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Microstructure, electrical properties and application of bismuth titanate ceramics and glass-ceramics for low-energy electronic devices

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Aurivillius family oxides including $Bi_4Ti_3O_{12}$ are of great interest in the last years due to their potential for:

- applications as tranducers, capacitors, and acoustic piezo-sensors with high temperature piezoelectric properties;

- ferpoelectrics with high Curie temperature;

- high temperatute glasses with various refractive index;

- electro-optical modulators and deflectors for lasers and high power light beams;

- glasses with various polarization, based on diffusion of titanium layers;

- cackade piroelectric devices up to 3 kW/kg and 20% thermo efectivity;

Applications of bismuth-based feroelectics are strongly influenced by the method of preparation.
Different methods of synthesis leads to the generation of different microstructures and specific electrical properties.

Purpose

The purpose of the present work is the preparation of composite materials in the system Bi_2O_3-TiO_2-SiO_2-Nd_2O_3 obtained by melt quenching method and the study of their electrical properties depending on composition and temperature.

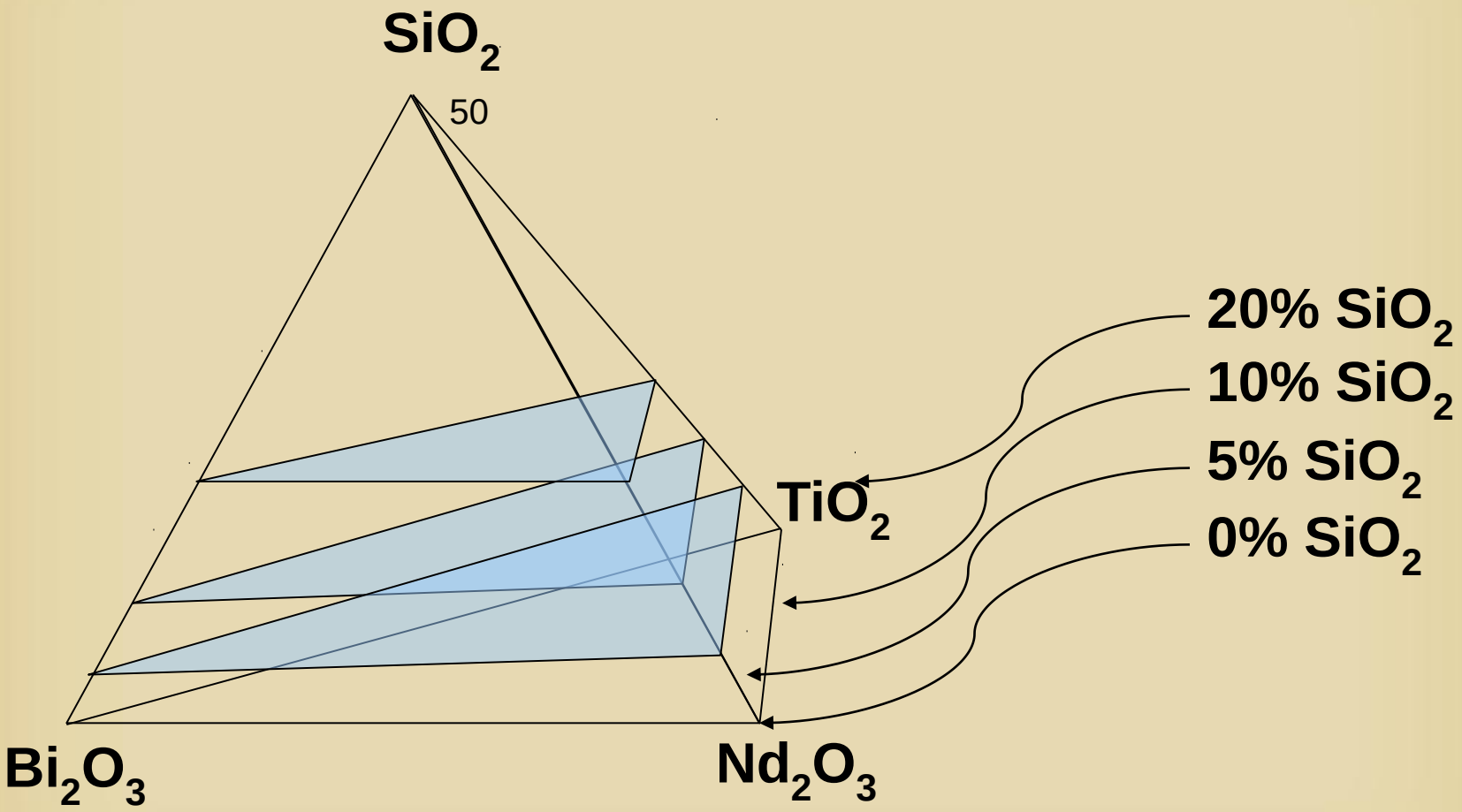
Experimental

The samples are synthesized by melt quenching method at fast cooling at room temperature, performed by pouring of the melts between two cooper plates. The melting is made in alumina crucibles at 1250 and 1500^{o}C depending of compositions.

The phase formation has been studied through x-ray diffraction analysis (XRD - TUR M62, Cu-Kα radiation).

Measurements of the electrical conductivity, capacitance and dielectric losses of selected samples are performed by DC resistible bridge and digital capacity meter E8-4 using two-terminal method and a suitable sample holder with graphite electrodes.

Results



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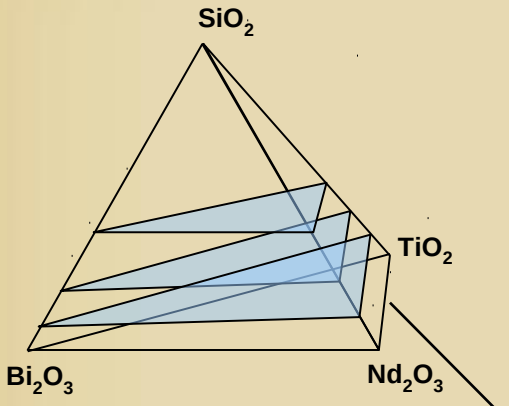
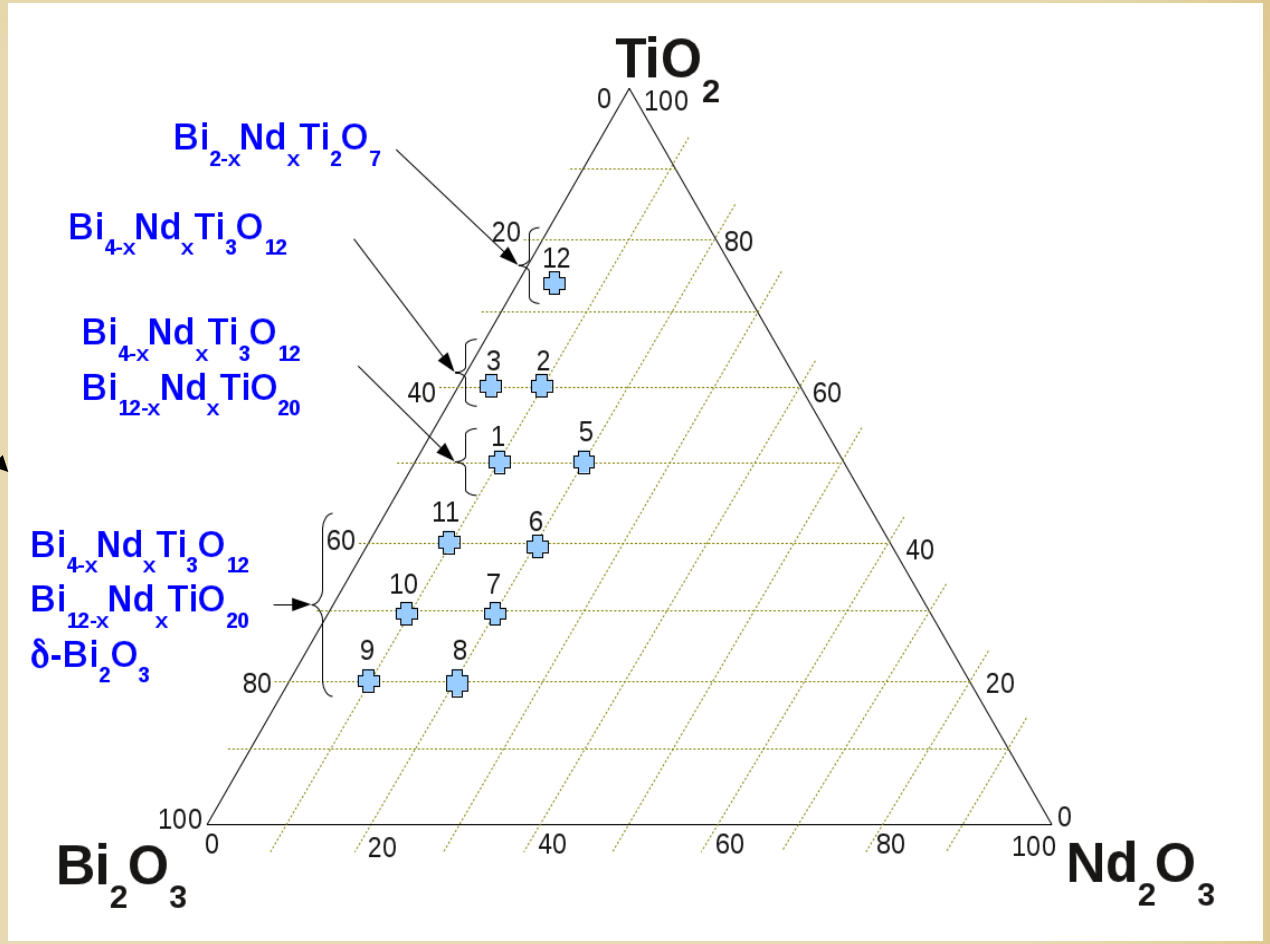
Results

