Thermal properties of Cr:LiSAF/Sapphire bonded materials

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1. Introduction

Despite being a more efficient material for tunable CW lasers compared to Ti:sapphire, Cr:LiSAF-based lasers are not widely spread, mainly because their output power is limited by thermal problems due to low thermal conductivity of the gain medium. In order to improve the heat extraction inside Cr:LiSAF, aimed to use inter-layer surface activated bonding (il-SAB) technique which consist to bond the low thermal conductivity Cr:LiSAF (~2.5 W/mK) with a transparent sapphire with high thermal conductivity (~36 W/mK). In this work we presents the improvement of Cr:LiSAF thermal properties using room temperature bonding.

2. Bonding

Successful bonding between uncoated 5 mm diameter and 1 mm thick c-cut Cr:LiSAF and same dimension sapphire crystal was realized after surface activation using Fast Atom Bombardment (FAB) under high vacuum conditions (10^{-5} Pa). An inter-layer was deposit on the samples surface before FAB to simulate the anti-reflection coating which will be required to match the refractive index difference between the two materials. Additional sample composed of Cr:LiSAF sandwiched by two sapphires was bonded for thermal properties measurements.

3. Thermal properties measurements

First, thermal diffusivity was measured by laser flash lamp method for the bulk c-cut Cr:LiSAF crystal and for the bonded samples in the 22 to 100ºC range (Figure 1-a). The results show that the bonded materials present a 2.5-3 times higher thermal diffusivity (3.04 mm^2/s for the two layers material) compared to the bulk crystal. Higher dispersion of the measured values can be noticed for the sandwiched sample as transverse thermal diffusion can occurs due to the higher length/diameter (1/2) aspect ratio compared to the two layers one (3/10). Additionally, the specific heat at constant pressure (C_P) of Cr:LiSAF was measured in the -20 to 220ºC using Differential Scanning Calorimetry (DSC) method.

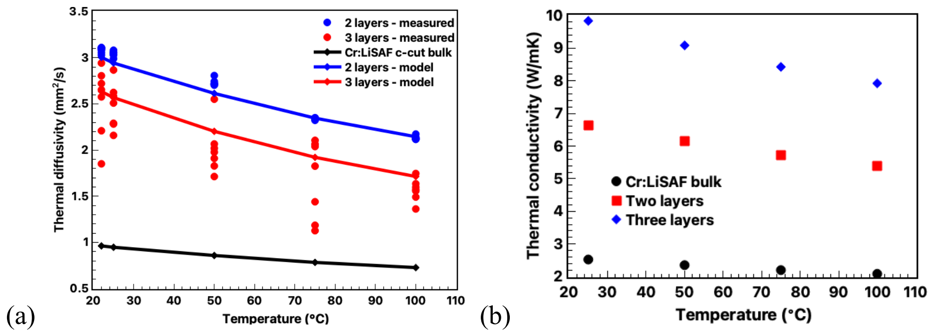

Fig. 1. Measured thermal diffusivity for bulk Cr:LiSAF and bonded samples (a) and calculated thermal conductivity of Cr:LiSAF bulk crystal and of bonded samples (b).

Then the difference between the calculated ideal thermal diffusivity and the measured value was estimated to be 3.7 % which is closed to the standard deviation of the measurement (3 %). In this case, the thermal resistance of the bonded interface between Cr:LiSAF and sapphire can be neglected. Finally, the thermal conductivity of the bonded material was calculated using the previous results in the 25-100ºC range (Figure 1-b). The results show a 4 times improvement from bulk (2.52 W/mK @25ºC) to sandwiched sample (9.84 W/mK @25ºC), highlighting the effect of the bonding on the thermal properties improvement.

4. Summary

We successfully demonstrated bonding between Cr:LiSAF and sapphire at room temperature. The thermal properties of the bulk and bonded samples were measured between 25 and 100ºC. A ~4-time improvement of thermal conductivity was demonstrated for bonded sample (9.84 W/mK) compared to bulk (2.52 W/mK). These results are promising for the power scaling of Cr:LiSAF using bonded laser chip.

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