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Optical and structural properties of $3CaO-2SiO_2$:Ce, $3CaF_2-2SiO_2$:Ce and $3Ca_xBa_{1-x}O-2SiO_2$:Ce (x=0, 0.5, 1) glasses

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Synthesis

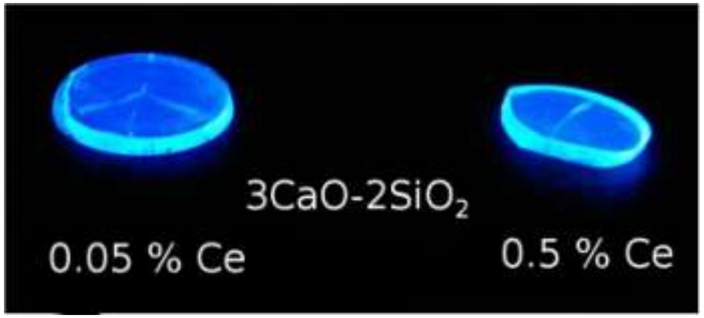
1. Obtaining $CaCO_3$, CaF_2 or $CaBa(CO_3)_2$ powders activated by Ce^{3+} ions by using coprecipitation method;

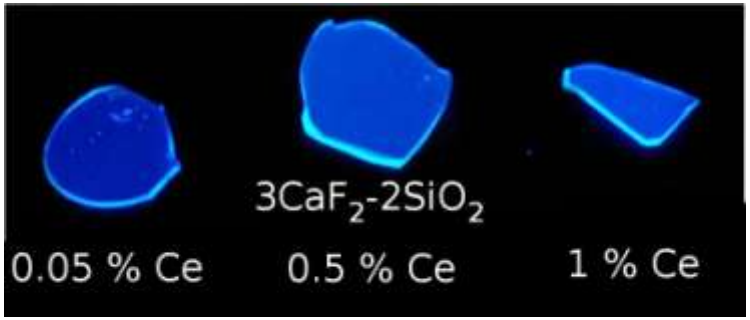
2. Obtaining SiO_2 gel by TEOS hydrolysis;

