Rare-earth doped crystals bonded on glass for optical quantum technologies platform.

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Abstract

Context:

Quantum memories are a key element for optical quantum communications. Quantum memories based on Rare-earth doped crystals-REC-offer long optical coherence lifetimes and stable operation at low temperature. Current devices suffer from a storage reduced efficiency related to the weak interaction between the light and the active ions. Bonding the REC on lower refractive index glass substrate and etching waveguides on the REC bonded membrane would allow building a photonic integrated platform where the increased interaction with the active ions will translate into better efficiency. Moreover, this highly scalable and versatile integrated photonic platform will allow developing new compact building blocks with extended functionalities such as fiber-integrated quantum memories, or microwave-to-optics photon transductors.

Bonding materials and issue

The REC under investigation is a Yttrium Orthosilicate crystal Y2SiO5 doped Er3+ (Er:YSO) elaborated from the melt by Czochralski (1-3). In order to be operated at very low temperature, bonding should be preferably obtained without any intermediate layer.

We investigate here surface preparations and bonding operating conditions in order to produce a bonded interface without alteration of both materials. Any alteration of YSO or glass at the interface should translate in propagation losses for the guided mode, thus hindering the expected performances.

Bonding without any intermediate bonding layer requires bonding at a temperature for which the mechanical properties of at least one of the two materials are modified. YSO is a very stable crystal elaborated at temperature above 2000∘C. Thus glass 'properties modification is considered, mainly glass viscosity allowing YSO crystal being set into the glass.

Experiments

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Both for bonding procedure and low temperature operation of the hybrid platform, both materials should have a coefficient of thermal expansion -CTE- as close as possible one from the other. The YSO CTE being = 7.4 x 10-6 ◦C-1, we have chosen the D 263 T Borosilicate glass from Schott, with a CTE= 7.2 x 10-6 ◦C-1.

Both surfaces are cleaned in ultra-sonic Isopropanol bath during 5 minutes. A thin amorphous SiO2 layer is deposited on the YSO surface by Plasma-Enhanced Chemical Vapor Deposition. Such a layer is expected allowing a smooth transition between the crystalline YSO structure and the amorphous glass structure. This SiO2 layer is activated by Ozone before being put down on the glass surface. Several different glass surface preparations and bonding conditions have been investigated. Bonding is operated under vacuum with a very low charge pressure. Related to the D263 transition temperature Tg=557◦C, bonding temperatures have been investigated in the 500-550◦C range.

Results and discussion

The different combinations of glass preparation / bonding conditions will be presented, pointing out the difficulty to limit bubbles formation in the glass. The origin of these bubbles will be discussed, related to the operating conditions. As a general trend, bubbles formation altering the glass close to the hybrid interface can be reduced by reducing the duration of the constant temperature plateau, according to the plateau's temperature.

Conclusion

Bonding YSO on glass is expected to build a photonic integrated platform for efficient interaction between light and active ions of Er-doped YSO, leading to improved efficiency. Bonding preparation and conditions have been investigated to reduce/suppress bubbles in the borosilicate glass close to the interface, which could generate optical losses of the guide mode.

(1) P. Goldner, A. Ferrier, and O. Guillot-Noël, Rare Earth-Doped Crystals for Quantum Information Processing, in Handbook on the Physics and Chemistry of Rare Earths, edited by J.-C. G. Bünzli and V. K. Pecharsky (Elsevier,Amsterdam, 2015), pp. 1–78.

(2) S. Welinsli, A.Tiranov, M. Businger, A.Ferrier, M.Afzelius and P.Goldner, Phys Rev X, 0.1060 (2020)

(3) Rakonjac et al., Sci. Adv.8, eabn3919 (2022)

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