0% SiO_2





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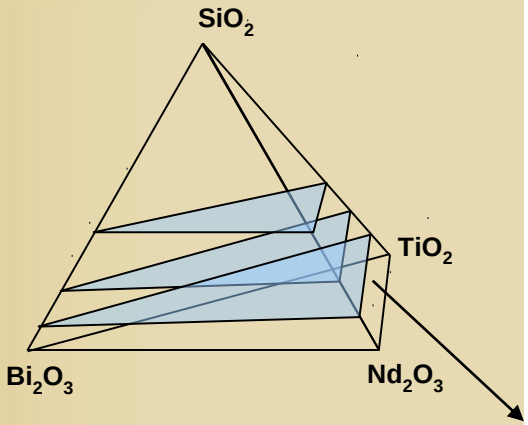
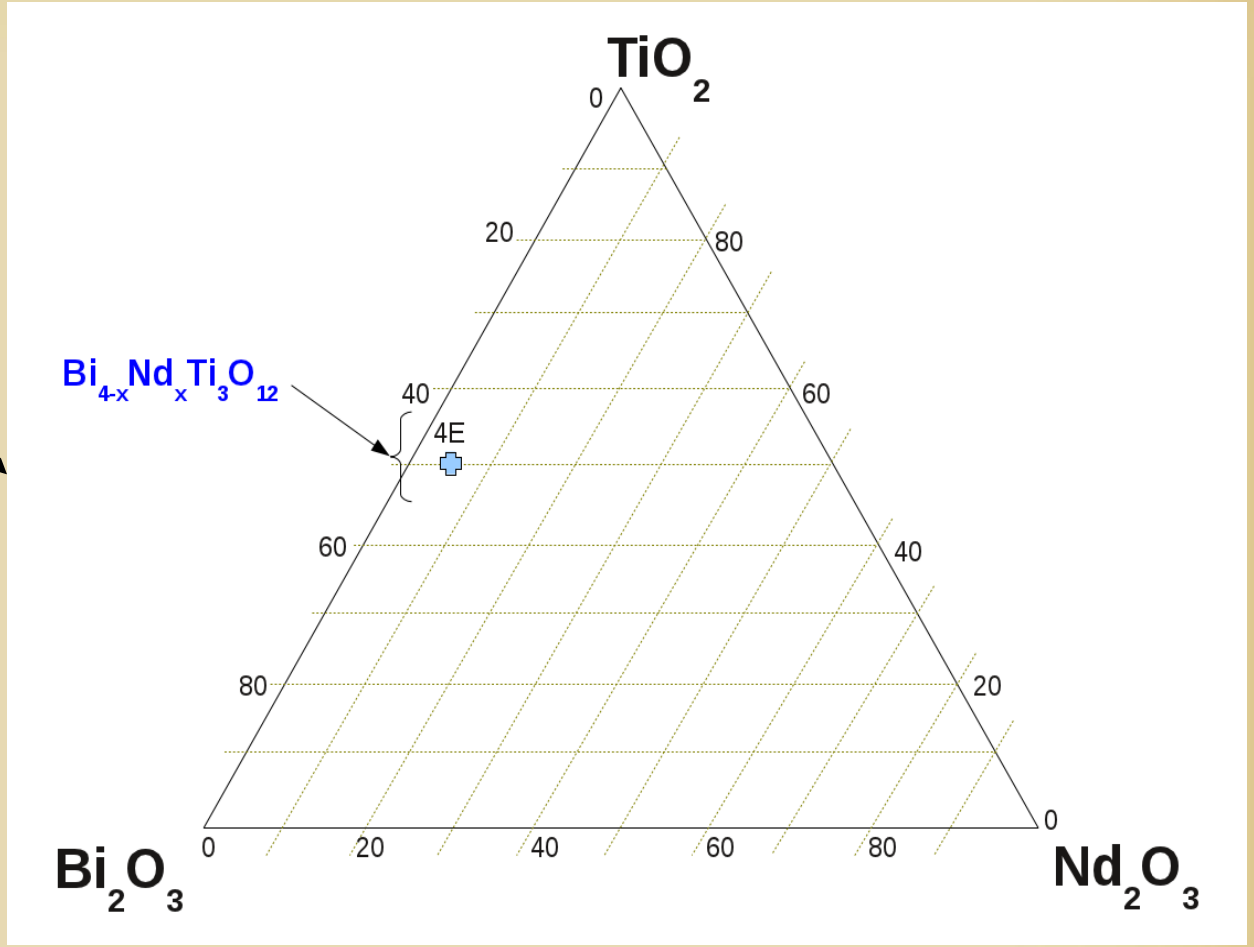
Results

5% SiO_2





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Results

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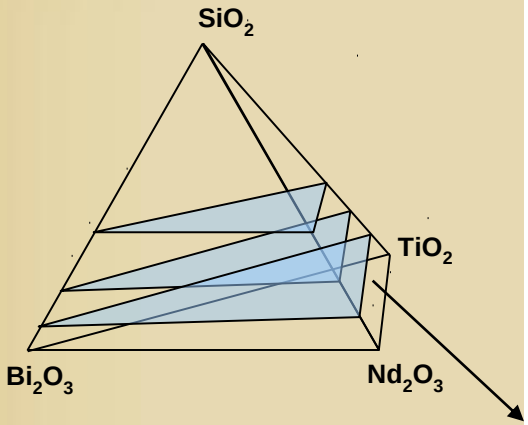