3. Introduction of $CaCO_3$, CaF_2 or $Ca_xBa_y(CO_3)_2$ powders into SiO_2 gel.

4. Drying on air at 80 C for 12-24 hours

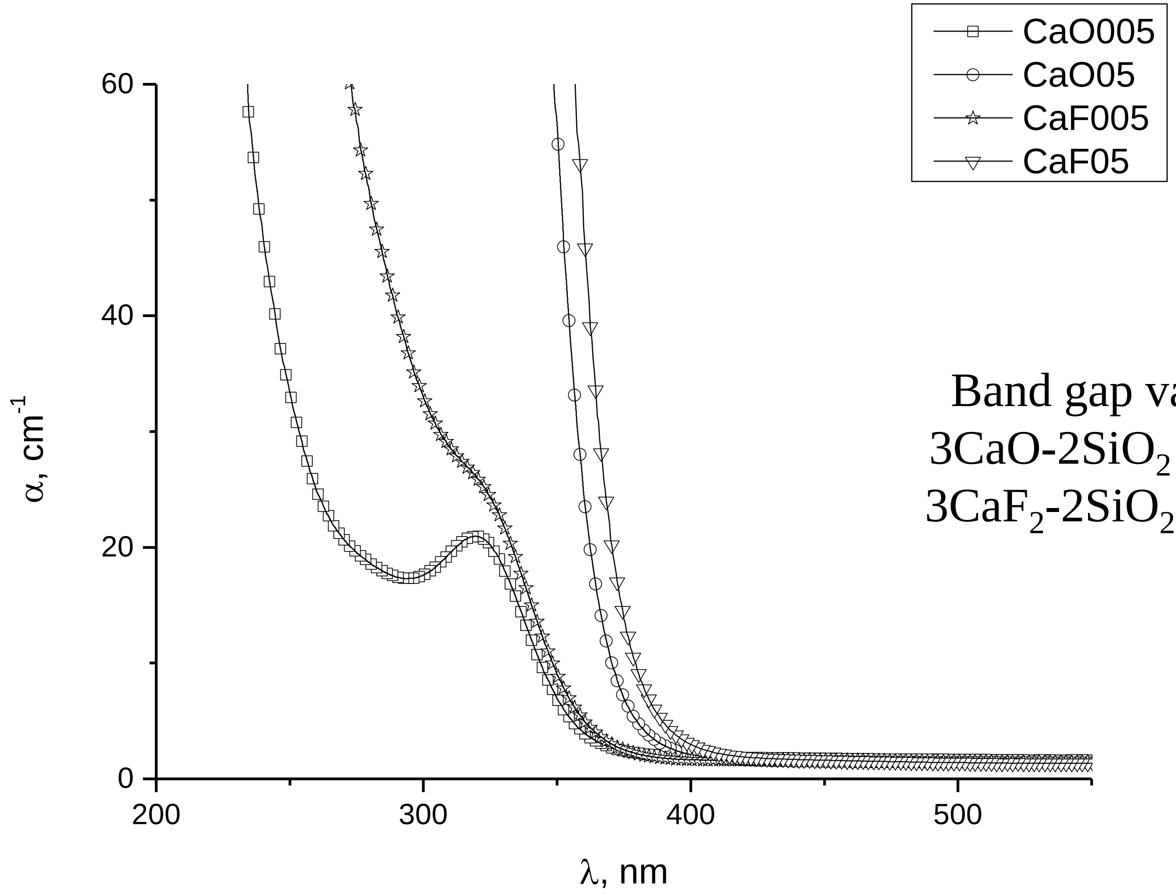
5. Melting in furnace





Samples glow under UV lamp (312 nm)

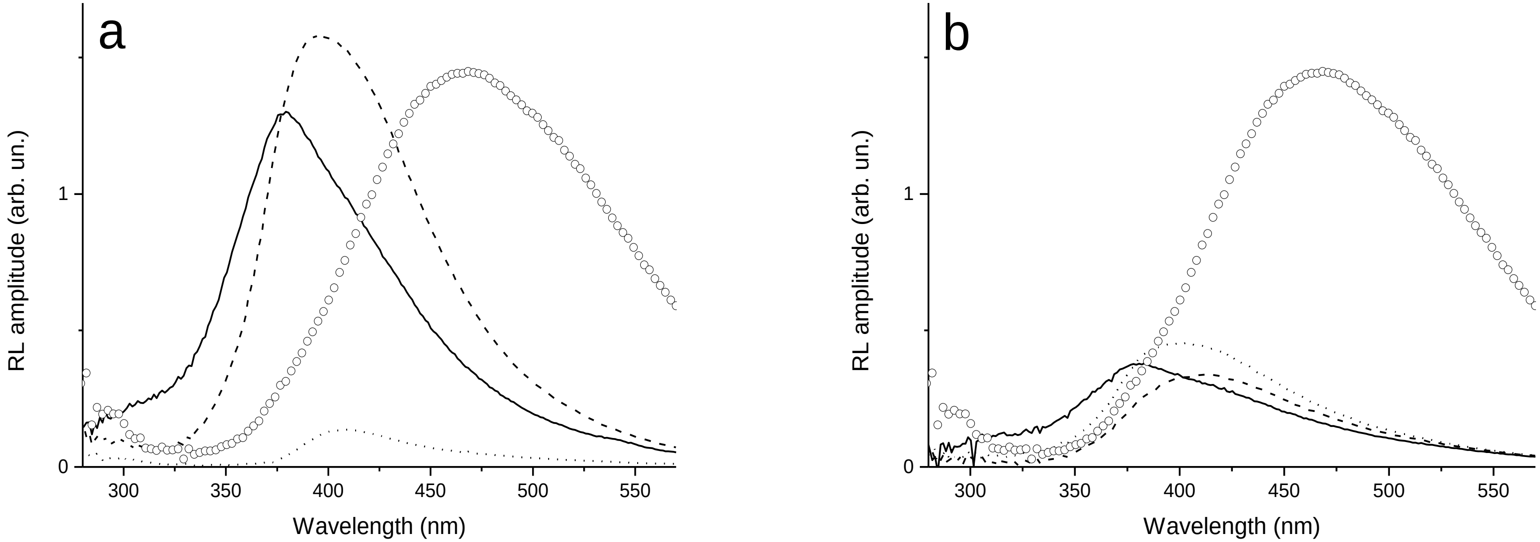
Absorption spectra of $3CaO\text{-}2SiO_2$ and $3CaF_2\text{-}2SiO_2$ glasses



Band gap values for:
$3CaO\text{-}2SiO_2$ – 4.67 eV
$3CaF_2\text{-}2SiO_2$ – 4.07 eV

