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Phonon-Photon Coupling in Nitride Semiconductors

The III-V GaN (3.4 eV) and AlN (6.2 eV) semiconductor compound with a hexagonal structure exhibits a large bandgap (as specified in brackets), hence ideal systems to explore the phonon-polariton coupling by near-forward Raman scattering in the visible spectral range^{1,2}. Phonon-polaritons propagating in crystal volume offer the possibility of transferring information throughout matter (via phonons) at high (photon-like) velocity and tunable frequency/wavelength in the far-infrared. However, from the phonon-polariton Raman cross section, the phonon and photon advantages seem mutually exclusive. Either the phonon-polaritons are fast (photon-like) but hardly supported by the lattice (not phonon-like), or they are well supported by the lattice (testified by a high Raman efficiency) but slow (not photon-like). An optimal phonon-photon coupling has been recently evidenced in GaN³ and is currently searched for in AlN (in progress) by near-forward Raman scattering across parallel crystal faces with in-plane singular c-axis. Two accessible phonons, i.e., the ordinary A_1 and E_1 ones, plus two refractive indices, i.e., the ordinary and extraordinary ones, generate various phonon-polariton candidates. Notably, in perfect forward Raman scattering and in crossed polarizations of the incident (IIC) and scattered lights, which, altogether, maximizes the transferred wavevector to the crystal at minimum scattering angle, a fast GaN phonon-polariton, stemming from the bottleneck of the E_1 dispersion on entry to the deep photon-like regime, is activated. It is well supported by the lattice since its Raman signal is strong and sharp, enhanced by multi-reflection of the laser beam between crystal faces at near-normal incidence. This fast Raman-enhanced phonon-polariton is interesting for infrared-photonics in that it cumulates the advantages of a photon (speed) and of a phonon (Raman intensity). Besides, it commutates from a phonon-polariton to a phonon by deviating from normal incidence or by permuting the incident and scattered polarizations, with potential applications as a vibrational/optical switch. A replication of such fast phonon-polaritons for AlN is currently under research.

References

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