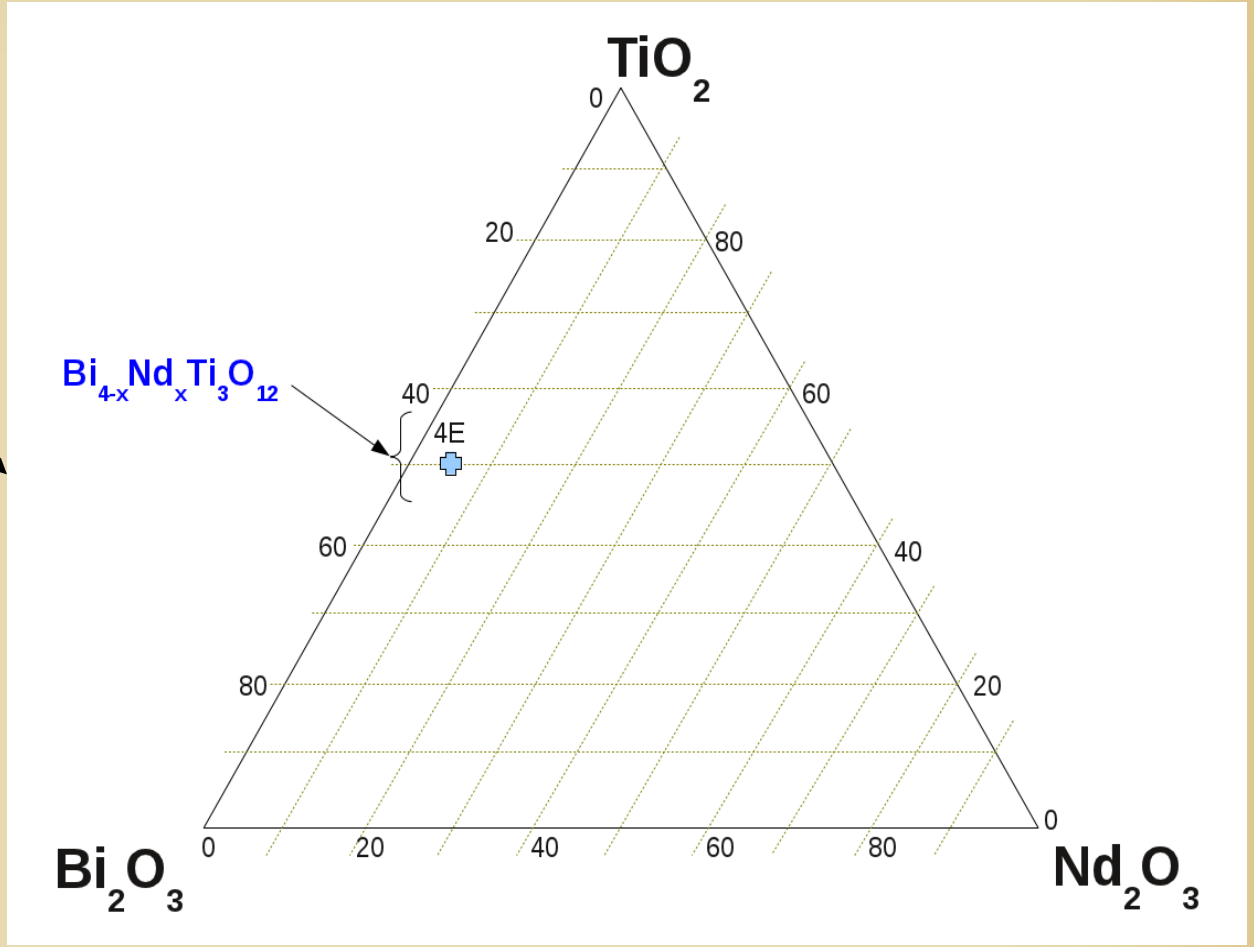

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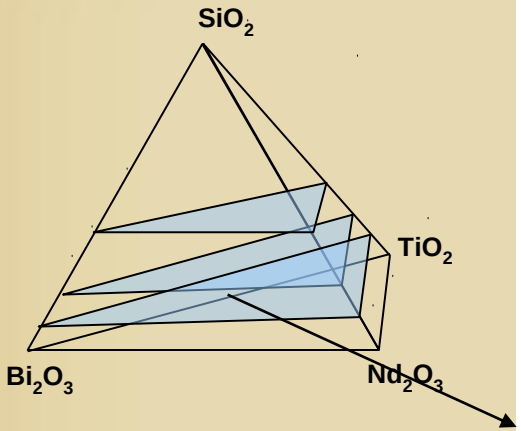
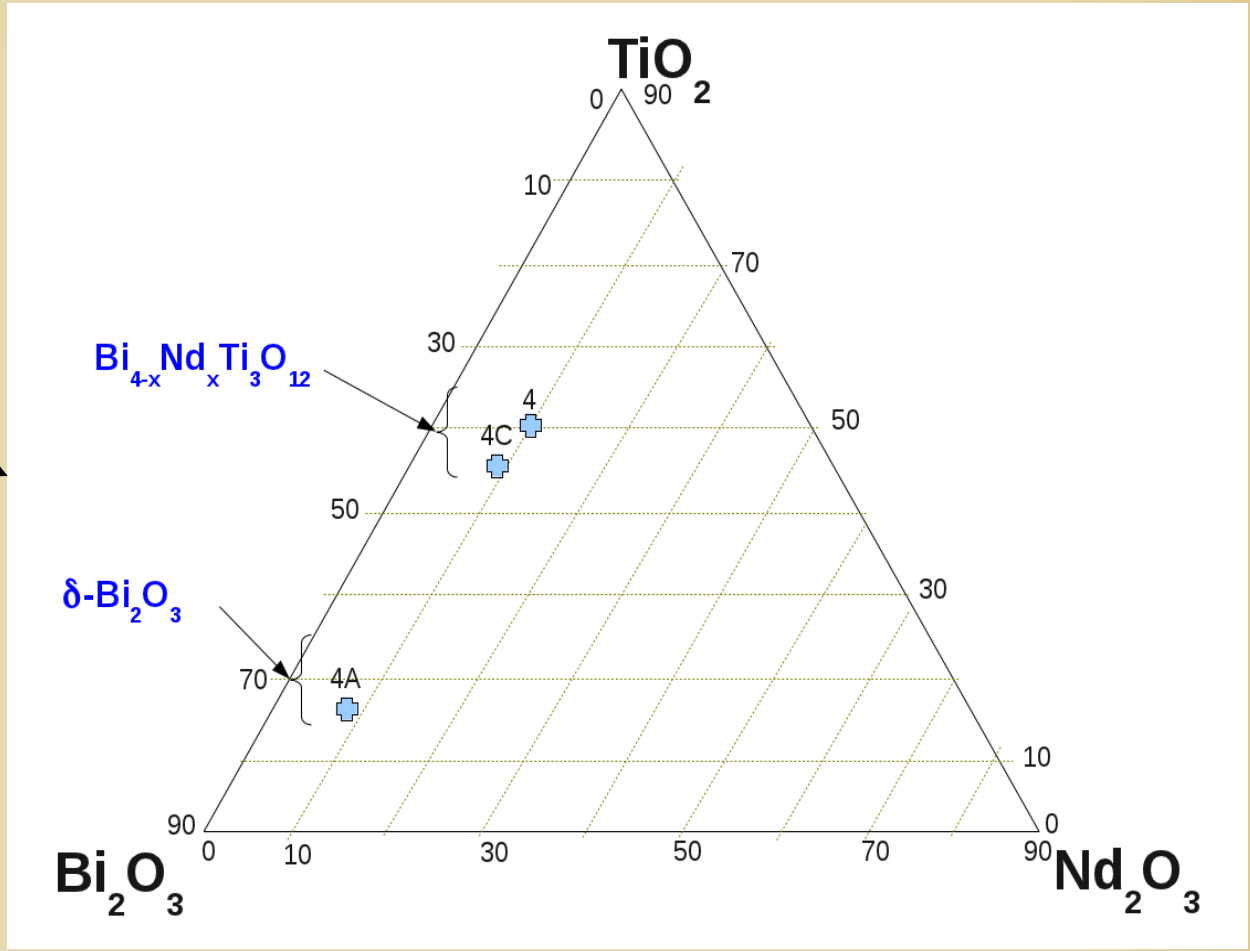
Results