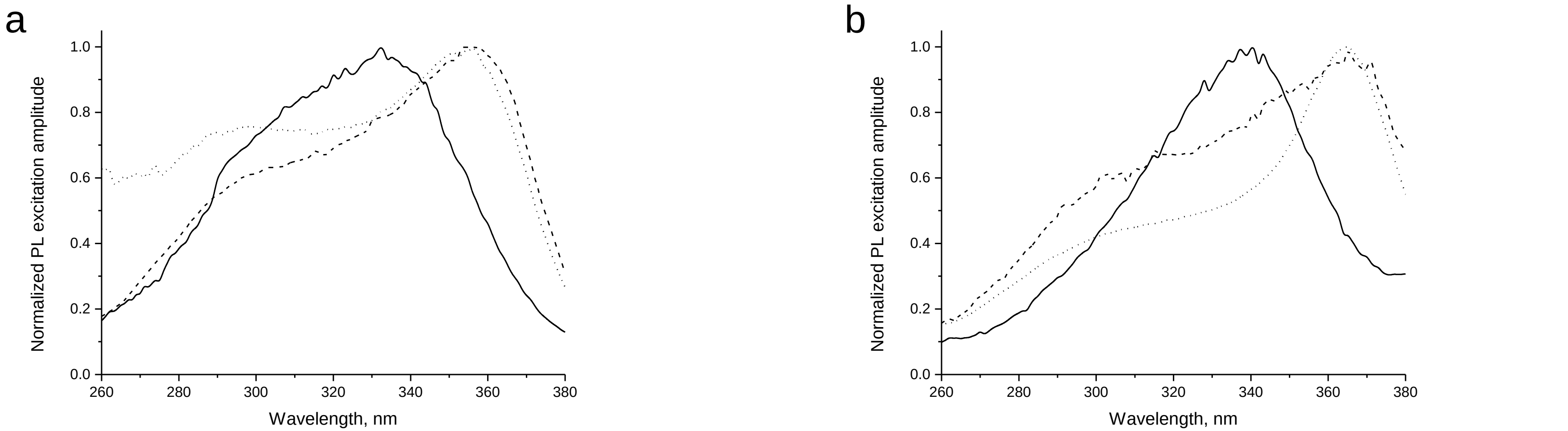
The absorption spectra for $3CaO\text{-}2SiO_2$ and $3CaF_2\text{-}2SiO_2$ glasses with 0.05 and 0.5 at. % of Ce^{3+} ions.

RL of the $3CaO\text{-}2SiO_2$:Ce and $3CaF_2\text{-}2SiO_2$:Ce glasses

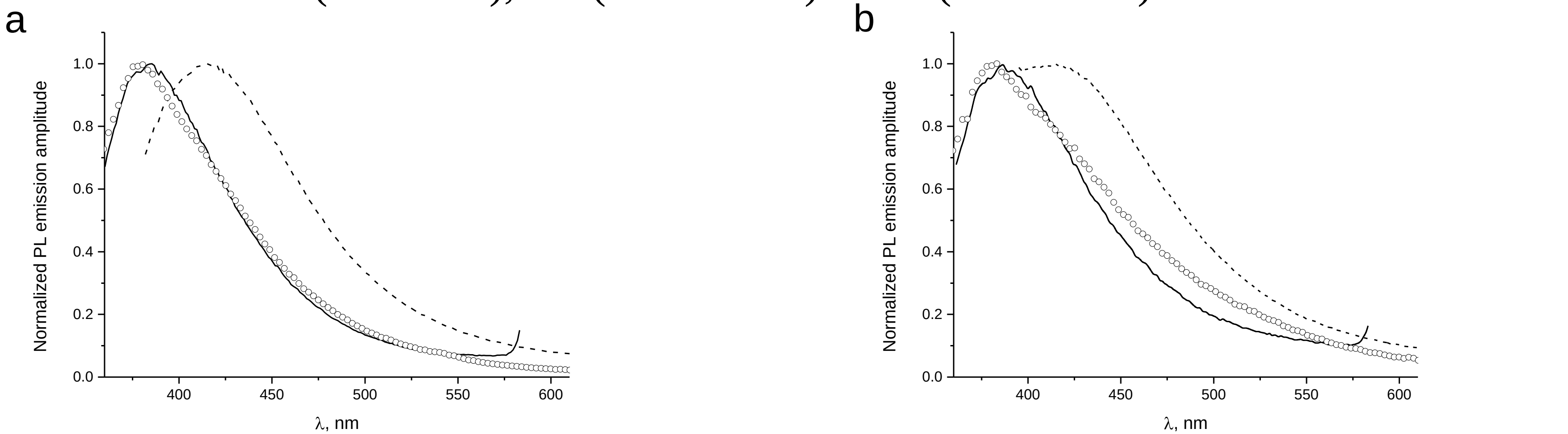


The RL spectra for investigated glasses with composition $3CaO\text{-}2SiO_2$ (a) and $3CaF_2\text{-}2SiO_2$ (b) with 0.05 (solid line), 0.5 (dashed line) and 1 (dotted line) at. % of Ce^{3+} ions in comparison with BGO (marked as circles, intensity decreased by 10 times)

Differencies in PL and RL properties of 3CaO-2SiO_2:Ce and 3CaF_2-2SiO_2:Ce glasses

