{1-x}N$ (x= 0.72)

K. Filintoglou[1], J. Arvanitidis[1], D. Christofilos[2], S. Ves[1], G. A. Kourouklis[2], C. Bazioti[1], G. P. Dimitrakopulos[1], A. Adikimenakis[3] and A. Georgakilas[3]

[1]Physics Department, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[2]Chemical Engineering Dept., Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[3]Department of Physics, Microelectronics Research Group, University of Crete and IESL, FORTH, 71110 Heraklion, Greece

Abstract: $In_xAl_{1-x}N$ nanostructures are important for optoelectronic devices owing to their exceptional electronic properties. Their *x*-dependent bandgaps cover the spectral range from ultraviolet to near-infrared. Raman and photoluminescence (PL) spectroscopy are well-established, non-destructive techniques for the study of these systems. In this work, high pressure Raman and PL spectroscopies (λ_{exc}= 515 nm) are used to probe the pressure response of the vibrational and electronic properties of a ternary $In_{0.72}Al_{0.28}N$ thin film grown by MBE on a GaN/Al_2O_3 substrate. Hydrostatic pressure up to 7 GPa was applied by means of a diamond anvil cell using the 4:1 methanol-ethanol mixture as pressure transmitting medium and the ruby fluorescence technique for pressure calibration.

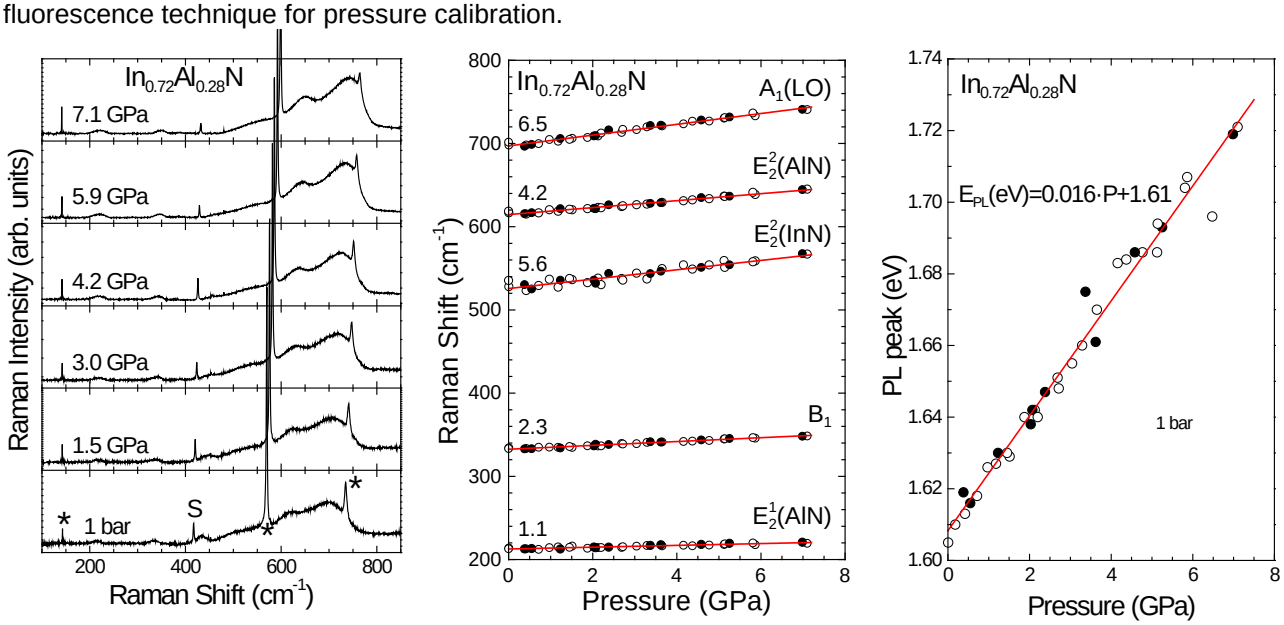

Figure 1. *Pressure evolution of the Raman spectra of the studied $In_xAl_{1-x}N$ film and pressure dependence of its Raman peak frequencies and PL peak energy.*

In the Raman spectrum of the $In_{0.72}Al_{0.28}N$ film (Figure 1), five broad Raman bands can be resolved at ambient conditions at 212 (E_2^1, AlN-like), 334 (B_1), 528 (E_2^2, InN-like), 611 (E_2^2, AlN-like), and 699 cm^{-1} (LO, asymmetric peak). In addition to those of the film, the narrow Raman peaks of the GaN buffer layer at 143 (E_2^1), 570 (E_2^2) and 735 cm^{-1} {A_1(LO)}, marked by asterisks in Figure 1, as well as that of the sapphire substrate at 417 cm^{-1} (A_{1g}), marked by "S", are also present. Pressure application causes the reversible hardening of all the Raman bands of the film with slopes 1.1-6.5 $cm^{-1}GPa^{-1}$. While the pressure slopes for the two E_2^2 peaks {5.4 (InN-like) and 4.5 $cm^{-1}GPa^{-1}$ (AlN-like)} are similar to those for the corresponding end members of the $In_xAl_{1-x}N$ series, the pressure slope for the LO peak (6.5 $cm^{-1}GPa^{-1}$) is higher than those for the end members. This may be attributed to pressure induced changes of the electron-phonon coupling and the resonance conditions. On the other hand, the obtained pressure slopes of the Raman peak frequencies of the GaN/Al_2O_3 substrate are in excellent agreement with the existing literature. The $In_{0.72}Al_{0.28}N$ PL peak appears at ~1.61 eV at ambient conditions, close to the absorption edge and in agreement with earlier studies. Its pressure slope is 16 meV·GPa^{-1}, suggesting a possible clustered arrangement of the In atoms.