Advanced $Cd_{1-x}Mn_xTe:Fe^{2+}$ semiconductor crystals for IR applications

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Crystals of solid solution $Cd_{1-x}Mn_xTe$ are promising materials for tunable laser sources emitting in the middle infrared range [1] as well as for ionizing radiation detectors [2]. At Mn concentrations x~0.05 the crystals may be used as radiation detectors. At higher concentrations of Mn, from x=0.1 up to x=0.76 the crystals doped with iron (active impurity) are of interest as active elements of tunable mid-IR lasers in the region 3-5 μm. $Cd_{1-x}Mn_xTe$ solid solutions have several advantages comparing with another $A^{II}B^{VI}$ compounds, including: the better lattice strengthening and mechanical stability, a wide bandgap tuning in the range 1.7-2.2 eV due to the strong compositional influence of Mn [2], high resistivity, well electron transport properties, near-unity segregation coefficient of Mn, etc. The latter property has a positive effect on the homogeneity of electrical and optical properties of grown crystals. The host crystal field forms such an energy spectrum of iron dopant ions that the resulting mid-IR band of luminescence and the optical gain are exhibited at longest wavelengths among all known host $A^{II}B^{VI}$ binary compounds and their solid solutions [1]. The main objective of our work was to investigate the compositional distribution, presence and nature of inclusions in the Fe-doped $Cd_{1-x}Mn_xTe$ solid solutions grown by high-pressure Bridgman method, and determine the optical properties of these crystals.

We have grown $Cd_{1-x}Mn_xTe:Fe^{2+}$ crystals throughout the whole range of concentration (between x=0.09 to x=0.76), in which this compound can exist in the zinc blende structure. The concentration of Fe^{2+} impurity was the same ~10^{-3} wt.% in all studied samples. Absorption spectra in the mid-IR and visible ranges of the optical spectrum were studied. A theoretical model is considered that explains the observed red-shift of IR absorption and emission bands in the spectra of transition metal ions in solid solutions of semiconductor compounds. The model has been used for estimating the long-wavelength shift of luminescence bands in the spectra of semiconductor solid solutions with increasing concentration of $Cd_{1-x}Mn_xTe:Fe^{2+}$. The correlation between the solid solution $Cd_{1-x}Mn_xTe$ composition, structural properties and the maxima positions of the Fe^{2+} ions absorption/emission spectra was found. Obtained results can be used for prediction of lasing range for $Cd_{1-x}Mn_xTe:Fe^{2+}$ active material in all range of possible Mn concentrations. The possibility of obtaining nonselective lasing from $Cd_{1-x}Mn_xTe:Fe^{2+}$ active material under 77 K temperature using an Er:YAG laser as a pumping source with a 2.94 μm wavelength has also been demonstrated. Optical pumping was carried out in pulsed mode with a pulse duration of 100 ns and 150 μs.

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References

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