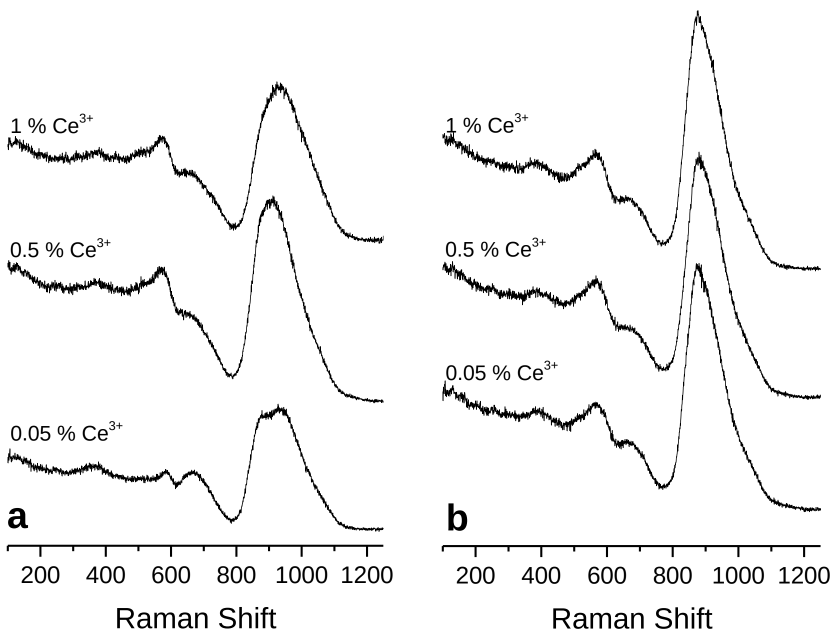


Normalized by intensity excitation spectra for 3CaO-2SiO_2 (a) and 3CaF_2-2SiO_2 (b) glasses with 0.05 (solid line), 0.5 (dashed line) and 1 (dotted line) at. % of Ce^{3+} ions



Normalized by PL intensity amplitude spectra at excitation at 300 nm (solid line) and 360 nm (dashed line) for 3CaO-2SiO_2 (a) and 3CaF_2-2SiO_2 (b) glasses with 0.05 at. % of Ce^{3+} ions in comparison with their RL spectra normalized by amplitude (marked by circles).

Structural properties of $3CaO\text{-}2SiO_2$:Ce and $3CaF_2$-$2SiO_2$:Ce

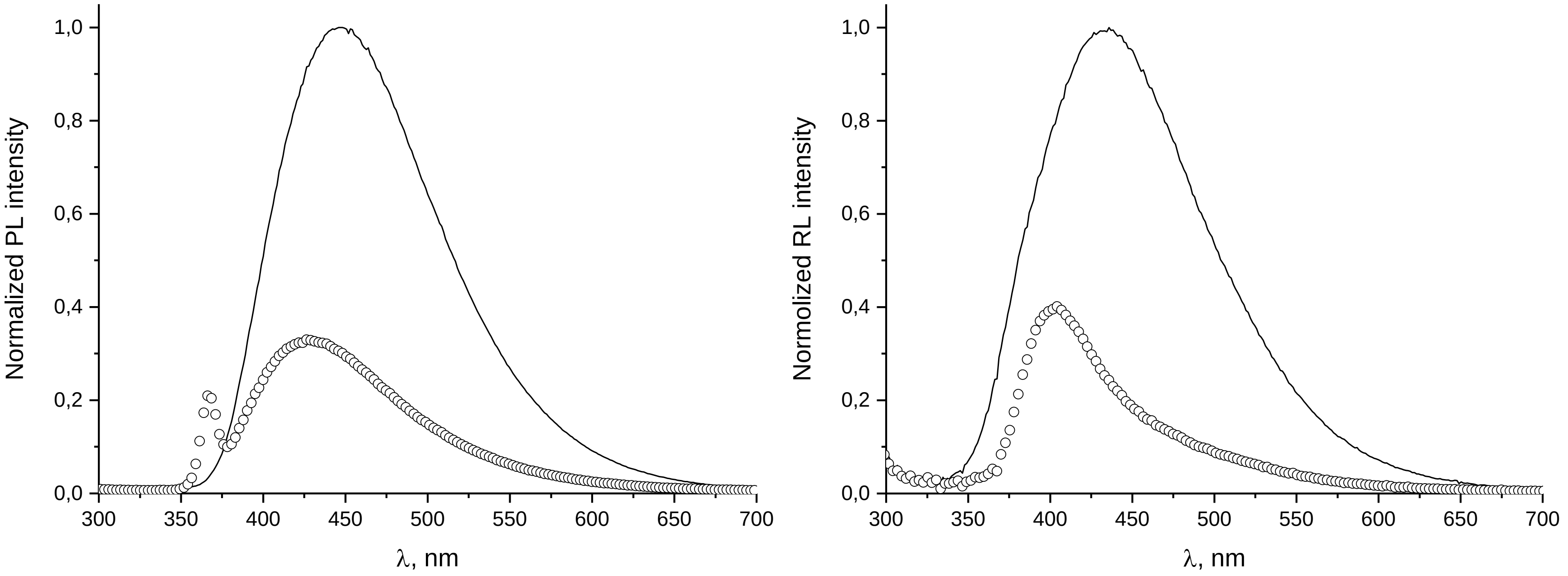


Raman spectra for $3CaO\text{-}2SiO_2$ (a) and $3CaF_2\text{-}2SiO_2$ (b) glasses with different Ce^{3+} ions concentration

