Materials Research Bulletin 74 (2016) 96–97

Contents lists available at ScienceDirect

Materials Research Bulletin

journal homepage: www.elsevier.com/locate/matresbu

Short review

On the enhancement of Er^{3+} diffusion in $LiNbO_3$ crystals by Er^{3+}/Ti^{4+} co-diffusion

José Manuel Marques Martins de Almeida[a,b,*], Cinzia Sada[c]

[a] INESC-TEC, Rua do Campo Alegre, 687, Porto 4169-007, Portugal
[b] Department of Physics, School of Science and Technology, University of Trás-os-Montes e Alto Douro, PO. Box 1013, 5001-801 Vila Real, Portugal
[c] Dipartimento di Fisica e Astronomia G. Galilei, Università di Padova, Via Marzolo 8, 35131 Padova, Italy

ARTICLE INFO

Article history:
Received 9 June 2015
Received in revised form 24 September 2015
Accepted 7 October 2015
Available online xxx

Keywords:
A. Optical materials
A. Thin films
D. Diffusion

ABSTRACT

After carrying out a revision of the literature on the enhancement of Er^{3+} diffusion in $LiNbO_3$ crystals by Er^{3+}/Ti^{4+} co-diffusion and analyzing our own experimental results, we conclude that no reproducible results were reported, meaning that further research on this subject is necessary.

1. Published SIMS studies

The enhancement of the diffusion of erbium ions (Er^{3+}) in lithium niobate crystals ($LiNbO_3$) by simultaneous diffusion of titanium ions (Ti^{4+}) has been the investigated by several research groups. However a systematic revision of the literature on the subject in still missing.

It should be pointed that real diffusion coefficient can be determined only if real quantitative diffusion model is constructed. To our best knowledge, the diffusion model for the case of Er/Ti layer source is absent in the literature. Thus, only effective diffusion coefficient can be obtained.

A 15-fold increase of the diffusion coefficient of Er^{3+} in Z-cut $LiNbO_3$ was reported by Gill et al. [1]. They compared the diffusions coefficients of single layers of Er with the corresponding values for co-diffusion processes in Z-cut crystals at 1050 °C, for several values of the Ti initial thickness.

From secondary ion mass spectrometry (SIMS) and Rutherford backscattering spectrometry (RBS) data it was measured, for a particular Er / Ti multilayer structure, that the diffusion coefficient increases ~25 % for X-cut and ~30 % for Z-cut with respect to the Er single layer [2].

For the simultaneous diffusion of Er^{3+} with a 100 nm thick Ti thin film at 1100 °C, Salas-Montiel et al. [3], found an increase of the Er^{3+} diffusion coefficient by a factor of 7 in X-cut substrates when compared with the Er single-layer value published by Caccavale et al. [2].

A systematic SIMS study on Er^{3+}/Ti^{4+} co-diffusion in $LiNbO_3$ was published recently [4]. A set of Z-cut $LiNbO_3$ substrates were coated with Er and Ti thin metal films and, then, annealed at 1130 °C. The increase in the Er^{3+} diffusion coefficient by a factor of two when the diffusion occurs simultaneously with a 200 nm thick Ti film was measured. Moreover, Fig. 1 (extracted from [4]) shows a linearly increase of the Er^{3+} diffusion coefficient with the initial thickness of the Ti thin film.

A methodical experimental and theoretical study was presented by Zhang et al. [5]. The authors present the concentration profiles of Er^{3+} measured by SIMS, the temperature and crystal orientation being the same as in [4]. For the co-diffused crystals, the authors concluded from the dada that the Er^{3+} diffusion coefficient increases linearly with the initial thickness of the Ti thin film, as illustrated in Fig. 2 (extracted from [5]). The crystalline phase, OH^- absorption, Er^{3+} doping effect on refractive index and Li^+ composition in the Er^{3+}/Ti^{4+} co-doped region were also studied.

