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SPECTROSCOPIC PROPERTIES OF Yb^{3+} DOPED PHOSPHATE GLASS PREPARED BY SOL-GEL METHOD

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ABSTRACT

Glass based Yb^{3+} doped P_2O_5-Al_2O_3-Na_2O has successfully been prepared by sol-gel method. Their spectroscopic properties have been investigated using UV-Vis Spectroscopy and IR Spectroscopy. It is found that the transmission cut-off varied from 300 nm - 400 nm and is very much depend on the Yb^{3+} contents. The vibrational frequency of Yb^{3+} doped P_2O_5-Al_2O_3-Na_2O spectrum are the PO_2 asymmetric stretching vibration band at 1280 cm^{-1}, $\nu_{as}(PO_2)$, the PO_2 symmetric stretching vibration band at 1211 cm^{-1}, $\nu_s(PO_2)$, the $\nu_{as}(PO_3)$ groups (chain-end groups) at 1100 cm^{-1}, the ν_s of PO_3 groups near 1020 cm^{-1}, the ν_{as} of POP groups at 980 cm^{-1}, the ν_s of POP groups at 773 and 730 cm^{-1} and the deformation modes groups at 545 and 496 cm^{-1}.

Keywords: Phosphate glass; sol-gel; FTIR; UV-VIS Spectroscopy;

INTRODUCTION

Recent technological applications have generated more interest in the studies of glass or ceramic materials. These materials doped with rare earth active ions find a place in the phosphor and luminescence materials applications such as has been used as lamp phosphors, cathode ray tube phosphors and scintillate phosphors, because of their unique spectroscopic properties [1, 2].

In recent years, phosphate based glasses have been of interest for a variety of applications due to their several special properties such as large thermal expansion coefficients, low melting temperatures, solubility, etc. [3, 4]. It is also an excellent material as host material due to properties of good chemical durability, ion exchange ability, high gain coefficient, wide band width capability and low up conversion emission. Their relatively poor chemical durability makes them generally unsuitable for practical applications. It was suggested that the addition of one or more of Al_2O_3 and Na_2O results in the formation of Al-O-P and Na-O-P bonds, and leads to improvement in the chemical durability of the modified phosphate glasses. Compared to studies of silicate sol-gels, those of phosphate sol-gels are very few. The solution chemistry of phosphate materials is very different from silicate which, consequently, continues to make the phosphate systems much more complex than the silicates [5].

In the present study, the spectroscopic around of phosphate glasses will be investigated. The mix of Na and Al oxide doped $YbCl_3$ to phosphate network will be examine using X-ray Diffraction, Infrared and UV-Visible Spectroscopy.

EXPERIMENTAL DETAILS

A nominal composition of P_2O_5-Al_2O_3-Na_2O_3 glass doped with $YbCl_3$ was prepared by sol-gel method where phosphate is taken as a glass precursor. Aluminum isopropoxide is dissolved in isopropanol at about 150 ºC at 2 h. Then, a mixture of HNO_3 and $NaNO_3$ in water is added to the alcoholic solution of aluminum ixopropoxide and stirred at 150ºC until a clear solution is attained and added another alcoholic solution of H_3PO_4 (that resulted from dissolving H_3PO_4 in isopropanol). To the resulting solution, solid $YbCl_3$ dissolved in water is added and they are stirred together under reflux at the same temperature for 3 hours, where a completely clear and stable solution is obtained. Then the gel is obtained after all the solvent and water has evaporated. The formed gels were then left in a furnace at 150 ºC for 72 h so that the xerogel powders would be formed. The powder is then melted in air temperature 950 ºC. The melts is then quickly poured on a stainless steel plate to obtain the colorless glass.

The degree of crystallites of the sample is determined by X-ray diffraction measurements (XRD), using powder form. A Siemens Diffractometer D5000, equipped with diffraction software analysis. Diffraction patterns were collected in the 2θ range from 10 to 80^o, in steps of 0.04^o and 4s counting time per step. Meanwhile, the actual glass composition is determined using Energy Dispersive X-ray microanalysis (EDX).

The transmission cut-off spectra in the visible and ultraviolet region are recorded at room temperature. These curves are traced for highly polished glass samples of ~3 mm thickness using a Perkin-Elmer spectrophotometer in the wavelength range of 200 – 800 nm.

FTIR spectra are recorded with a Perkin-Elmer (Spectrum One FT-IR spectrometer) in the frequency range of 400-4000 cm^{-1} at room temperature. Pellets are prepared for FTIR measurements by mixing and grinding a small quantity of powder sample with spectroscopic grade dry KBr powder and then compressing the mixtures to form pellets for measurements.

