**Table 1.** Melting and annealing temperatures and the periods of them. In addition to glass transition temperatures of all samples (Tg).

| Sample sample | Ratio of O  **Oxides** | (Tg) | Tm (°C) | Time of stability  **(minutes)** | Annealing temperature Tan (°C) | Time of stability (minutes) |
| --- | --- | --- | --- | --- | --- | --- |
| GF1 | 70 | 413.6 | 1100 | 150 | 390 | 120 |
| GF2 | 60 | 431.8 | 1130 | 90 | 390 | 120 |
| GF3 | 50 | 457.0 | 1200 | 90 | 410 | 30 |
| GF4 | 70 | 396.3 | 1100 | 150 | 390 | 120 |
| GF5 | 60 | 390.7 | 1090 | 90 | 390 | 180 |
| GF6 | 50 | 418.2 | 1150 | 90 | 410 | 45 |
| GP1 | 70 | 431.8 | 1070 | 90 | 370 | 135 |
| GP2 | 60 | 431.0 | 1130 | 30 | 410 | 75 |
| GP3 | 50 | 455.6 | 1200 | 90 | 410 | 30 |
| GP4 | 70 | 432.2 | 1070 | 30 | 365 | 30 |
| GP5 | 60 | 417.0 | 1090 | 30 | 375 | 30 |
| GP6 | 50 | 425.8 | 1190 | 5 | 395 | 15 |
| GM1 | 70 | 372.8 | 1070 | 30 | 375 | 75 |
| GM2 | 60 | 427.8 | 1130 | 30 | 410 | 75 |
| GM3 | 50 | 454.2 | 1200 | 90 | 410 | 30 |
| GM5 | 60 | 409.3 | 1090 | 30 | 375 | 30 |
| GM6 | 50 | 423.7 | 1150 | 60 | 370 | 90 |
|  | | | | | | |
| Mix | 7.6 | 542.6 | 1380 | 5 | 25 | 0 |
|  | | | | | | |
| GFCe | 60 | 438.8 | 1160 | 5 | 395 | 30 |
| GPCe | 60 | 417.6 | 1160 | 5 | 395 | 30 |
| GMCe | 60 | 432.6 | 1160 | 5 | 395 | *30* |

