

Thermally stable antireflection coatings for active elements of $ZnMgSe:Cr^{2+}$-laser: preparation and properties

V.A.Khristyan, Yu.A.Zagoruiko, N.O.Kovalenko, P.V.Mateychenko, D.S.Sofronov

Institute for Single Crystals, STC "Institute for Single Crystals", National Academy of Sciences of Ukraine, 60 Lenin Ave., 61001 Kharkiv, Ukraine

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Oxide broad-band interference coatings are obtained by the method of photothermal treatment on the surface of active elements of $Zn_{1-x}Mg_xSe:Cr^{2+}$-laser. It is established that such antireflection coatings reduce the optical loss of the active element by 15–20 % within the whole of the working range of the radiation generation wavelengths, as well as within the wavelength region of optical pumping of lasers. The active elements with such coatings are thermally stable and withstand repeated thermal cycling without breaking. The optical transmittance in the range 20–150°C remains unchanged.

Методом фототермической обработки на поверхности активных элементов $Zn_{1-x}Mg_xSe:Cr^{2+}$-лазеров получены оксидные широкополосные интерференционные покрытия. Установлено, что такие антиотражающие покрытия позволяют снизить оптические потери на отражение активного элемента на 15–20 % в рабочем диапазоне длин волн генерации излучения, а также в области длин волн оптической накачки лазеров. Активные элементы с такими покрытиями термостабильны и выдерживают многократные термоциклирования без разрушения, а их оптическое пропускание в интервале 20–150°C остается практически неизменным.

1. Introduction

Binary and ternary semiconductor $A^{II}B^{VI}$ compounds doped with divalent ions of transition metals (Cr^{2+}, Fe^{2+}, Co^{2+}, etc.), represent a new class of active media for tunable mid-IR range [1–3]. Laser radiation of this wavelength range (2 to 5 μm) is required for diagnostic, therapeutic and surgical applications in medicine and cosmetology, for environmental monitoring with LIDAR systems, for optical communication channels, infrared countermeasures systems, and for other purposes. In particular, the efficient lasing was obtained for $ZnSe:Cr^{2+}$ crystals [3, 4] with tuning range 1.88–3.10 μm [3, 4] and $Zn_{1-x}Mg_xSe:Cr^{2+}$ crystals, with tuning range, shifted to longer wavelength side [5 – 7], respectively.

In the present study, to decrease the reflection losses of $Zn_{1-x}Mg_xSe:Cr^{2+}$-active elements, we obtained broad-band antireflection interference oxide coatings on the surface of such active elements, and investigated their optical characteristics in a wide temperature range. Such coatings were obtained on the surface of $Zn_{1-x}Mg_xSe:Cr^{2+}$ single crystals by the method of photothermal oxidation (PTO) of semiconductor crystals of $A^{II}B^{VI}$ group [8] earlier developed at the Institute for Single Crystals. To maintain the optical characteristics of samples unchanged, the temperature of the PTO process did not exceed 500°C. The operation characteristics of the active laser elements

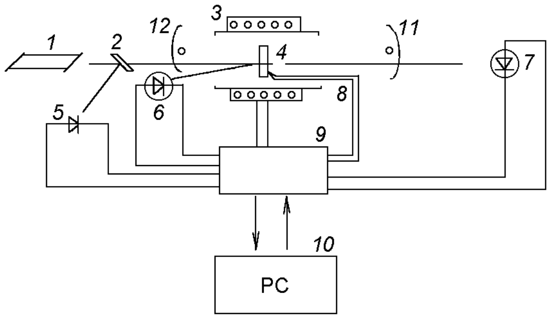

Fig. 1. Block diagram of the apparatus for photostimulated treatment of crystalline $A^{I}B^{VI}$ compounds: (*1*) low-intensity controlling laser, (*2*) beam splitter, (*3*) electric furnace, (*4*) oxidized sample, (*5*) photoreceiver for measurement of laser radiation source intensity, (*6*) photoreceiver for measurement of the intensity of laser radiation, reflected from the sample; (*7*) photoreceiver for measurement of the intensity of laser radiation transmitted through the sample; (*8*) thermocouple for measurement of the oxidized sample temperature, (*9*) MCU for preliminary treatment of analog signals, coupled with personal computer; (*10*) computer for visualization and storage of digital data; *11*, *12* — UV-lamps.