RESULTS AND DISCUSSION

The Yb^{3+} doped phosphate glass samples obtained are colorless and transparent. XRD spectra of the studied glasses have shown that all the samples are completely amorphous and they do not present any crystalline phase. The X-ray diffraction patterns of this sample are shown in Figure 1.

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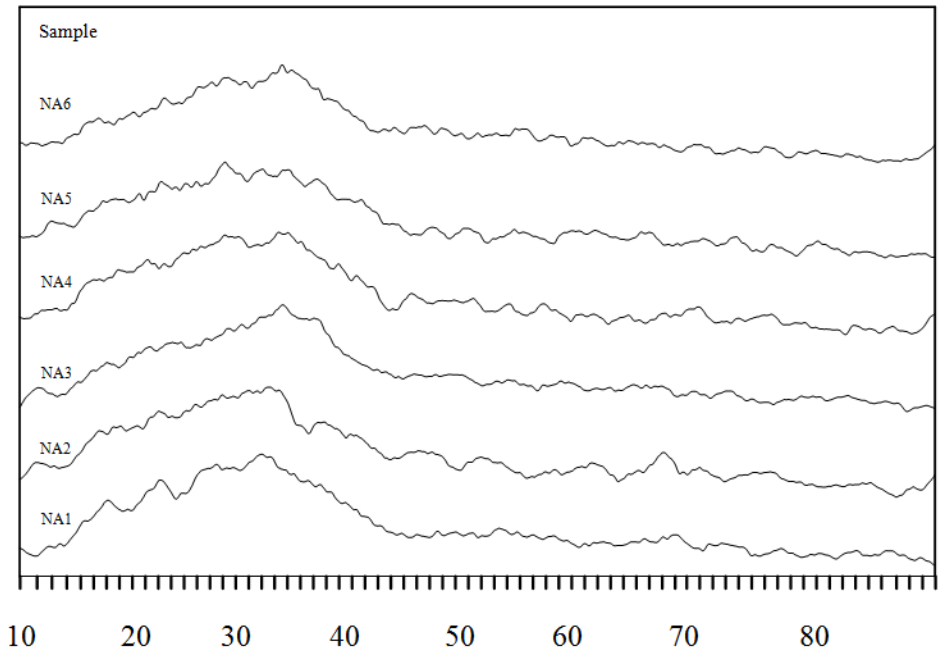

Figure 1: The X-ray diffraction (XRD) patterns of Yb^{3+} doped phosphate glass samples

Table 1 shows the actual composition of the glass by using Energy Dispersive X-ray microanalysis (EDX). From Table 1 it can be seen that a wide glass formation range may be obtained. The phosphate up to 63.5 mol% can easily be used to form a stable glass.

Table 1: Actual glass composition measured by EDX (mol %)

Sample	Glass calculated-composition (mol %)			
	Na_2O	Al_2O_3	P_2O_5	Yb^{3+}
NA-1	40.0	10.0	50.0	-
NA-3	39.1	6.2	53.1	1.6
NA-3	35.6	5.1	57.6	1.7
NA-4	27.2	7.8	63.1	1.9
NA-5	35.2	5.7	56.8	2.3
NA-6	27.1	7.0	63.5	2.4

UV-Vis transmission spectra of Yb^{3+} doped phosphate glasses are shown in Figure 2. From these spectra, it was observed that undoped sample is having UV cut-off at 350 nm wavelength whereas the samples containing 1.6 %, 1.7 %, 1.9 %, 2.3 % and 2.4 % Yb^{3+} have UV cut-off at around 360, 365, 368, 370 and 375 nm, respectively.