From Fig. 1, the diffusion coefficient obtained for the case of the Er^{3+} single layer, as measured in [4] is 0.064 $\mu m^2\,h^{-1}$, and the value is similar to that reported in [5], 0.0659 $\mu m^2\,h^{-1}$. However, the rate of increase of the diffusion coefficient calculated from Fig. 1 (from [4]) is approximately $3.0 \times 10^{-4}\,\mu m^2\,h^{-1}/nm$. The corresponding value shown in Fig. 2 (from [5]) is $6.405 \times 10^{-4}\,\mu m^2\,h^{-1}/nm$, a rate that is the double of the former value.

* Corresponding author at: INESC-TEC, Rua do Campo Alegre, 687, Porto 4169-007, Portugal. Fax: +351 259350480.
E-mail address: jmmma@utad.pt (J.M.M.M.d. Almeida).

http://dx.doi.org/10.1016/j.materresbull.2015.10.018
0025-5408/

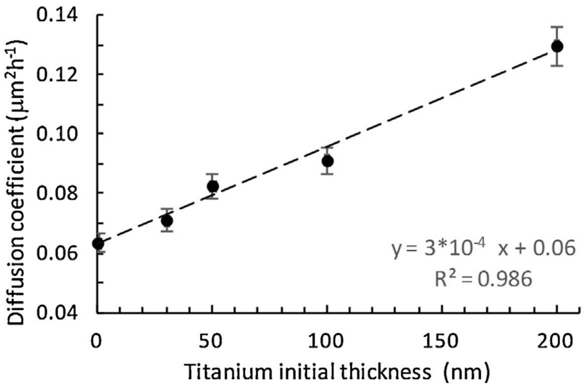

Fig. 1. Graph of the variation of the Er diffusion coefficient with the Ti initial film thickness. Linear fitting and regression coefficient. (Extracted from [4]).

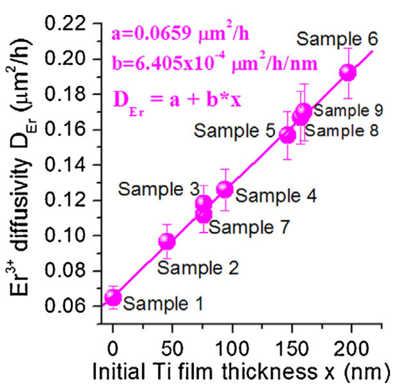

Fig. 2. Er^{3+} diffusivity at 1130 °C versus Ti-metal film thickness. Continuous line represents the linear fit (fitting expression is shown). (Extracted from [5]).

2. Conclusions

In conclusion, a revision of the literature on the promotion of the Er^{3+} diffusion to $LiNbO_3$ by simultaneous diffusion with Ti^{4+} was presented. In view of the findings, it must be concluded that further research on this subject is necessary. This letter brings a further insight into the topic of co-diffusion of Er^{3+}/Ti^{4+} ions into $LiNbO_3$.

Acknowledgements

This work was partially financed by the FCT—Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) within project UID/EEA/50014/2013.

References

[1] D.M. Gill, A. Judy, L. McCaughan, J.C. Wright, Appl. Phys. Lett. 60 (1992) 1067–1069.
[2] F. Caccavale, F. Segato, I. Mansour, J.M. Almeida, A.P. Leite, J. Mater. Res. 13 (1998) 1672–1678.
[3] R. Salas-Montiel, M.E. Solmaz, O. Eknoyan, C.K. Madsen, IEEE Photonics Technol. Lett. 22 (2010) 362–364.
[4] J.M.M.M. de Almeida, F. Marinho, D. Alexandre, C. Sada, IEEE Photonics Technol. Lett. 26 (2014) 1307–1309.
[5] D.-L. Zhang, Q. Zhang, W.-H. Wong, D.-Y. Yu, E.Y.-B. Pun, Mater. Res. Bull. 67 (2015) 126–133.