Abstract

Due to their simple structure, the zincblende $A_{1-x}B_xC$ semiconductor alloys (zb-SCA) set a benchmark to explore how physical properties are impacted by disorder. A longstanding controversy was whether the lattice dynamics (phonons), governed by the bond force constant, *i.e.*, a local physical property, is "blind" to the alloy disorder or actually "sees" it. Over the past two decades, my team introduced the percolation model (PM) that distinguishes between like bonds depending on whether they vibrate in *homo* or *hetero* environments (1-bond→2-phonon scheme). So far, the PM seems to apply universally among zb-SCA, and hence would solve the controversy in favor of the second scenario.

However, the PM-situation is not so clear for the III-V zb-$GaAs_{1-x}P_x$ alloy despite its phonon behavior was extensively studied since the 1960's, yet remaining a subject of debate to this day. Here we take advantage of novel and abundant IR-ellipsometry recently published by Zollner *et al*. on this system, nicely made available to us, to evaluate objectively the relative bias and merits of the historical cluster model (CM) and of the novel percolation model (PM) successively used – in several variants – to explain the vibration spectra of this paradigmatic system. Our evaluation is conclusive, in the positive sense for the PM, further supporting the universality of the PM.

Our next ambition is to complete in the main lines a PM-based taxonomy of high-pressure vibration spectra of zb-SCA. It is a matter to clarify how a zb-SCA, seen by each bond species in terms of a "*homo/hetero*" composite at the unusual mesoscopic scale from the angle of the PM, behaves on approach to a pressure-induced structural transition. For doing so, we focus on the II-VI zb-$Cd_{1-x}Zn_xTe$ alloy as the last sensitive pending case.

One prerequisite is to clarify the vibration spectra of $Cd_{1-x}Zn_xTe$ at ambient pressure, a highly-compact one in fact. The compacity favors the coupling of polar optic modes in both the transverse and longitudinal symmetries via the related ($E_{L,T}$) long-wave electric fields. The E_L-coupling achieves maximum in the Zn-dilute limit leaving the impression of a unique {Cd-Te,Zn-Te}-mixed longitudinal optic (LO) phonon across most of the composition domain. However, the purely-mechanical transverse optic (PM-TO) phonons, that hardly couple, reveal an underlying PM-type 3-mode {1×(Cd-Te),2×(Zn-Te)} fine structure that distinguishes between Zn-Te vibrations in Zn- and Cd-like environments up to second neighbors. Further refinement arises by exploring the phonon-polariton (polar-TO) regime at large Zn content. On reducing the scattering angle, the E_T-coupling develops into a sequential softening of phonon-polaritons from ZnTe- down to CdTe-like ones, which transiently unveils a bimodal pattern behind the Cd-Te signal. Altogether, this results in a (rare) canonical 4-mode {2×(Cd-Te),2×(Zn-Te)} PM-pattern for $Cd_{1-x}Zn_xTe$, *i.e.*, a close II-VI replica of the twin III-V $In_{1-x}Ga_xAs$.

At large Zn content the PM-TO Zn-Te Raman signal of $Cd_{1-x}Zn_xTe$ splits in two, distinguishing between *homo* and *hetero* environments, as explained by the PM. This offers the possibility to explore experimentally the pressure-induced convergence of the PM-type Raman doublet due to a matrix-like bond in a zb-SCA. The convergence proceeds via crossing into a genuine doublet inversion post resonance, governed by the free mechanical coupling of oscillators at the resonance. This deviates from the achievement of a "phonon exceptional point" manifesting the interruption of crossing at the resonance, earlier observed with similar bonds dispersed in chains. Different convergence scenarios for matrix-like bonds and bonds dispersed in chains endorse in a new light our view that the lattice dynamics of the zb-SCA basically falls into the scope of percolation. A PM-based taxonomy of high-pressure Raman spectra of zb-SCA is accordingly outlined.