Bands interpretation

υ, cm^{-1}	Description
~1025	anti-symmetric stretch vibrations in a three-dimensional array of SiO_4 tetrahedra
~875	symmetric stretch vibrations of nonbridging oxygen bonds in separate SiO_4^{4-} structures in **orthosilicate structure**
~910-935	$Si_2O_7^{6-}$ structures vibrations in pyrosilicate structures; $(SiO_4)_n^{2-}$ chain structures vibrations
~650-660	Si-O-Si linkages vibrations
~720	asymmetric stretch vibrations of bridging oxygen bonds in crystalline pyrosilicates
~575-580	bending motions of oxygen bonds in direct structures in quenched SiO_2
~400	bending vibrations of the Si–O–Si linkage with oxygen motion perpendicular to the Si–Si line and/or to the O–Si–O deformation of the coupled “tetrahedra” SiO_4 groups

Comparison PL and RL efficiency $3CaO\text{-}2SiO_2$ glasses

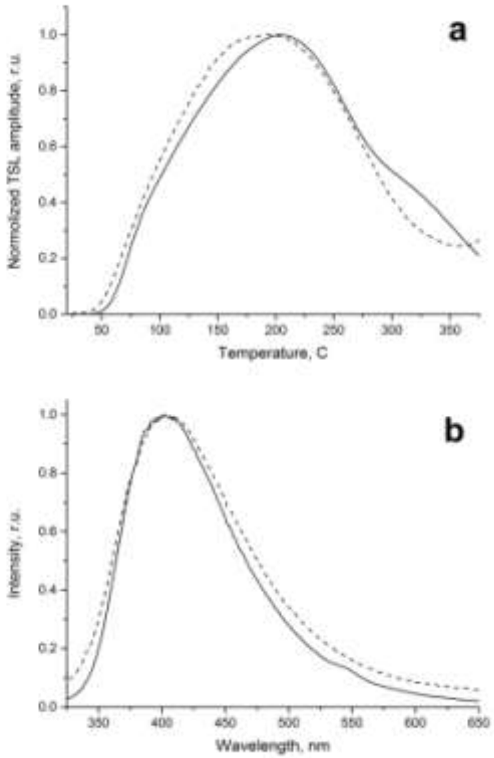


a

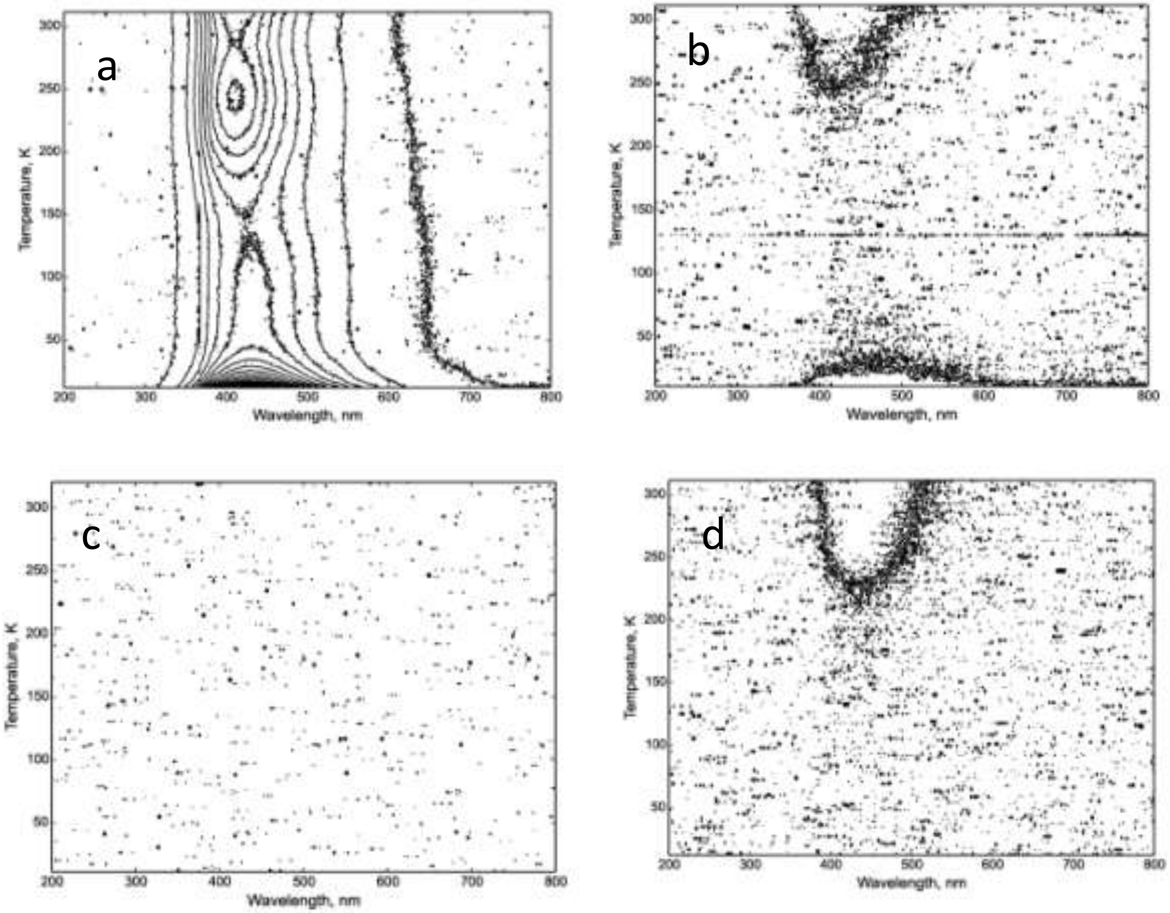
b

Normalized PL (a) at excitation at 350 nm and RL (b) spectra for $3CaO\text{-}2SiO_2$ glass (circles) with 0.5 % Ce^{3+} ions by the intensity of SiO_2:Ce glass (solid line). On figure b the relative intensity for $3CaO\text{-}2SiO_2$ glass increased at 100 times.

TSL results for $3CaO\text{-}2SiO_2$:Ce and $3CaF_2\text{-}2SiO_2$:Ce glasses

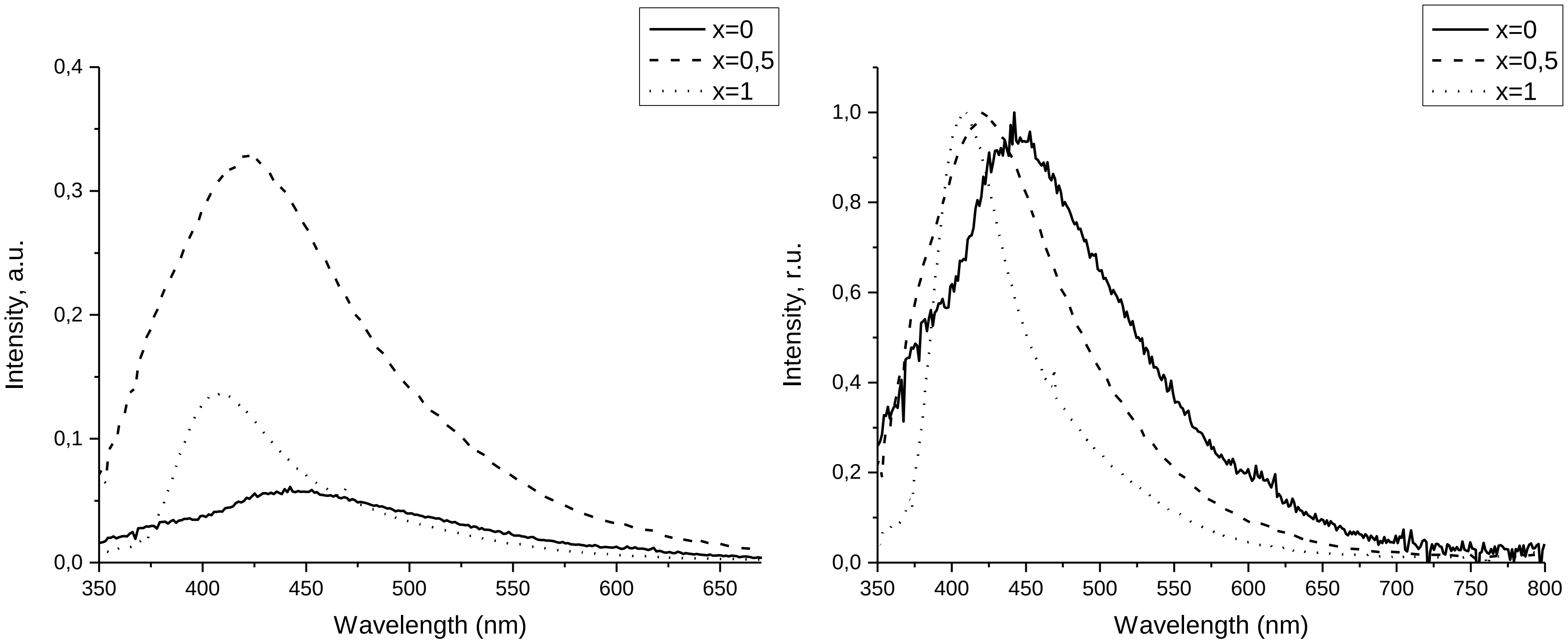


TSL glow curves (a) and TSL spectra (b) for $3CaO\text{-}2SiO_2$ (solid line) and $3CaF_2\text{-}2SiO_2$ (dash line) samples with 0.05 at. % Ce^{3+}



