Temperature behavior of the zero-phonon line of vanadium photoluminescence in $SrTiO_3$:V crystal

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Strontium titanate ($SrTiO_3$) is a model ABO_3 perovskite-type oxide with highly polarizable structure and soft TO phonon modes. However, $SrTiO_3$ crystals remain in paraelectric phase down to the lowest temperatures because transition to ferroelectric phase is suppressed by quantum effects. Very unusual and large temperature shift of the zero-phonon R-line was observed in the emission spectra of photoluminescence of Cr^{3+} and Mn^{4+} impurity ions ($3d^3$ electron configuration) substituted for octahedral coordinated Ti^{4+} ions in $SrTiO_3$:Cr and $SrTiO_3$:Mn crystals, respectively [1, 2]. Besides, this temperature shift was found to be proportional to the reciprocal permittivity of $SrTiO_3$ crystals and to the square of temperature-dependent TO_1 soft phonon mode frequency below the temperature of structural phase transition from the cubic to tetragonal phase in the vicinity of 105 K. At the same time, the R-line temperature shift occurs in the case of Cr^{3+} and Mn^{4+} ions in the opposite direction. Better understanding of these effects that are very unusual in the spectroscopy of transition metal impurity ions in ionic crystals requires an analysis of temperature behavior of zero-phonon emission lines for other impurity ions with different $3d^n$ electron configuration in $SrTiO_3$ crystals.

Recently we have found structured photoluminescence in the near infrared spectral region in the slightly vanadium doped $SrTiO_3$ single crystals that at low temperatures consisted of a pronounced zero-phonon line near 1157 nm accompanied by well developed vibrational sidebands. We suppose that this photoluminescence originates from V^{3+} ions ($3d^2$ electron configuration) substituted for Ti^{4+} ions in $SrTiO_3$:V crystal. Present detailed analysis of emission spectra at temperatures between 4.2 and 300 K showed an unusually large temperature shift of the zero-phonon line for studied photoluminescence of $SrTiO_3$:V crystal as well. The origin of the observed line shift to lower energy side with increasing temperature will be discussed taking into consideration structure of vanadium impurity center in $SrTiO_3$:V crystal and the specificity of impurity-lattice interaction in ABO_3 perovskite-type oxides with soft TO phonon modes.

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