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Electrical properties of selected types of glass as candidates for the manufacture of metal-glass structures by melt extrusion

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Summary: In the present study the chemical composition and electrical properties of three glass samples: quartz glass, sodium glass, and tempered glass were analyzed. Using SEM-EDS, it was identified that besides the Si, such elements like Na, Mg, Al, K or Ca in sodium and tempered glass were present. Electrical resistivity results indicated that doping with these elements significantly reduced resistivity compared to undoped quartz glass.

Key words: copper, glass, additive manufacturing, extrusion melting process

1. MOTIVATION AND DESCRIPTION OF WORK

Glass is highly valued for its chemical, mechanical, and optical properties, as well as its thermal stability and insulating capabilities, making it essential in technology and electronics. However, its forming and shaping processes require large amounts of energy. Additive manufacturing, or 3D printing, offers a solution for creating complex structures and is gaining popularity in materials manufacturing, including polymers, ceramics, and metals. This paper presents the research results obtained during the course of a project aimed at developing an innovative material concept for electronic applications, based on copper as a highly conductive material and glass as an insulating one, produced by the melt extrusion process. An important issue studied in the project is the question of achieving good adhesion of printed copper with glass. Therefore, to improve adhesion, it uses glass with a modified composition, which, however, affects the electrical properties of the glass itself.

2. RESULTS

Quartz glass was used as a reference material, while sodium glass is typically used for the manufacture of window glass, and tempered (protective) glass. The chemical composition and its effect on the electrical properties (volume resistivity) were analyzed. The study performed using the SEM-EDS method indicated that window glass and protective glass, in addition to silicon, consisted of Na, Mg, Al and also K, in the case of protective glass, and Ca, in the case of window glass. Electrical resistivity was determined using a Keithley (6517A) electrometer with a special own-build measurement fixture developed in accordance with standards [1,2]. The measurement was performed using the recommended procedure for determining the volume resistivity of high-resistivity materials. The measurement procedure included the so-called pre-discharge of the test sample for 10s to allow any charge to dissipate, biasing the sample with 500V for 1s which allows currents in the test sample to stabilize, applying the measurement voltage of 500V and discharging the sample for 2s. Results of the performed tests are summarized in Tab. 1 and in Fig. 1.

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Tab.1. Selected properties of investigated glass samples

Glass sample	Composition	Thickness (mm)	Electrical resistivity (Ωcm)
SiO_2	Si	0.49	$(1.035 \pm 0.096) \cdot 10^{15}$
Tempered glass	Na, Mg, Al, Si, K	0.34	$(3.701 \pm 0.142) \cdot 10^{14}$
Window glass	Na, Mg, Al, Si, Ca	1.87	$(9.856 \pm 0.142) \cdot 10^{13}$

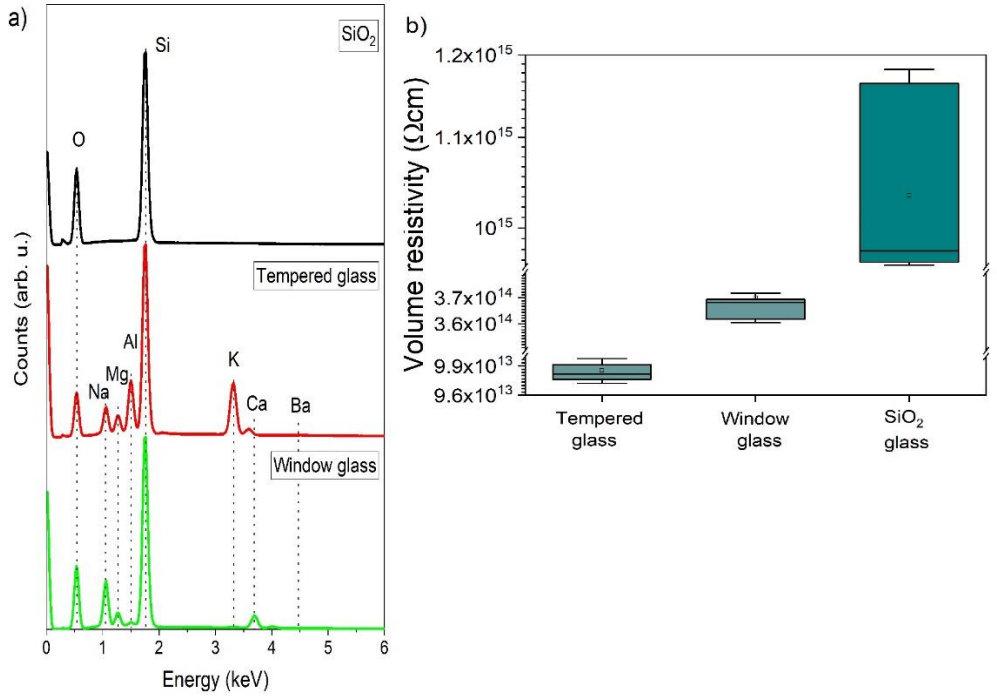

Fig. 1. Results of: a) EDS and b) electrical resistivity measurements of selected glass test samples

Performed measurements show the effect of doping on the electrical properties of selected glass samples. The addition of components such as Na, Mg, Al, K or Ca results in a reduction of the material's resistivity by one to two orders of magnitude compared to undoped quartz glass. Further work planned in the project will focus on fabricating glasses with appropriately selected additives to achieve the best possible adhesion of printed copper conductive lines to glass substrates.

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3. REFERENCES

[1] ASTM Standards, C657-19 Standard Test Method for D-C Volume Resistivity of Glass

[2] ASTM Standards, D257 – 07 Standard Test Methods for DC Resistance or Conductance of Insulating Materials