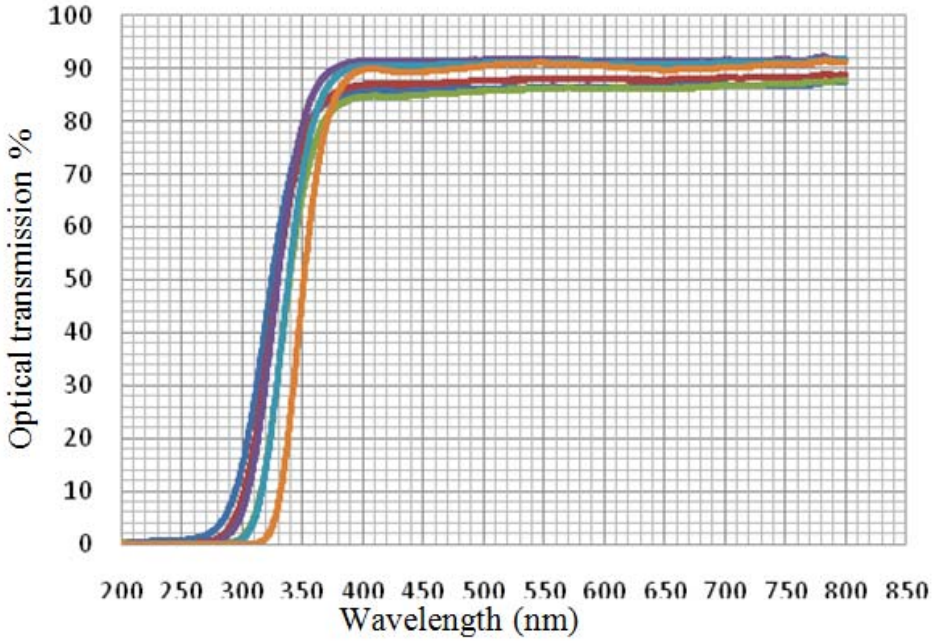

Figure 2: Optical transmission versus wavelength (nm)

If a plot of cut-off wavelength (nm) against Yb^{3+} content is being made, a graph as shown in Figure 3 may be obtained.

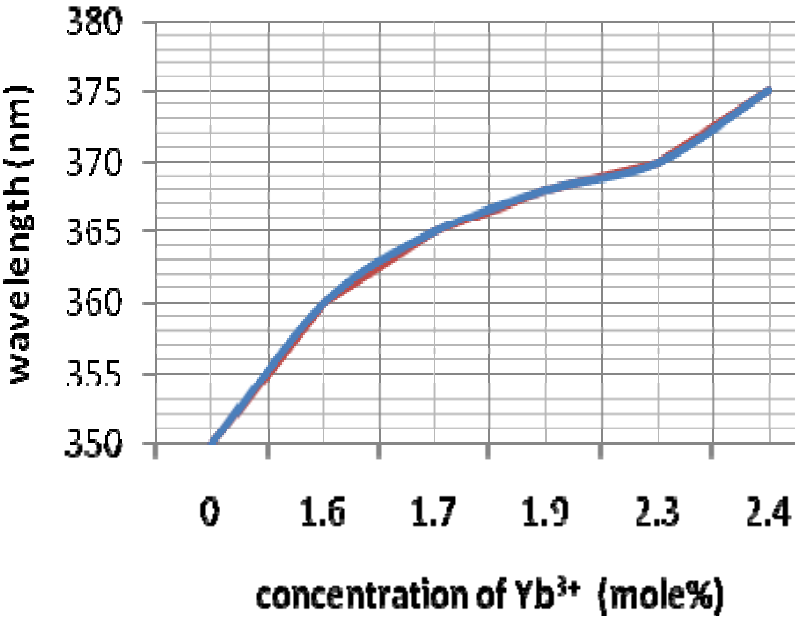

Figure 3: Cut-off wavelength (nm) against Yb^{3+}

From Figure 3 it can be clearly seen that the wavelength (nm) increases gradually as the Yb^{3+} content is increased up to 2.4 mol%. This may be attributed to the effect of Yb^{3+} on the structural network. As the Yb^{3+} increases, it would loosen the glass structure thus increase the cut-off wavelength.