10% SiO_2





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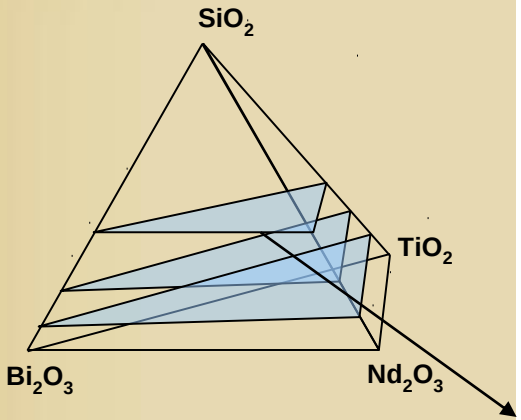
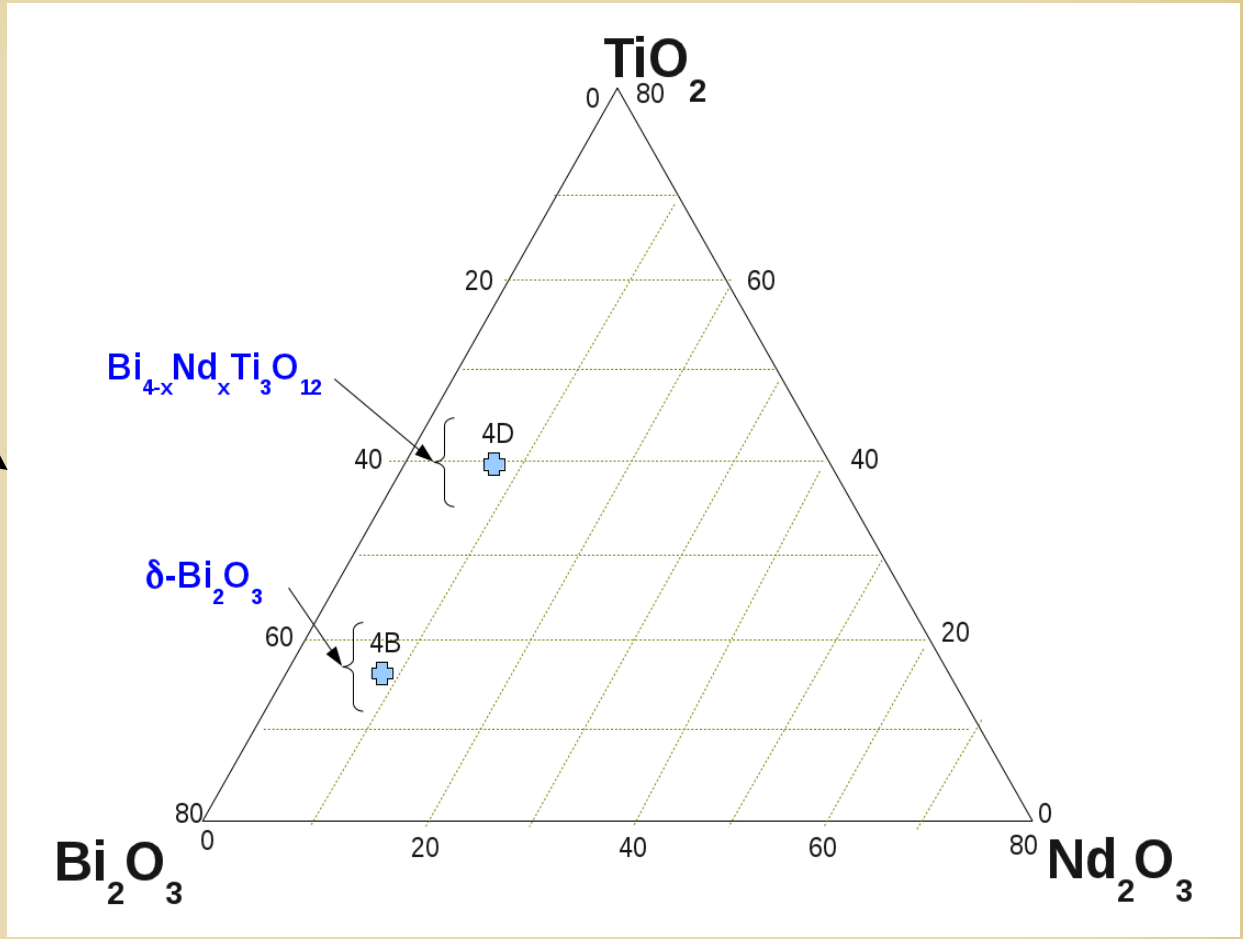
Results

20% SiO_2





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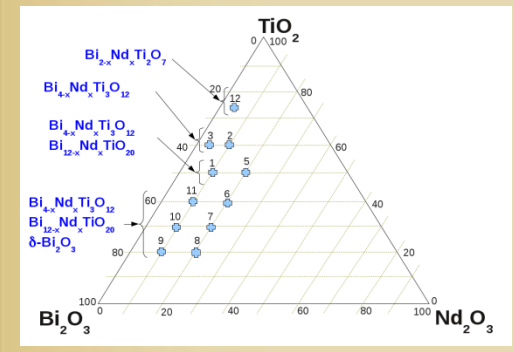
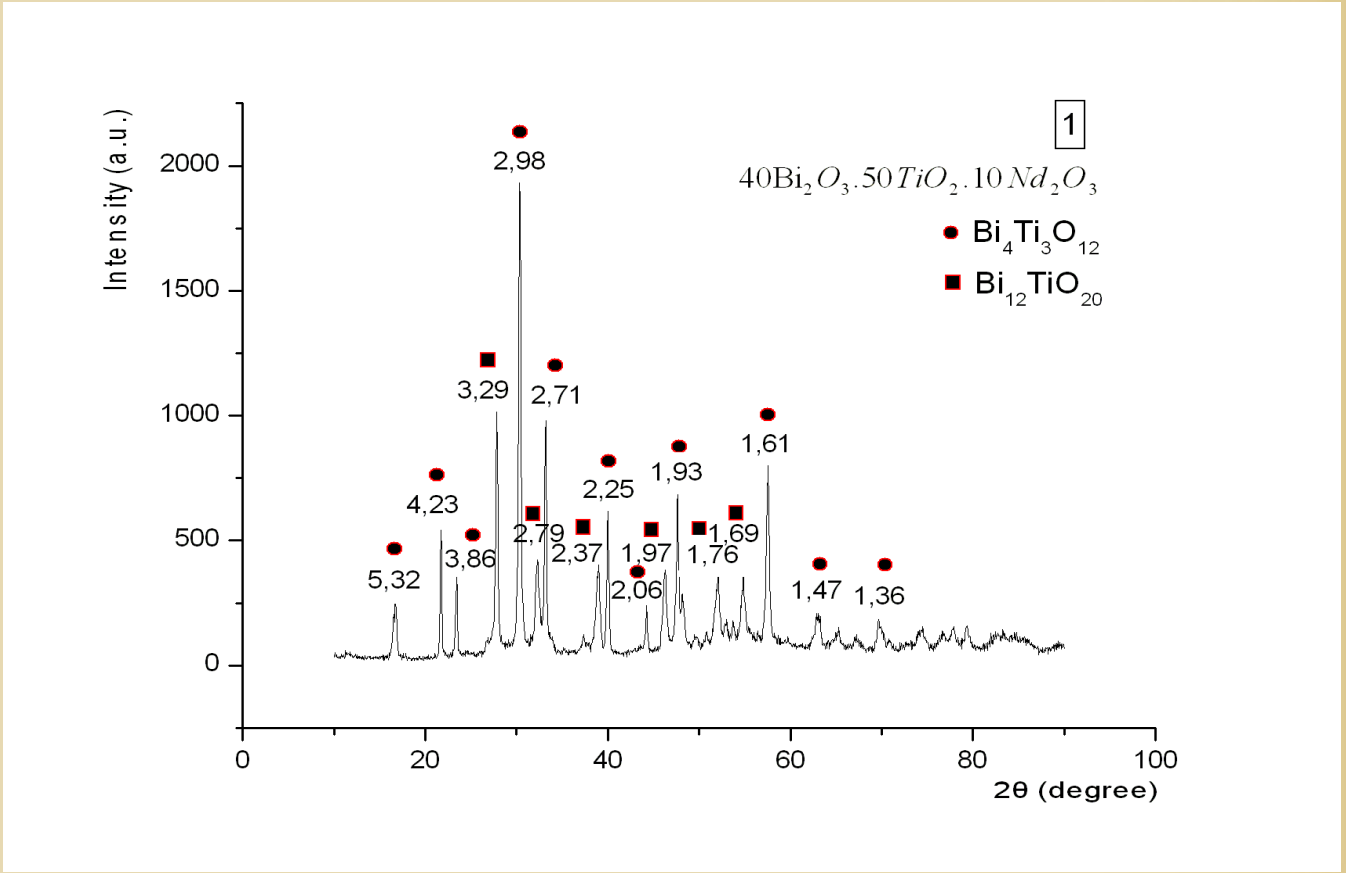
Results