**Table 2.** Ratios of oxides of the group GF.

| Oxides | GF1 | GF2 | GF3 | GF4 | GF5 | GF6 |
| --- | --- | --- | --- | --- | --- | --- |
| B2O3 | 2.63 | 3.51 | 4.38 | 2.07 | 2.88 | 3.71 |
| Na2O | 2.24 | 2.98 | 3.73 | 1.76 | 2.45 | 3.16 |
| MgO | 0.65 | 0.87 | 1.09 | 0.51 | 0.71 | 0.92 |
| Al2O3 | 1.87 | 2.49 | 3.11 | 1.47 | 2.04 | 2.63 |
| SiO2 | 17.51 | 23.35 | 29.18 | 13.78 | 19.19 | 24.72 |
| K2O | 2.32 | 3.09 | 3.87 | 8.22 | 9.66 | 10.92 |
| CaO | 1.32 | 1.76 | 2.20 | 1.04 | 1.45 | 1.87 |
| SrO | 0.56 | 0.75 | 0.93 | 0.44 | 0.61 | 0.79 |
| ZrO2 | 0.31 | 0.42 | 0.52 | 0.25 | 0.34 | 0.44 |
| Sb2O3 | 0.02 | 0.03 | 0.04 | 0.02 | 0.03 | 0.03 |
| BaO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| CeO2 | 0.16 | 0.21 | 0.27 | 0.13 | 0.17 | 0.22 |
| PbO | 69.50 | 59.34 | 49.18 | 69.61 | 59.46 | 49.30 |
| SnO | 0.02 | 0.03 | 0.04 | 0.02 | 0.02 | 0.03 |
| TiO2 | 0.18 | 0.24 | 0.30 | 0.14 | 0.20 | 0.25 |
| P2O5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bi2O3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| As2O3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3. Ratios of oxides of the group GP.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Oxides | GP1 | GP2 | GP3 | GP4 | GP5 | GP6 |
| B2O3 | 2.26 | 3.01 | 3.76 | 1.86 | 2.57 | 3.30 |
| Na2O | 2.03 | 2.71 | 3.39 | 1.68 | 2.32 | 2.97 |
| MgO | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 |
| Al2O3 | 0.60 | 0.79 | 0.99 | 0.49 | 0.68 | 0.87 |
| SiO2 | 16.42 | 21.89 | 27.36 | 13.54 | 18.71 | 23.96 |
| K2O | 1.70 | 2.26 | 2.82 | 6.67 | 7.76 | 8.69 |
| CaO | 0.28 | 0.37 | 0.47 | 0.23 | 0.32 | 0.41 |
| SrO | 2.85 | 3.79 | 4.74 | 2.35 | 3.24 | 4.15 |
| ZrO2 | 0.73 | 0.98 | 1.22 | 0.60 | 0.84 | 1.07 |
| Sb2O3 | 0.08 | 0.10 | 0.12 | 0.06 | 0.09 | 0.11 |
| BaO | 2.36 | 3.15 | 3.94 | 1.95 | 2.69 | 3.45 |
| CeO2 | 0.12 | 0.16 | 0.20 | 0.10 | 0.14 | 0.18 |
| PbO | 70.00 | 60.00 | 50.01 | 70.00 | 59.99 | 50.00 |
| SnO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TiO2 | 0.10 | 0.13 | 0.17 | 0.08 | 0.11 | 0.15 |
| P2O5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bi2O3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| As2O3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 4. Ratios of oxides of the group GM and samples that have 1% of CeO2.

| Oxides | GM1 | GM2 | GM3 | GM4 | GM5 | GM6 | GFCe | GPCe | GMCe |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| B2O3 | 2.02 | 2.69 | 3.36 | 1.64 | 2.27 | 2.91 | 3.42 | 2.94 | 2.62 |
| Na2O | 1.99 | 2.66 | 3.32 | 1.62 | 2.25 | 2.88 | 2.91 | 2.65 | 2.59 |
| MgO | 0.25 | 0.33 | 0.41 | 0.20 | 0.28 | 0.36 | 0.85 | 0.03 | 0.32 |
| Al2O3 | 0.89 | 1.19 | 1.48 | 0.72 | 1.00 | 1.28 | 2.43 | 0.77 | 1.16 |
| SiO2 | 16.94 | 22.58 | 28.23 | 13.77 | 19.07 | 24.47 | 22.76 | 21.36 | 22.04 |
| K2O | 2.14 | 2.85 | 3.56 | 7.36 | 8.63 | 9.74 | 3.02 | 2.20 | 2.78 |
| CaO | 0.50 | 0.67 | 0.84 | 0.41 | 0.57 | 0.73 | 1.72 | 0.37 | 0.66 |
| SrO | 2.24 | 2.98 | 3.73 | 1.82 | 2.52 | 3.23 | 0.73 | 3.70 | 2.91 |
| ZrO2 | 0.66 | 0.88 | 1.10 | 0.54 | 0.75 | 0.96 | 0.41 | 0.95 | 0.86 |
| Sb2O3 | 0.05 | 0.06 | 0.08 | 0.04 | 0.05 | 0.07 | 0.03 | 0.10 | 0.06 |
| BaO | 1.85 | 2.47 | 3.08 | 1.50 | 2.08 | 2.67 | 0.00 | 3.08 | 2.41 |
| CeO2 | 0.12 | 0.16 | 0.20 | 0.10 | 0.14 | 0.17 | 1.20 | 1.14 | 1.13 |
| PbO | 69.66 | 59.55 | 49.43 | 69.72 | 59.61 | 49.51 | 59.36 | 60.00 | 59.56 |
| SnO | 0.20 | 0.27 | 0.34 | 0.16 | 0.23 | 0.29 | 0.03 | 0.00 | 0.26 |
| TiO2 | 0.14 | 0.19 | 0.23 | 0.11 | 0.16 | 0.20 | 0.23 | 0.13 | 0.18 |
| P2O5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bi2O3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| As2O3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 5.** Densities and refractive indexes of samples.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| The sample | Ratio of PbO (%) | Density (g.cm-3) (± 0.01) | Refractive index Nd at (655 ± 25 nm) (± 3.5%) | Thickness of sample after polishing (mm) (± 0.05 mm) |
| GF1 | 70 | 5.26 | 1.906 | 5.10 |
| GF2 | 60 | 4.72 | 1.807 | 2.80 |
| GF3 | 50 | 4.11 | 1.790 | 5.60 |
| GF4 | 70 | 5.12 | 1.813 | 5.70 |
| GF5 | 60 | 4.55 | 1.746 | 6.05 |
| GF6 | 50 | 4.07 | 1.734 | 6.35 |
| GP1 | 70 | 4.79 | 1.827 | 6.30 |
| GP2 | 60 | 4.92 | 1.880 | 6.35 |
| GP3 | 50 | 4.41 | 1.760 | 4.60 |
| GP4 | 70 | 5.28 | 1.908 | 6.40 |
| GP5 | 60 | 4.61 | 1.842 | 3.25 |
| GP6 | 50 | 4.24 | 1.700 | 6.35 |
| GM1 | 70 | 5.38 | 1.833 | 6.25 |
| GM2 | 60 | 4.97 | 1.807 | 6.35 |
| GM3 | 50 | 4.36 | 1.689 | 4.10 |
| GM5 | 60 | 4.61 | 1.856 | 6.40 |
| GM6 | 50 | 4.19 | 1.743 | 5.80 |
| Mix | 7.6 | 2.88 | 1.505 | 4.10 |

