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Thermal, Optical Properties and Structural Investigation of Tm^{3+} doped TeO_2-ZnO-TiO_2 Glass System

İdris KABALCI[a] , Neşe ÖZTÜRK KÖRPE[b], Tuğba DURAN[c], and Mustafa ÖZDEMİR[c], Turgay Tay[d], Gönül Özen[e]

[a]Department of Physics Education, University of Harran, Şanlıurfa, Turkey
[b]Department of Material Science and Engineering, Eskişehir Osmangazi University, İstanbul, Turkey
[c]Department of Physics , Marmara University , İstanbul, Turkey
[d]Department of Chemistry, Anadolu University, Eskişehir, Turkey
[e]Department of Physics, Istanbul Technical University, Istanbul, Turkey

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[a]Department of Physics Education, University of Harran, Şanlıurfa, Turkey
[b]Department of Material Science and Engineering, Eskişehir Osmangazi University, İstanbul, Turkey
[c]Department of Physics , Marmara University , İstanbul, Turkey
[d]Department of Chemistry, Anadolu University, Eskişehir, Turkey
[e]Department of Physics, Istanbul Technical University, Istanbul, Turkey

ABSTRACT

Tellurite based infrared glasses in the Tm^{3+} doped TeO_2-ZnO-TiO_2 system were prepared and its optical properties and crystallization kinetics investigated by using UV-VIS-NIR spectrophotometer and differential thermal analysis method (DTA). All the glasses were transparent from visible to near infrared region for different ZnO glass compositions (x=5, 10, 20, and 30 mol%). In the experiments, optical energy band gaps and Urbach energies were estimated from the optical absorption spectra between 300 and 800nm wavelength region. The spectroscopic properties including absorption spectra and absorption cross sections of Tm^{3+} doped TeO_2-ZnO-TiO_2 were measured and calculated. In addition, glass transition (T_g), crystallization (T_p) and melting temperature (T_m) were determined by using the DTA plots. Crystallization activation energies and crystallization mechanism were determined from the DTA curves measured with different heating rates (20, 30, and 40°C/min). Finally, DTA results obtained with a heating rate of 20°C/min show that the peak crystallization temperature increases from 463 to 533°C as the ZnO content increases from 5 to 30 mol%.

TeO_2-ZnO-TiO_2 Glasses

▪Potential Applications:

- Fiber-optic amplifier @1400-2000 nm
- Infrared fiber lasers @1800 nm

▪Physical Properties:

- Low melting temperature
- Non-Linear Optical Properties
- High refractive index
- Low phonon energies
- Transmission window in the IR region (0.35-5 μm)
- Resistant to atmospheric moisture

Synthesis of Tm^{3+}: TeO_2-ZnO-TiO_2

- Three sets of samples: yTm^{3+}: $(95-x)TeO_2$-(x) ZnO-5TiO_2
- Set 1: x=05, 10, 20, and 30 mol%, undoped.
- Set 2: y=1.0 mol, x=05, 10, 20, and 30 mol%.
- Set 3: x=20 mol, y=0.2, 0.5, and 1.0 mol%.
- Batch size=7 gm
- Melting temperature=850°C(60 minutes, platinum crucible)
- Rapid quenching between graphite slabs

Synthesis of Tm^{3+}: TeO_2-ZnO-5TiO_2

Chemicals

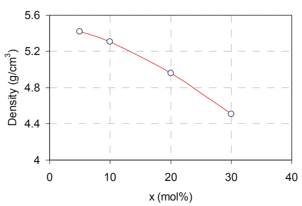
TeO_2 : 99.999% purity,Sigma- Aldrich
ZnO : 99+% purity, Sigma-Aldrich
TiO_2 : 99+% purity, Merck
Tm_2O_3: 99.9% purity, Aldrich

Furnace

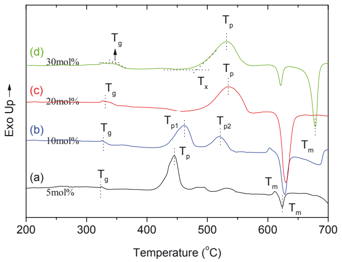
Laser & Photonics Lab., Department of Physics Education, Harran University

Density (d)