TSL measurements at low temperature for $3CaO\text{-}2SiO_2$ (a, c) and $3CaF_2\text{-}2SiO_2$ (b, d) glasses with 0.05 (a, b) and 1 (c, d) at. % of Ce^{3+} ions.

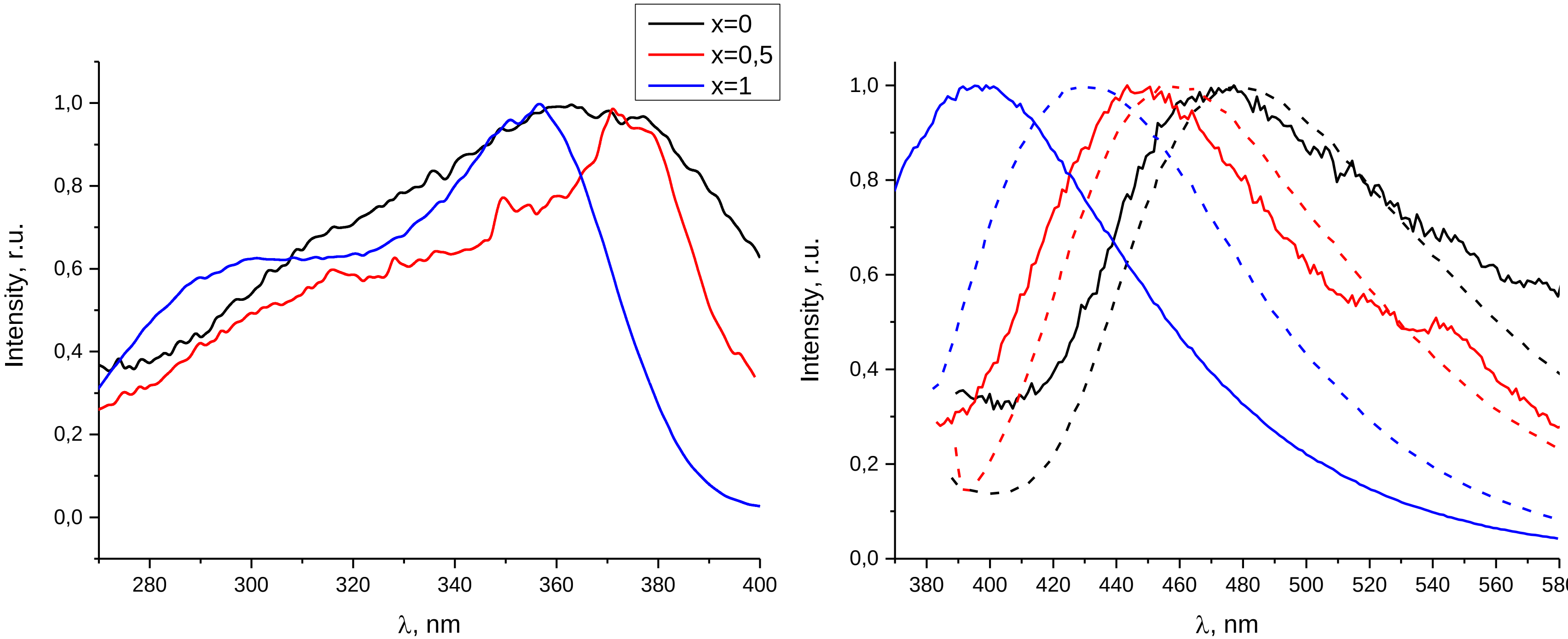
RL properties of the $3Ca_xBa_{1-x}O\text{-}2SiO_2$:Ce (x=0, 0.5, 1) glasses



a b

Corrected RL spectra (a) and normalized by intensity (b) for glass samples $3Ca_xBa_{1-x}O\text{-}2SiO_2$:Ce (x=0, 0.5, 1)