0% SiO_2





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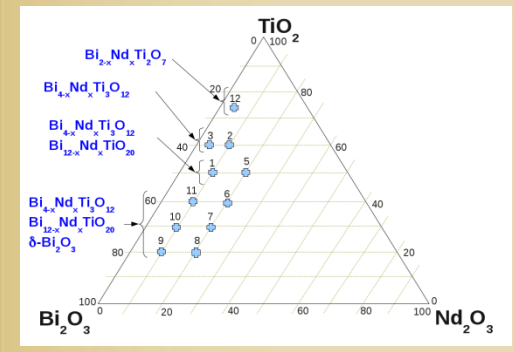

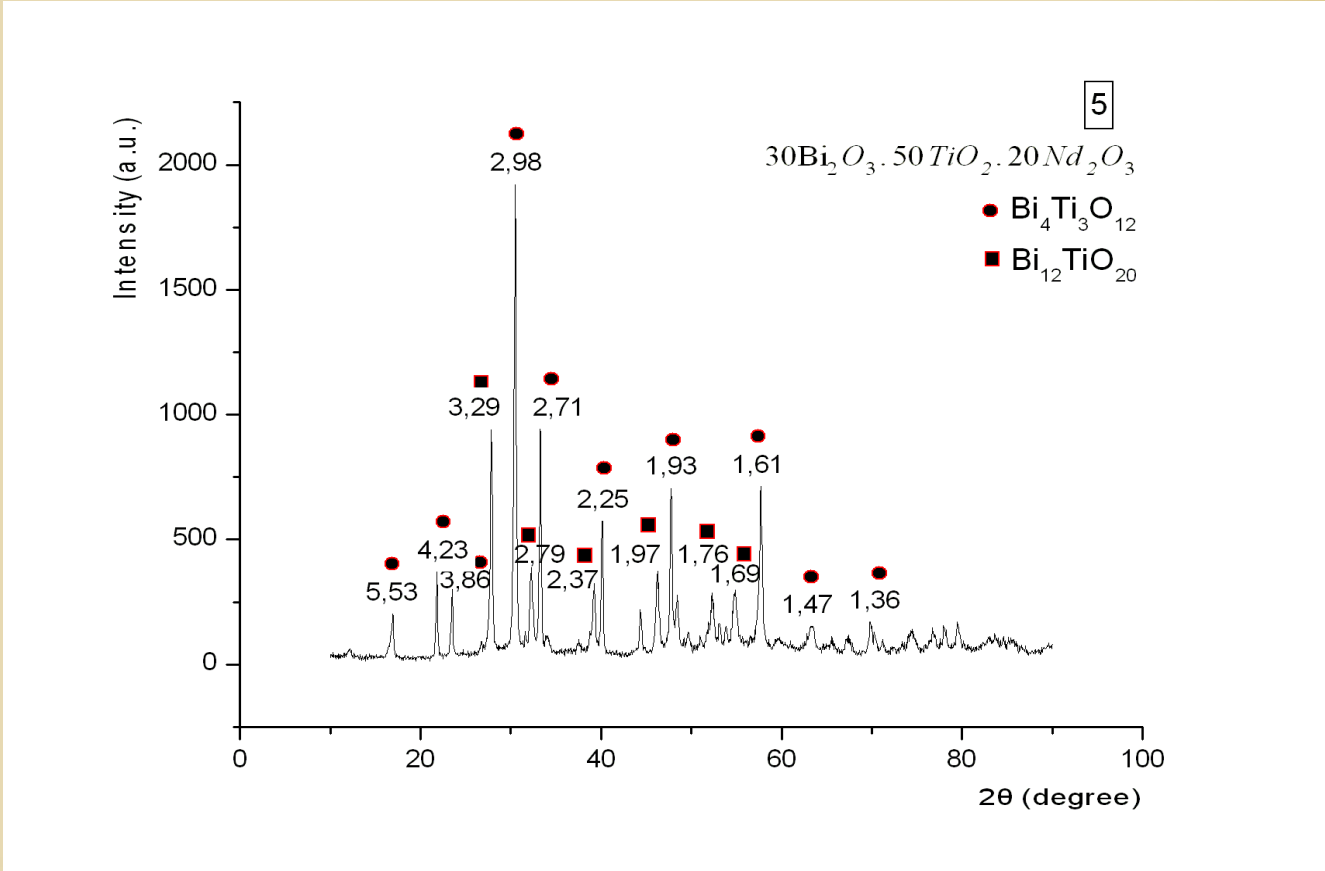

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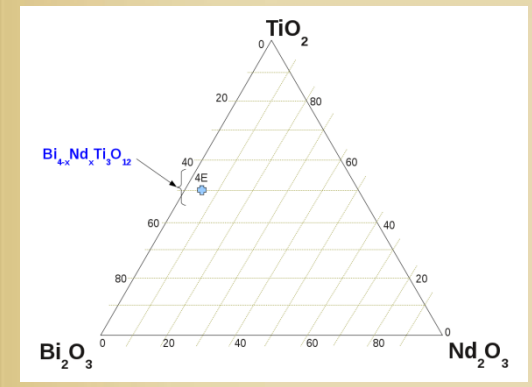