Table 6. Attenuation coefficients experimentally and theoretically (XCOM code).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| The sample | Density (g.cm-3) | Experimental attenuation coefficients (cm-1) | | Theoretical attenuation coefficients by using the code XCOM (cm-1) | | | |
|  |  | At energy Co-60 (keV) | | At energies (keV) | | | |
| X-Ray | Cs-137 | Co-60 | |
| 1332.5 | 1173.24 | 100 | 661.6 | 1173.24 | 1332.5 |
| GF1 | 5.26 | 0.32 | | 19.18 | 0.52 | 0.32 | 0.29 |
| GF2 | 4.72 | 0.22 | | 14.86 | 0.45 | 0.28 | 0.26 |
| GF3 | 4.11 | 0.23 | | 10.84 | 0.38 | 0.25 | 0.23 |
| GF4 | 5.12 | 0.32 | | 18.70 | 0.50 | 0.31 | 0.28 |
| GF5 | 4.55 | 0.27 | | 14.33 | 0.43 | 0.27 | 0.25 |
| GF6 | 4.07 | 0.22 | | 10.78 | 0.37 | 0.24 | 0.23 |
| GP1 | 4.79 | 0.31 | | 17.87 | 0.47 | 0.29 | 0.27 |
| GP2 | 4.92 | 0.30 | | 16.00 | 0.47 | 0.29 | 0.27 |
| GP3 | 4.41 | 0.23 | | 12.26 | 0.41 | 0.26 | 0.24 |
| GP4 | 5.28 | 0.28 | | 19.66 | 0.52 | 0.32 | 0.29 |
| GP5 | 4.61 | 0.29 | | 14.96 | 0.44 | 0.28 | 0.25 |
| GP6 | 4.24 | 0.25 | | 11.71 | 0.39 | 0.25 | 0.23 |
| GM1 | 5.38 | 0.32 | | 19.93 | 0.53 | 0.33 | 0.30 |
| GM2 | 4.97 | 0.29 | | 15.99 | 0.47 | 0.30 | 0.27 |
| GM3 | 4.36 | 0.26 | | 11.91 | 0.40 | 0.26 | 0.24 |
| GM5 | 4.61 | 0.28 | | 14.82 | 0.44 | 0.28 | 0.26 |
| GM6 | 4.19 | 0.24 | | 11.43 | 0.39 | 0.25 | 0.23 |
| Mix | 2.88 | 0.17 | | 1.92 | 0.23 | 0.17 | 0.16 |
| GFCe | 4.74 | 0.30 | | 15.01 | 0.45 | 0.29 | 0.26 |
| GPCe | 4.93 | 0.32 | | 16.12 | 0.47 | 0.29 | 0.27 |
| GMCe | 4.85 | 0.30 | | 15.68 | 0.46 | 0.29 | 0.27 |
| *Pb* | 11.342 | 0.66 | | 62.94 | 1.25 | 0.70 | 0.64 |