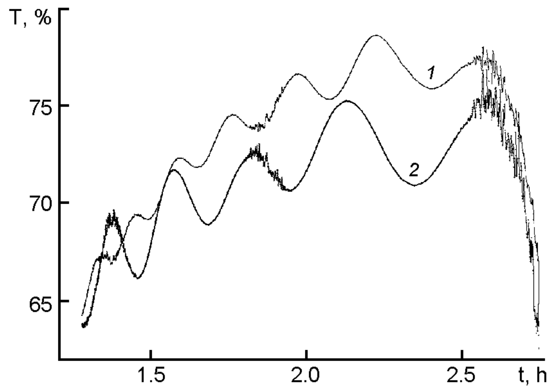

Fig. 2. Interference curves obtained during the growth of the oxide films on the surface of $ZnSe:Cr^{2+}$ and $Zn_{1-x}Mg_xSe:Cr^{2+}$ substrates.

$Zn_{1-x}Mg_xSe:Cr^{2+}$ with the antireflection coatings were compared with those of the active laser elements $ZnSe:Cr^{2+}$ which has been oxidized in the same conditions.

2. Results and discussion

The study was performed on oriented samples 15×8×10 mm^3, cut out of $Zn_{1-x}Mg_xSe:Cr^{2+}$ and $ZnSe:Cr^{2+}$ single crystals, grown by the vertical Bridgman method in graphite crucibles under an excess pressure of argon. After orientation and cutting, all samples were subjected to the standard procedure of mechanical treatment, including finish polishing.

The interference antireflection coatings on $Zn_{1-x}Mg_xSe:Cr^{2+}$ and $ZnSe:Cr^{2+}$ active elements were obtained by means of a setup for photostimulated treatment of crystals. The diagram of this setup is shown in Fig. 1. Analysis of the interference curves (Fig. 2) obtained during the growth of the oxide coatings on two different substrates under the same conditions of PTO allow to calculate the rate of the growth of ZnMgO films on $Zn_{1-x}Mg_xSe:Cr^{2+}$ substrate in comparison with the rate of the growth of ZnO film on $ZnSe:Cr^{2+}$ substrate. The rate of growth of the oxide film on the $Zn_{1-x}Mg_xSe:Cr^{2+}$ was found to be approximately by one and a half times slower than the one for $ZnSe:Cr^{2+}$.

For the active elements of $Zn_{1-x}Mg_xSe:Cr^{2+}$ with the interference oxide coatings the optical transmission spectra were measured in the band that match with the tuning range of lasing. Comparison of the spectra of

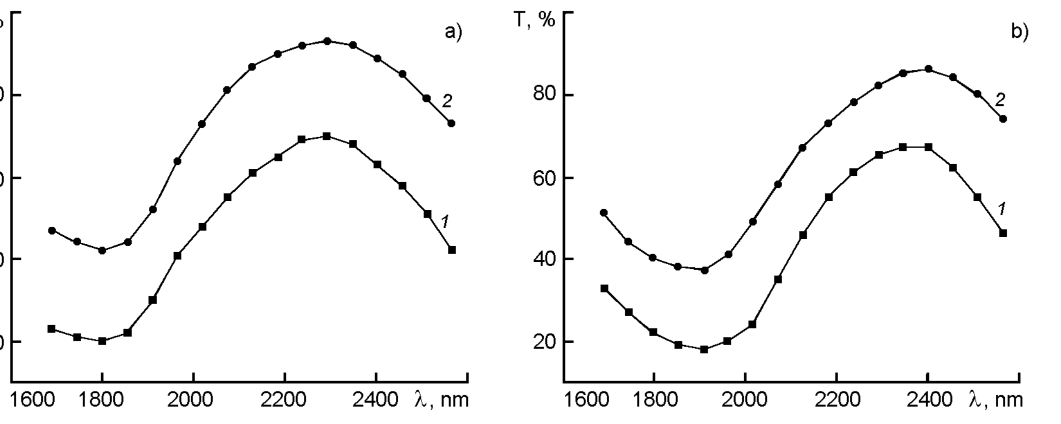

Fig. 3. The spectra of optical transmission of single crystals $ZnSe:Cr^{2}$ and $ZnMgSe:Cr^{2+}$: a) *1* — $ZnSe:Cr^{2+}$ initial; *2* — $ZnSe:Cr^{2+}$ after PTO. b) *1* — $ZnMgSe:Cr^{2+}$ initial; *2* — $ZnMgSe:Cr^{2+}$ after PTO.