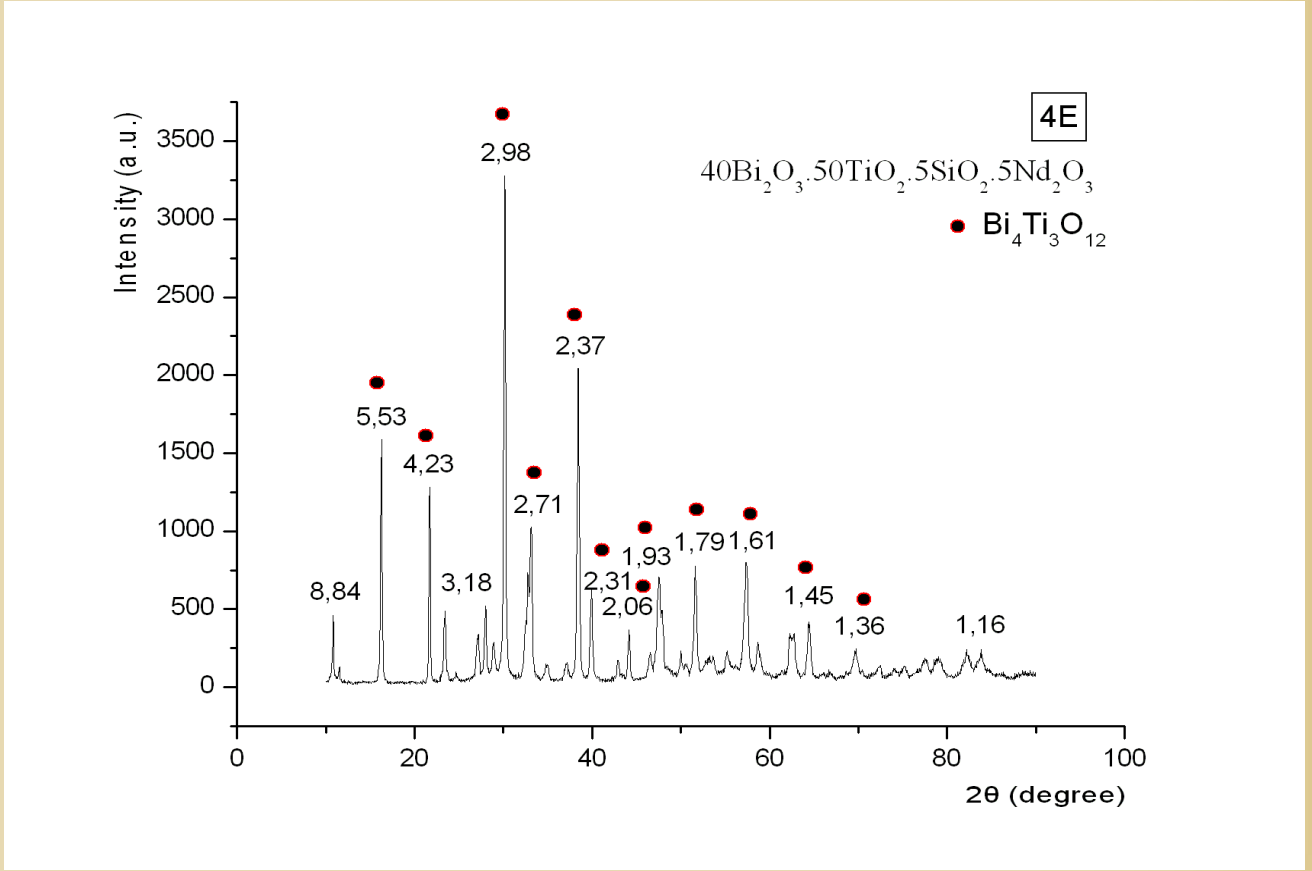

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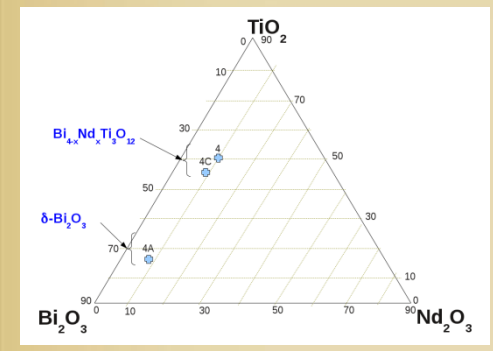
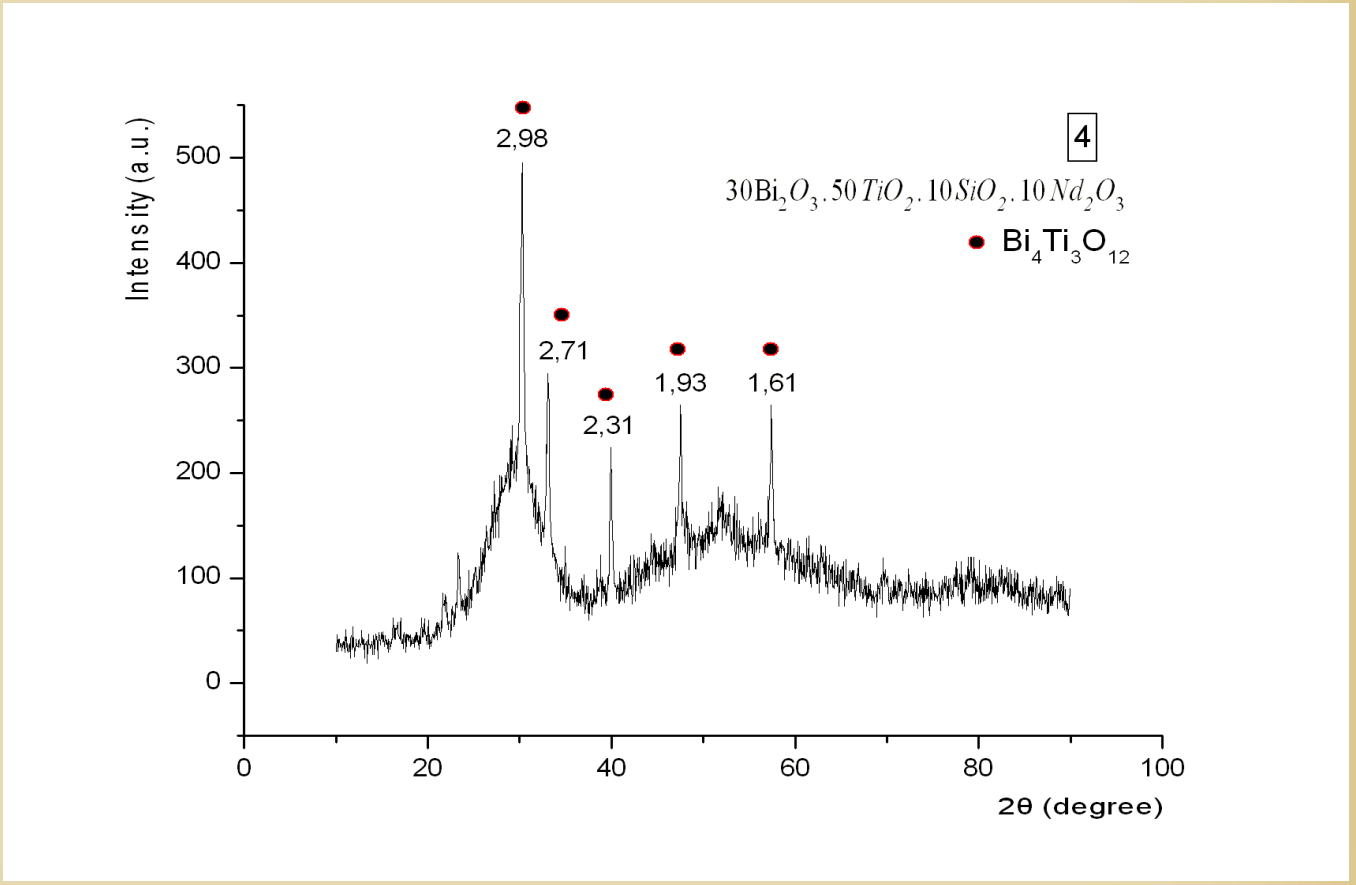
Results

10% SiO_2





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Results

Sample	Starting composition (mol %)				Indentified phases XRD
	Bi_2O_3	TiO_2	Nd_2O_3	SiO_2	
1	40	50	10	--	Bi4, Bi12
2	25	65	10	--	Bi4
3	35	60	5	--	Bi4
4	30	50	10	10	Bi4
5	30	50	20	--	Bi4, Bi12
6	40	40	20	--	Bi4, Bi12, δ
7	50	30	20	--	Bi4, Bi12, δ
8	60	20	20	--	Bi4, Bi12, δ
9	70	20	10	--	Bi4, Bi12, δ
10	60	30	10	--	Bi4, Bi12, δ
11	50	40	10	--	Bi4, Bi12, δ
12	21	72	7	--	P
4A	63	18	10	9	δ
4B	56	16	20	8	δ
4C	36	45	10	9	Bi4
4D	32	40	20	8	Bi4
4E	40	50	5	5	Bi4

