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Exciton-phonon interaction in AlGaN ternary alloys

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In III-nitrides, Coulomb interaction between electrons and electric field associated with the longitudinal-optical (LO) phonons (Fröhlich interaction) is strong because of their ionic nature [1]. The electron-phonon interaction plays a significant role in optical and electrical properties of III-nitride devices. The electron-phonon interaction can be observed as phonon replicas of exciton emission, and the exciton-phonon interaction has been particularly studied in binary AlN and GaN as well as in InGaN/GaN, GaN/AlGaN and AlGaN/AlN quantum wells [2-5]. In this work, we study the exciton-phonon interaction in $Al_xGa_{1-x}N$ ternary alloys with various Al compositions x.

C-plane $Al_xGa_{1-x}N$ layers were grown on sapphire or SiC (0001) substrates using AlN buffer layers by MOVPE. Photoluminescence of the $Al_xGa_{1-x}N$ layers was measured at 9 K. Figure 1 shows a PL spectrum of an $Al_xGa_{1-x}N$ layer with $x = 0.85$. The main peak at 5.593 eV can be assigned to the exciton emission. At the low energy side, shoulder peaks due to the LO phonon replicas are observed. The emission peaks are deconvoluted using a multiple Gaussian fitting function as shown by dotted lines in Fig. 1. In a Franck-Condon approximation [6], the distribution of their intensities depends on the exciton-phonon coupling strength, which is described by Huang-Rhys (S) factor, and the emission intensities of the main emission peak (I_0) and the nth phonon replica (I_n) are related by $I_n = I_0(S^n/n!)$. The S factor of the $Al_xGa_{1-x}N$ layer with $x = 0.85$ was estimated to be 0.35.

Figure 2 shows the S factors of the $Al_xGa_{1-x}N$ layers as a function of Al composition x. The S factors of the $Al_xGa_{1-x}N$ ternary alloys are larger than binary GaN ($S = 0.017$) and AlN ($S = 0.056$), indicating a stronger exciton-phonon interaction. A non-linear trend of S factor with composition is observed. This result implies that the exciton-phonon coupling strength in the $Al_xGa_{1-x}N$ ternary alloys is influenced by alloy broadening and/or compositional fluctuation.

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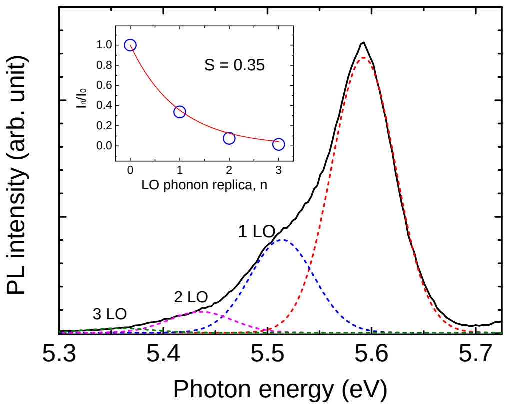

Fig. 1. PL spectrum of $Al_xGa_{1-x}N$ layer with $x = 0.85$ at 9 K. Inset shows the normalized intensities of nth phonon replicas with respect to the main peak (I_n/I_0).

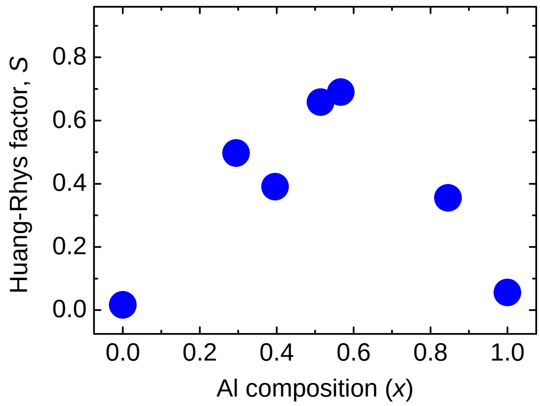

Fig. 2. Huang-Rhys (S) factor of $Al_xGa_{1-x}N$ layers as a function of Al compositions x.