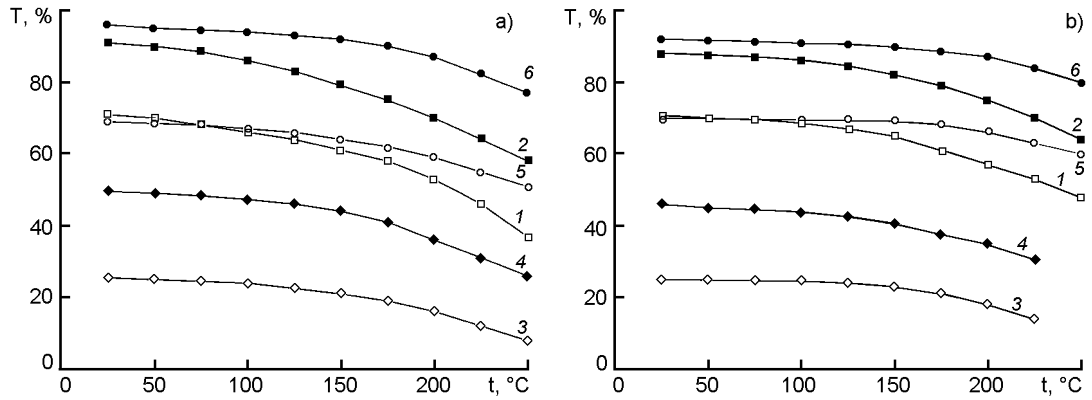

Fig. 4. Temperature dependences of the optical transmission of $ZnSe:Cr^{2+}$ (a) and $Zn_{1-x}Mg_xSe:Cr^{2+}$ (b) samples with antireflection oxide coatings (OC) and without coatings. These dependences were measured at different wavelengths: a) *1* — $ZnSe:Cr^{2+}$, λ = 2.3 μm; *2* — $ZnSe:Cr^{2+}$ with OC, λ = 2.3 μm; *3* — $ZnSe:Cr^{2+}$, λ = 1.8 μm; *4* — $ZnSe:Cr^{2+}$ with OC, λ = 1.8 μm; *5* — $ZnSe:Cr^{2+}$, λ = 1.06 μm; *6* — $ZnSe:Cr^{2+}$ with OC λ = 1.06 μm; b) *1* — $Zn_{1-x}Mg_xSe:Cr^{2+}$, λ = 2.46 μm; *2* — $Zn_{1-x}Mg_xSe:Cr^{2+}$ with OC λ = 2.46 μm; *3* — $Zn_{1-x}Mg_xSe:Cr^{2+}$, λ = 1.8 μm; *4* — $Zn_{1-x}Mg_xSe:Cr^{2+}$ with OC λ = 1.8 μm; *5* — $Zn_{1-x}Mg_xSe:Cr^{2+}$, λ = 1.06 μm; *6* — $Zn_{1-x}Mg_xSe:Cr^{2+}$ with OC λ = 1.06 μm.

$Zn_{1-x}Mg_xSe:Cr^{2+}$ active elements with the coating and without coating shows that in the generation band of $Zn_{1-x}Mg_xSe:Cr^{2+}$-laser the optical transmission of the former sample is by 17–20 % higher than that for the latter sample (Fig. 3).

As seen from the data of Fig. 4, in comparison with the optical transmission spectra of the samples $ZnSe:Cr^{2+}$, those of $Zn_{1-x}Mg_xSe:Cr^{2+}$ samples are almost constant in the temperature range from 20 to 150°C. Moreover, in the temperature range from 20 to 250°C the decrease of the optical transmission of $Zn_{1-x}Mg_xSe:Cr^{2+}$ samples is lower than the one for $ZnSe:Cr^{2+}$ samples.

It is established that the interference antireflection oxide are characterized by thermal stability and high adhesion to the surface of $Zn_{1-x}Mg_xSe:Cr^{2+}$ and withstand multiple thermal cycling (300 K–525 K–300 K) at a changing rate of temperature not less than 5 $K \cdot s^{-1}$.

3. Conclusion

Thus, the obtained results show both the reduction of the optical losses in $Zn_{1-x}Mg_xSe:Cr^{2+}$-lasers with antireflection oxide coatings and the possibility to use these lasers under hard temperature conditions. The antireflection oxide coatings on the surface of active elements make it possible to reduce optical losses within the whole of the lasing range.

References

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Термостабільні просвітлюючі покриття для активних елементів $ZnMgSe:Cr^{2+}$-лазерів; отримання і властивості

В.А.Христьян, Ю.А.Загоруйко, Н.О.Коваленко, П.В.Матейченко, Д.С.Софронов

Методом фототермічної обробки на поверхні активних елементів $ZnMgSe:Cr^{2+}$-лазерів отримано оксидні широкополосні інтерференційні покриття. Встановлено, що такі антивідбиваючі покриття дозволяють знизити оптичні втрати активного елемента на 15–20 % в робочому діапазоні довжин хвиль генерації випромінювання, а також в області довжин хвиль оптичної накачки лазерів. Активні елементи з такими покриттями термостабільні і витримують багаторазові термоциклювання без руйнування, а їх оптичне пропускання в інтервалі 20–150°C залишається практично незмінним.