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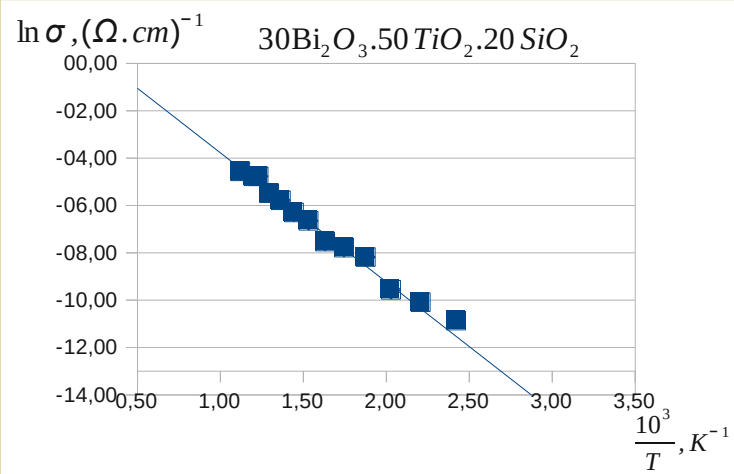
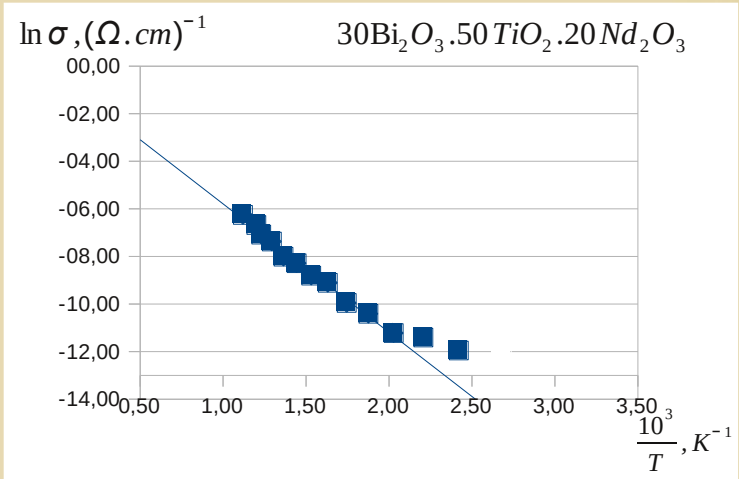
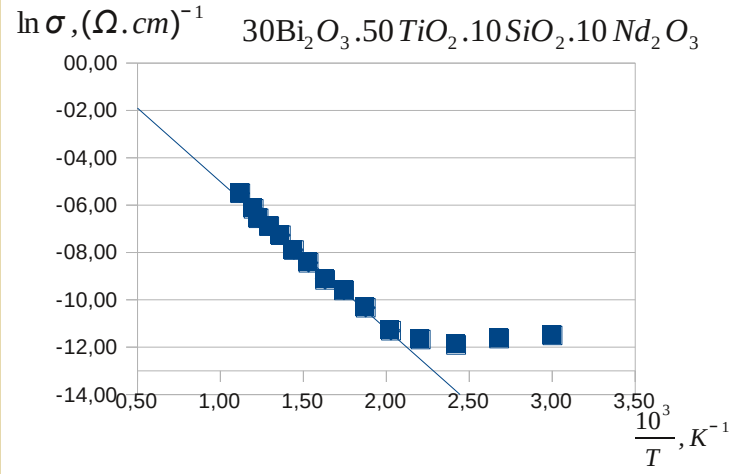
Results







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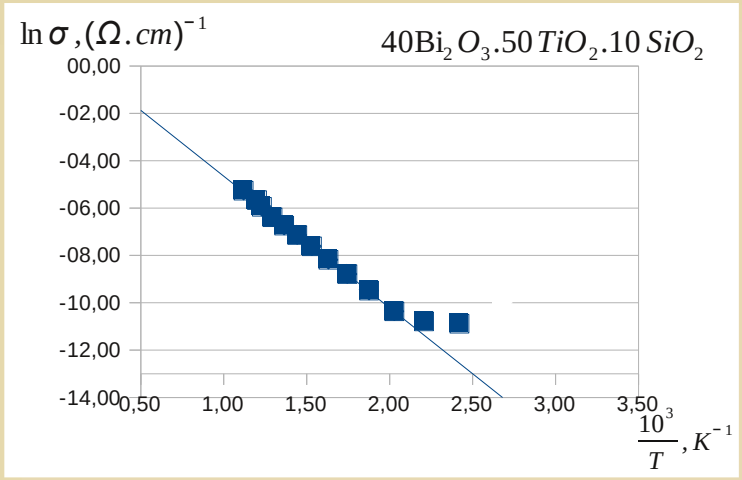

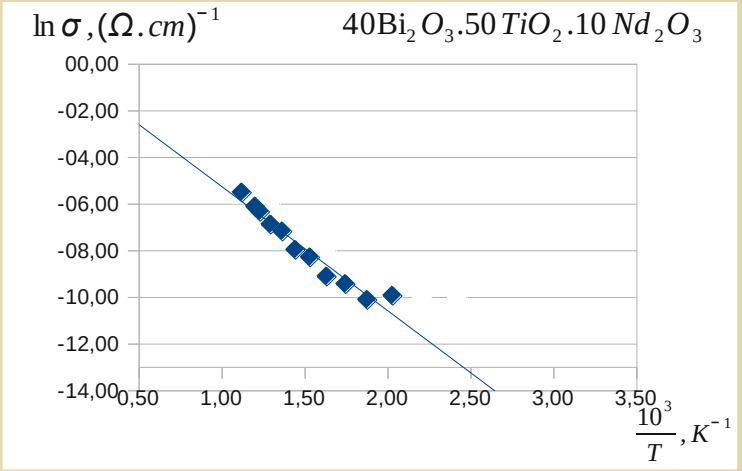

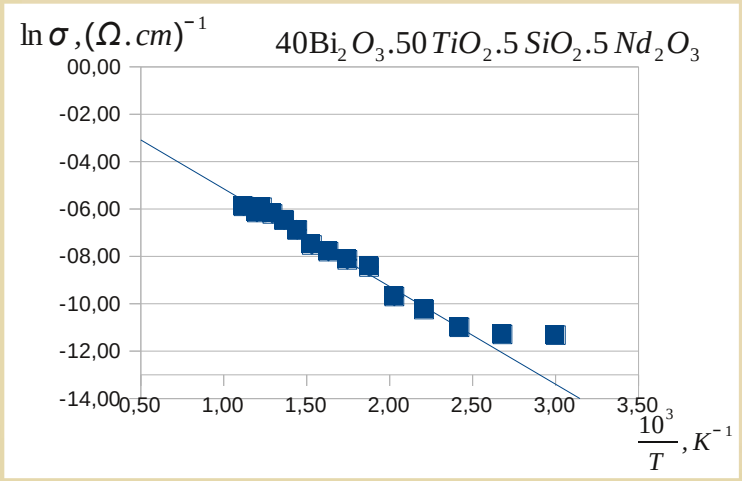

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Results

	Sample	Visual observation	Method of cooling	d, 10^{-3} m	σ, 10^{-7} $(\Omega.cm)^{-1}$	ΔE eV
A	$30Bi_2O_3.50TiO_2.20SiO_2$		T_m=1400 °C		33,10	1,21
		Black with milky regions	Fast Cooling	1,59		
4	$30Bi_2O_3.50TiO_2.10SiO_2.10Nd_2O_3$		T_m=1450 °C		1,29	1,38
		Dark silver	Fast Cooling	0,67		
5	$30Bi_2O_3.50TiO_2.20Nd_2O_3$		T_m=1500 °C		0,42	1,19
		Milk silver with yelow additives	Fast Cooling	0,75		
B	$40Bi_2O_3.50TiO_2.10SiO_2$		T_m=1260 °C		7,09	1,23
		Black with milky regions	Fast Cooling	0,63		
4E	$40Bi_2O_3.50TiO_2.5SiO_2.5Nd_2O_3$		T_m=1450 °C		6,19	1,14
		Milk silver	Fast Cooling	1,37		
1	$40Bi_2O_3.50TiO_2.10Nd_2O_3$		T_m=1450 °C		4,63	1,18
		Dark yelow with silver additives	Fast Cooling	0,89		