PL properties of the $3Ca_xBa_{1-x}O\text{-}2SiO_2$:Ce (x=0, 0.5, 1) glasses

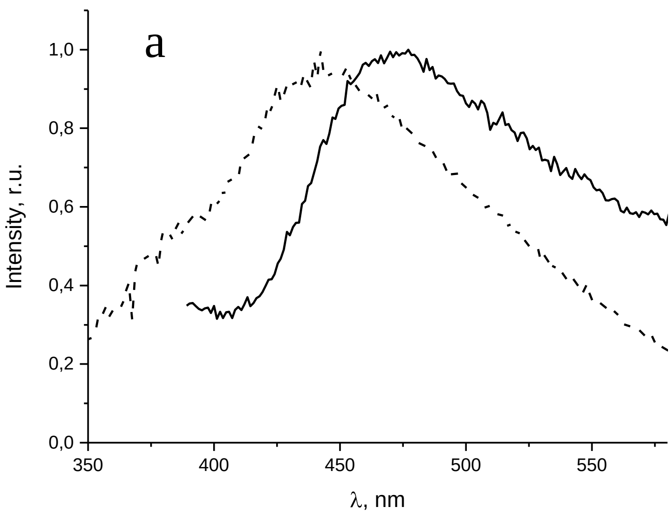


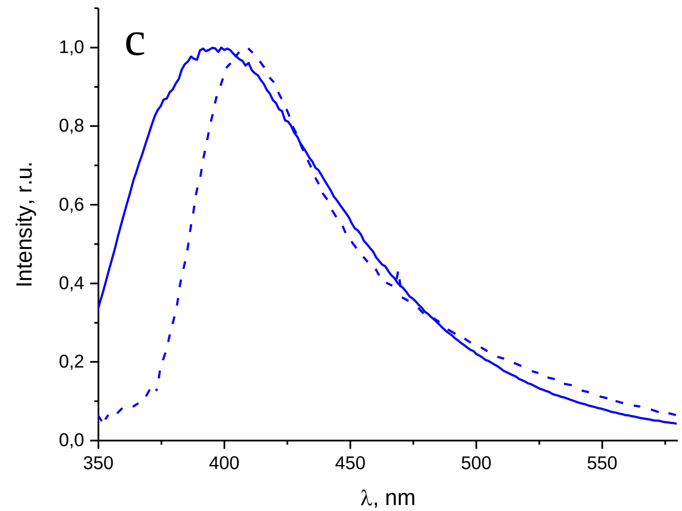
a

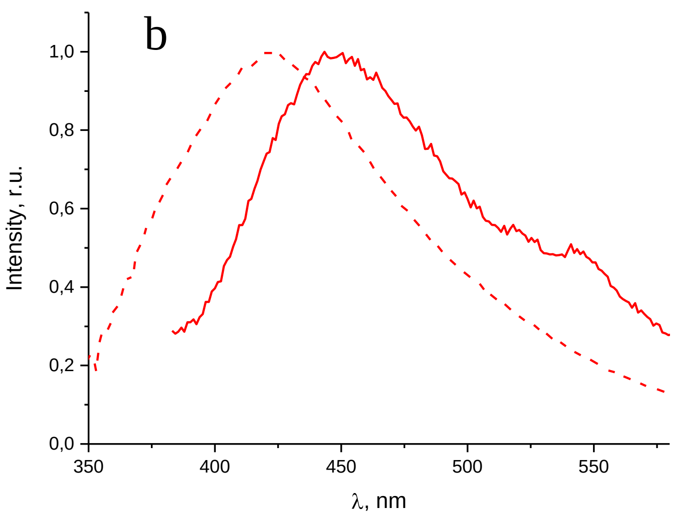
b

Normolized by intensity the excitation (a, λreg = 425 nm) and luminescence (b, λex = 305 nm (solid lines) and 366 nm (dash lines)) spectra for $3Ca_xBa_{1-x}O\text{-}2SiO_2$:Ce (x=0, 0.5, 1) samples.

Comparison PL and RL properties of the $3Ca_xBa_{1-x}O\text{-}2SiO_2$:Ce (x=0, 0.5, 1) glasses







Comparison PL (excited at 305 nm, solid lines) and RL spectra (dashed lines) for $3Ca_xBa_{1-x}O\text{-}2SiO_2$:Ce glasses, where x=0 (a), 0.5 (b) and 1 (c)

Main results

1. Substitutance of O^{2-} ions in anionic sublattice onto F^{-} ions and Ca^{2+} ions in cationic sublattice onto Ba^{2+} ions do not contribute to increasing of scintillation efficiency. In both cases possibility of presence Ce^{3+} ions in different surrounding was found. With increase of the Ce^{3+} content, some part of them are localized in new different surroundings of silica groups and do not contribute in scintillation;

2. Presence a low intensity (or it absence) signal on TSL spectra for $3CaO\text{-}2SiO_2$ and $3CaF_2\text{-}2SiO_2$ glasses can be result of the formation by calcium ions energy levels that lying deeper the level formed by cerium ions. Thus, the levels of calcium ions act as nonradiative recombination centers;

3. Overlapping of excitation band of investigated glasses with CeF_3 scintillation band make these glasses promising as wavelength shifters from UV to blue region.

Thank you for attention!