**Table 7.** The half value and tenth value layers, in addition to the lead equivalent.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| The sample | Half value layers at isotope’s energies (cm) | | Tenth value layers at isotope’s energies (cm) | | The lead equivalent for 1 cm thickness of each sample at isotope’s energies (cm) | |
|  | Co-60 | Cs-137 | Co-60 | Cs-137 | Co-60 | Cs-137 |
| GF1 | 2.24 | 1.33 | 7.43 | 4.43 | 0.47 | 0.45 |
| GF2 | 2.57 | 1.54 | 8.53 | 5.12 | 0.41 | 0.39 |
| GF3 | 2.89 | 1.82 | 9.59 | 6.06 | 0.36 | 0.33 |
| GF4 | 2.31 | 1.39 | 7.68 | 4.61 | 0.45 | 0.43 |
| GF5 | 2.67 | 1.61 | 8.86 | 5.35 | 0.39 | 0.37 |
| GF6 | 3.01 | 1.87 | 10.01 | 6.22 | 0.35 | 0.32 |
| GP1 | 2.48 | 1.47 | 8.22 | 4.90 | 0.42 | 0.41 |
| GP2 | 2.48 | 1.47 | 8.22 | 4.90 | 0.42 | 0.41 |
| GP3 | 2.77 | 1.69 | 9.21 | 5.62 | 0.38 | 0.36 |
| GP4 | 2.24 | 1.33 | 7.43 | 4.43 | 0.47 | 0.45 |
| GP5 | 2.57 | 1.58 | 8.53 | 5.23 | 0.41 | 0.38 |
| GP6 | 2.89 | 1.78 | 9.59 | 5.90 | 0.36 | 0.34 |
| GM1 | 2.17 | 1.31 | 7.20 | 4.34 | 0.48 | 0.46 |
| GM2 | 2.39 | 1.47 | 7.94 | 4.90 | 0.44 | 0.41 |
| GM3 | 2.77 | 1.73 | 9.21 | 5.76 | 0.38 | 0.35 |
| GM5 | 0.03 | 1.58 | 0.09 | 5.23 | 0.41 | 0.38 |
| GM6 | 2.89 | 1.78 | 9.59 | 5.90 | 0.36 | 0.34 |

**Table 8.** Ratios of oxides of CRT parts analyzed by SEM-EDX.

| Oxides | Panel | Funnel | Mixture | Neck |
| --- | --- | --- | --- | --- |
| B2O3 | 7.53 | 6.90 | 6.21 | 5.37 |
| Na2O | 6.78 | 5.86 | 6.15 | 1.58 |
| MgO | 0.07 | 1.71 | 0.76 | 0.18 |
| Al2O3 | 1.98 | 4.89 | 2.74 | 2.45 |
| SiO2 | 54.72 | 45.92 | 52.20 | 43.21 |
| K2O | 5.65 | 6.08 | 6.59 | 7.11 |
| CaO | 0.94 | 3.47 | 1.55 | 1.30 |
| SrO | 9.48 | 1.47 | 6.89 | 2.27 |
| ZrO2 | 2.44 | 0.82 | 2.04 | 0.37 |
| Sb2O3 | 0.25 | 0.06 | 0.14 | 0.69 |
| BaO | 7.88 | 0.00 | 5.70 | 0.42 |
| CeO2 | 0.41 | 0.42 | 0.37 | 0.44 |
| PbO | 0.00 | 20.03 | 6.50 | 33.15 |
| SnO | 0.00 | 0.06 | 0.62 | 0.11 |
| TiO2 | 0.33 | 0.47 | 0.43 | *0.21* |