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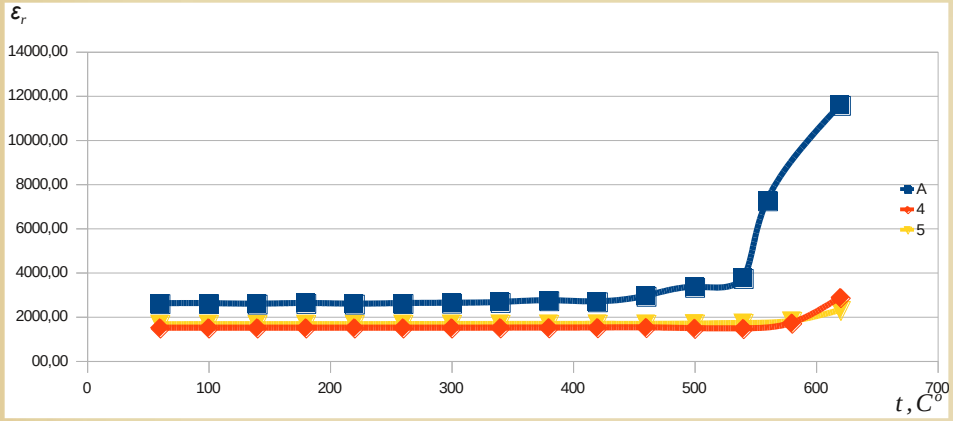
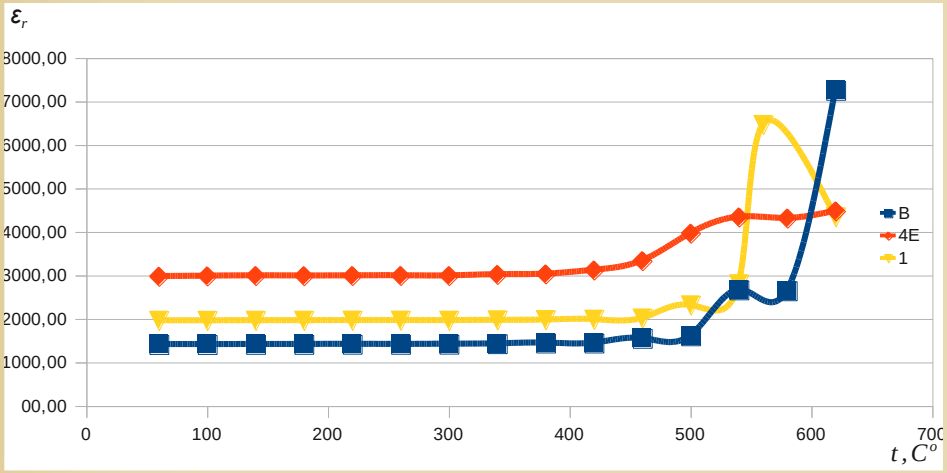
Results





Sample	
A	$30Bi_2O_3.50TiO_2.20SiO_2$
4	$30Bi_2O_3.50TiO_2.10SiO_2.10Nd_2O_3$
5	$30Bi_2O_3.50TiO_2.20Nd_2O_3$
B	$40Bi_2O_3.50TiO_2.10SiO_2$
4E	$40Bi_2O_3.50TiO_2.5SiO_2.5Nd_2O_3$
1	$40Bi_2O_3.50TiO_2.10Nd_2O_3$

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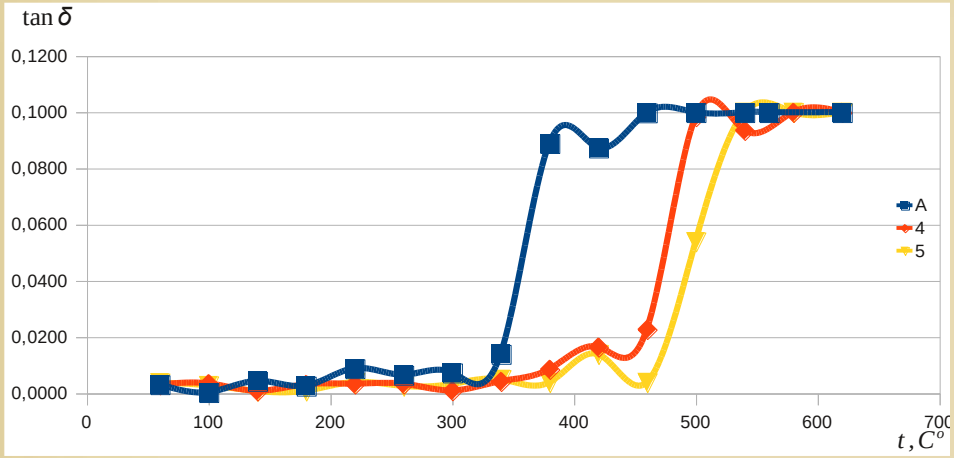

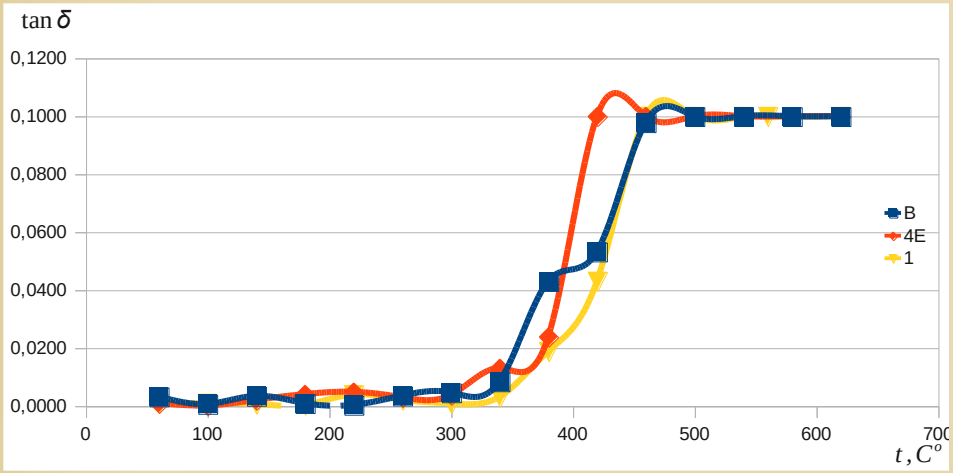

Sample	
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5	$30Bi_2O_3.50TiO_2.20Nd_2O_3$
B	$40Bi_2O_3.50TiO_2.10SiO_2$
4E	$40Bi_2O_3.50TiO_2.5SiO_2.5Nd_2O_3$
1	$40Bi_2O_3.50TiO_2.10Nd_2O_3$

Conclusion

1. The investigation carried out confirms that depending on the condition of the melting of the super-cooled melt different poly-phase glass-ceramic materials with various microstructure could be obtained containing mainly the bismuth titanate phase in the system Bi_2O_3-TiO_2-SiO_2-Nd_2O_3.

2. Addition of Nd_2O_3 in the samples leads to increase of the melting themperature and decrease of glass-formation tendensy.

3. It is established that all investigated samples are dielectric materials with conductivity between 10^{-9}-10^{-13} $(\Omega\ cm)^{-1}$ at room temperature, dielectic permetivity near 1000 to 3000 and dielectric losses tagδ between 0,0002 – 0,1.

4. Addition of SiO_2 in the samples leads to increasing of dielectric losses and conductivity.

Thanks for your attention