(1-x)(TeO_2)-xZnO-5TiO_2

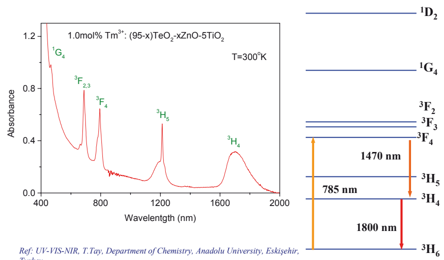


Differantial Thermal Analysis

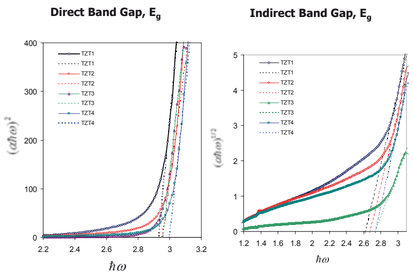


DTA:Pof. Remzi Gürler, Institute of Materials Science, Eskişehir Osmangazi University, Eskişehir, Turkey

Absorption of the Tm^{3+}:0.90TeO_2-0.05ZnO-0.05TiO_2

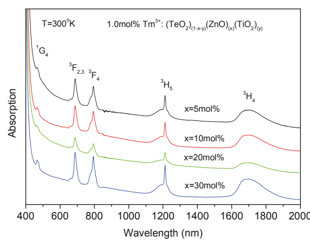


Ref: UV-VIS-NIR, T.Tay, Department of Chemistry, Anadolu University, Eskişehir, Turkey



TZT1: x=5 mol% ZnO : E_g=2.94; E_g=2.6 eV
TZT2: x=10 mol% ZnO: E_g=2.96; E_g=2.67 eV
TZT3: x=20 mol% ZnO: E_g=2.97; E_g=2.73 eV
TZT4: x=30 mol% ZnO: E_g=3.0; E_g=2.74 eV

Absorption Spectrum



Judd-Ofelt Parameters

$$f_{cal}(J,J') = \frac{8\pi^3 e^2}{3ch}\frac{(n^2+2)^2}{9n}\frac{\bar{\lambda}N_0}{(2J+1)} x \sum_{t=2,4,6}\Omega_t \left|\left\langle SLJ \left\| U^{(t)} \right\| S'L'J' \right\rangle\right|^2$$

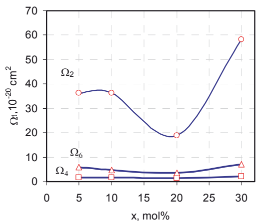
$$f_{den} = \int_{band}\mu(\lambda)d\lambda \qquad \mu(\lambda) = \frac{2.303\log_{10}(I_o/I)}{l}$$

$$S^{ed}(J,J') = \sum_{t=2,4,6}\Omega_t \left|\left\langle SLJ \left\| U^{(t)} \right\| S'L'J' \right\rangle\right|^2$$

$$\int_{band}\mu(\lambda)d\lambda = \frac{8\pi^3 e^2}{3ch}\frac{(n^2+2)^2}{9n}\frac{\bar{\lambda}N_0}{(2J+1)} \times S^{ed}(J,J')$$

$\Omega_2, \Omega_4, \Omega_6$ = Judd-Ofelt intensity parameters
c = speed of light, cm/sec; n= refractive index
$\bar{\lambda}$= mean wavelength, **SLJ**=Quantum number
N_0 = Tm^{3+} concentration
$U^{(t)}$ = irreducible tensor operator

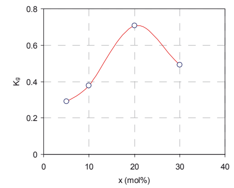
Judd-Ofelt Intensity Parameters



Refractive index = 2.05

Ref: E.R. Taylor, L.N. Ng, N.P. Sessions, J. Appl. Phys.92(1), 112-117, (2002).

Glass Forming Ability, K_g



Glass Tendency: K_g

$$K_g = \frac{(T_c - T_g)}{(T_m - T_c)}$$

Ref: Maharian N.B., Physc. Stat. Sol. (a), 178. p.663. 2000

- x = 5, 10, 20, and 30 mol.% (1-x)TeO_2-xZnO-5TiO_2 new glasses are synthesized,
- Density,UV-VIS, DTA, XRD measurements were reported for these samples,
- Energy band gaps (E_g) calculated,
- T_g, T_p, and T_m temperatures were determined,
- α-TeO_2 and γ-TeO_2 were dominant structure,
- The values of K_g indicates that the composition with 20 mol.% ZnO is the easiest to form glass.

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