Hydride Vapor Phase Epitaxial Growth of ZnSe on GaAs Substrates and Orientation-Patterned GaAs Templates for Nonlinear Optical Applications

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Zinc selenide (ZnSe) is attractive for numerous optical applications in the mid and long-wave infrared (MLWIR) spectrum ranging from solid state lasers to nonlinear optical (NLO) frequency conversion. Specifically, ZnSe doped with transition metals, like Cr^{2+} and Fe^{2+}, can act as an active laser material for tunable mid-IR lasers operating in the 2-5 μm wavelength region. Its relatively high nonlinear coefficient, d_{ij} ~ 47 pm/V, and large optical transmission window from 400 nm to 20 μm, makes it an excellent NLO material for frequency conversion in the MLWIR. In fact, ZnSe has been identified as one of the promising quasi-phase-matched (QPM) materials beyond GaAs and GaP [1]. Despite this, there are only a few reports on thick growth of orientation-patterned (OP) ZnSe structures that are limited to physical vapor transport (PVT) [2]. Another impediment is that OP-ZnSe templates do not currently exist for nonlinear frequency conversion due to the lack of large-area, single-crystal ZnSe substrates, as well as the lack of methodology needed to develop orientation patterns in ZnSe for QPM structures. One solution, however, to develop such ZnSe QPM structures comes in the form of GaAs. ZnSe has a small lattice mismatch of 0.26% with GaAs, a well-developed QPM material with a matured OP template processing technology. Thus, both the GaAs substrates and the OP-GaAs templates are expected to be good alternatives for ZnSe substrates for the epitaxial growth of ZnSe and OP-ZnSe using advanced, thick-epitaxial growth methods such as hydride vapor phase epitaxy (HVPE).

In this paper we will discuss our latest HVPE growth results of ZnSe on GaAs substrates and OP-GaAs templates towards developing OP-ZnSe QPM material for nonlinear frequency conversion devices. We have now achieved over 400 μm thick single crystalline ZnSe on GaAs (001) vicinal substrates with growth rates exceeding 100 μm/hr in a single growth run. The current growth rate is almost double the growth rate we reported in our recent publication [3]. We have further modified the growth conditions to extend the growth duration to 6 hours without exhausting the Zn source due to its high vapor pressure. A suite of material characterization techniques including SEM, HR-XRD, XTEM, and PL have been used to determine the quality of the HVPE grown material that will be presented to show that the crystalline and optical properties are comparable to that of commercially available ZnSe substrates. Growth on OP-GaAs templates resulted in ~ 115 μm thick OP-ZnSe QPM structures with the domains tapering off in the direction of [1-10] as the growth progressed. Further optimization of the growth conditions is warranted to achieve high domain fidelity QPM structures, however, the progress made so far shows that HVPE is a promising growth technique to realize such ZnSe QPM structures for frequency conversion in the MLWIR region.

References

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