**Table 9.** Weights of added components of mixtures for samples.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| The sample | Weights of added glasses (g) | | | Weights of added raw materials (g) | | |
|  | Funnel | Panel | Mix | Pb3O4 | K2CO3 | CeO2 |
| The first step of samples | | | |  | | |
| GF1 | 80 | - | - | 132.9 | - | - |
| GF2 | 100 | - | - | 99 | - | - |
| GF3 | 120 | - | - | 70.5 | - | - |
| GF4 | 80 | - | - | 149.2 | 10 | - |
| GF5 | 100 | - | - | 125.2 | 25 | - |
| GF6 | 120 | - | - | 87.9 | 25 | - |
| GP1 | - | 80 | - | 191.1 | - | - |
| GP2 | - | 100 | - | 153.6 | - | - |
| GP3 | - | 120 | - | 122.9 | - | - |
| GP4 | - | 80 | - | 231.8 | 25 | - |
| GP5 | - | 100 | - | 179.7 | 25 | - |
| GP6 | - | 120 | - | 140.3 | 25 | - |
| GM1 | - | - | 80 | 170.5 | - | - |
| GM2 | - | - | 100 | 134.3 | - | - |
| GM3 | - | - | 120 | 104.3 | - | - |
| GM5 | - | - | 100 | 160.4 | 25 | - |
| GM6 | - | - | 120 | 121.8 | 25 | - |
| The second step of samples | | | |  | | |
| GFCe | 100 | - | - | 102.1 | - | 2 |
| GPCe | - | 100 | - | 157.4 | - | 2.5 |
| *GMCe* | - | - | 100 | 137.8 | - | 2.3 |

**Table 10.** Ratios of added components of mixtures.

| Sample | Ratios of added glasses (%) | | | Ratios of added Oxides (%) | | |
| --- | --- | --- | --- | --- | --- | --- |
|  | Funnel | Panel | Mix | PbO | K2O | CeO2 |
| The first step of samples | | | |  | | |
| GF1 | 38.1 | - | - | 61.9 | - | - |
| GF2 | 50.8 | - | - | 49.2 | - | - |
| GF3 | 63.5 | - | - | 36.5 | - | - |
| GF4 | 34.4 | - | - | 62.7 | 2.9 | - |
| GF5 | 41.8 | - | - | 51.1 | 7.1 | - |
| GF6 | 53.8 | - | - | 38.5 | 7.7 | - |
| GP1 | - | 30 | - | 70 | - | - |
| GP2 | - | 40 | - | 60 | - | - |
| GP3 | - | 50 | - | 50 | - | - |
| GP4 | - | 24.7 | - | 70 | 5.3 | - |
| GP5 | - | 34.2 | - | 60 | 5.8 | - |
| GP6 | - | 43.8 | - | 50 | 6.2 | - |
| GM1 | - | - | 32.5 | 67.5 | - | - |
| GM2 | - | - | 43.3 | 56.7 | - | - |
| GM3 | - | - | 54.1 | 45.9 | - | - |
| GM5 | - | - | 36.5 | 57.2 | 6.3 | - |
| GM6 | - | - | 46.9 | 46.5 | 6.6 | - |
| The second step of samples | | | |  | | |
| GFCe | 49.6 | - | - | 49.4 | - | 1 |
| GPCe | - | 39 | - | 60 | - | 1 |
| *GMCe* | - | - | 42.2 | 56.8 | - | 1 |