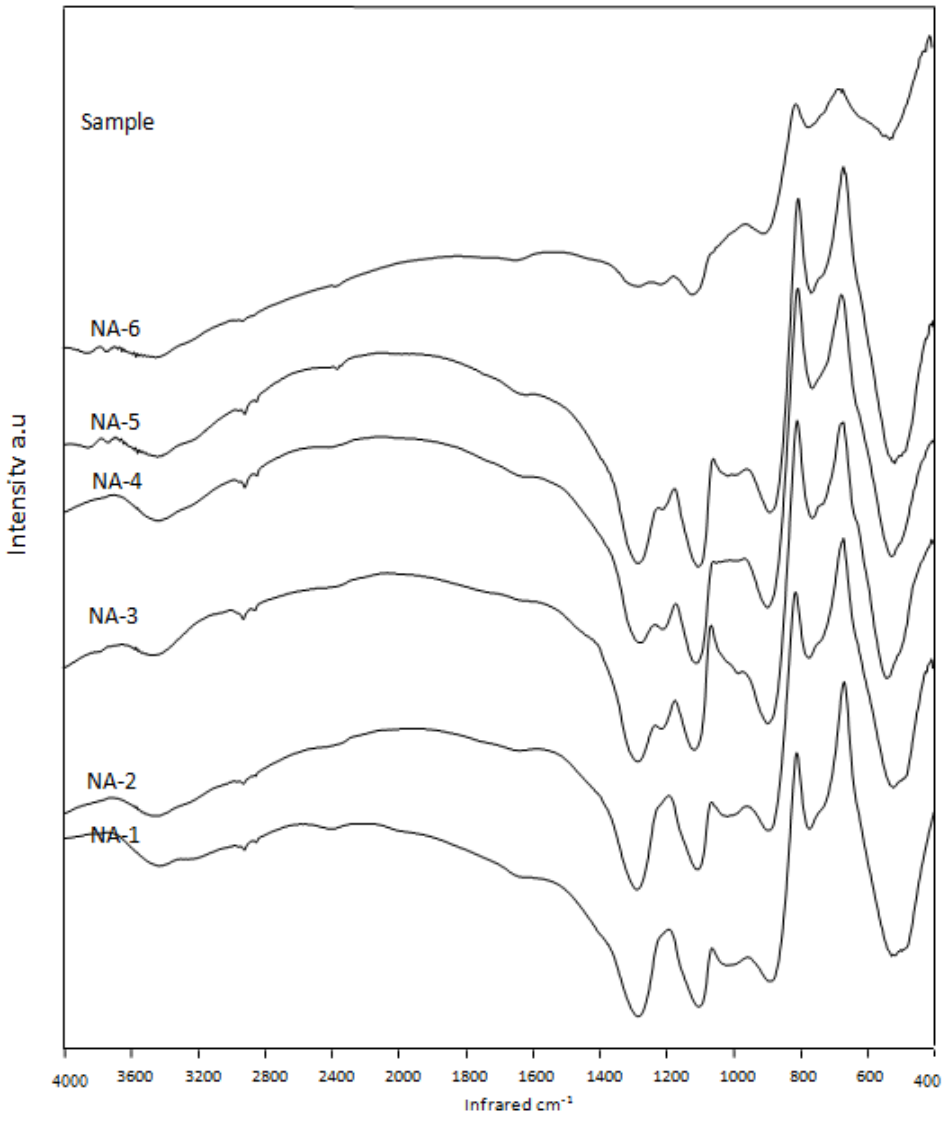

Figure 4: The Infrared spectra for Yb^{3+} doped phosphate glass samples

The FT-IR spectra of Yb^{3+} doped phosphate glasses samples in the frequency range 4000 cm^{-1} and 400 cm^{-1} are shown in Figure 4. The IR bands are assigned based on the literature data on the wave number ranges related to the corresponding vibrations of the structural units in various glassy and crystalline phosphates [6-9]. The strong near 3400

cm^{-1} can be accounted for by a different role of H_2O molecules in the structure. In particular, the atmospheric moisture is easily absorbed by the sample or by the pellet, causing the appearance of IR band belonging to H_2O molecules although the sample under investigation does not contain H_2O molecules in the network. The bands located in the range 2900 cm^{-1} are relatively weak and can be ascribed to the stretching vibrations of P-O-H group in different structural sites. This group forms the strongest hydrogen bonding with the non-bridging oxygen. The strong band at about 1600 cm^{-1} can be attributed to the O-H bending vibration.

The strong band near 1300 cm^{-1} is attributed to P=O stretching mode. The band near 1280 cm^{-1} and 1211 cm^{-1} is assigned to asymmetric and symmetric stretching modes of the two non-bridging oxygen atoms bonded to phosphorus atoms, v_{as} (PO_2) and $v_s(PO_2)$. The band at 1100 cm^{-1} is attributed to v_{as} (PO_3) and assigned to $(PO)^-$ groups. The band near 1020 cm^{-1} is assigned to (PO_3). The absorption bands near 980 cm^{-1} and 773-730 cm^{-1} are assigned to the asymmetric and symmetric stretching modes of the (P-O-P) linkages, respectively. The absorption bands near 545 cm^{-1} and 496 cm^{-1} are assigned to the stretching and deformation modes.

CONCLUSION

A sample of Yb^{3+} doped phosphate glass is successfully prepared by sol-gel method. The sample was confirmed by x-ray diffraction method and the result shows that the sample is phosphate glass. FTIR showed the presence of all characteristic phosphate groups and bonds, especially the P=O and the P-O-P bonds. The transmission cut-off of these glasses was shifted to higher wavelength with increasing concentration of Yb^{3+}.

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