Glass binding agents for nanocomposite materials for thick film hybrid integrated circuits

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Introduction

Modern multilevel hybrid integrated circuits (HIC) and microelectronic sensors are widely used as thick-film functional elements of nanodispersed composites based on "glass-metal compounds", which represent a multiphase heterogeneous system consisting of powders of a functional material, glass powders, organic compounds and are formed by annealing. The formation of composites is accompanied by complex physicochemical processes that determine, under the selected annealing modes, the phase composition, microstructure, and electrophysical parameters (EPhP). One of the main structural elements that determine the relationship between the structure and the nanocomposite (EPhP) is the glass component.

The glasses perform two functions: they keep the particles of the functional material in contact and ensure the fixation of the composition on the substrate. By ensuring the stability of the glass component characteristics it will be possible to solve the problems associated with negative processes occurring in nanocomposite over time and causing HIC failure.

Methods

Experimental studies on the development of new glass compositions were carried out using the method of constructing diagrams of multicomponent systems based on a picture of sections by hyperplanes with a given percentage of one or more components of multidimensional figures depicting systems in multidimensional space (fig.1).

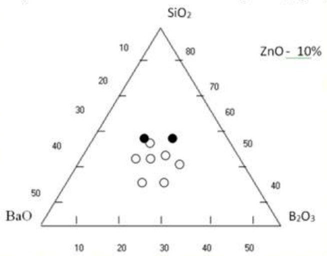

Fig.1. Skilting in the SiO_2-B_2O_3-Bi_2O_3-BaO-ZnO ZnO systems at a brew glass 1430⁰C. (● -- milky colored glasses, ○ – glazed glass).

The method makes it possible to find out the influence of the components of the systems on the glasses properties. Glasses were obtained by melting the charge in a fiery gas furnace. The charge was made up of quartz sand, chemically pure barium carbonate, boric acid, and bismuth dioxide. Glass melting was carried out at temperatures of 900-1200°C in porcelain. A neutral environment was maintained in the furnace during the entire cooking process. Samples were annealed in an electric muffle at a temperature of 300-350°C for 1 h. Cooling was carried out inertially together with the furnace during the day. The glass crystallization ability was determined by the gradient method in the range of 400-800°C with a two-hour exposure. The temperature in the gradient furnace was maintained automatically. When studying the crystallization ability, the temperature of the upper and lower crystallization boundaries was visually determined. The beginning of softening was recorded by a dial indicator with a graduation value of 0.002 mm. The linear thermal expansion coefficient (LTEC) was measured by the dilatometric method in the temperature range 20-400°C. The chemical stability of the experimental glasses was determined by the accelerated powder method with respect to the action of water, alkali and acids.

Results and discussion

The glass component is a complex system, divided into two main parts: unchanged (main) - an alloy of silex, which in most glasses is 60% of weight and variable - metal oxides, and besides their nature and ratio determine the main properties of glasses. Analysis showed that it is advisable to use borosilicate glasses as a glass component, which contain oxides of barium, zinc and bismuth. Bismuth oxide promotes stabilization dielectric constant of pastes, does not affect the conductive and is introduced into the glass composition as a neutral material in this respect. It also improves the wetting and adhesion of glass to the substrate, takes part in the structure creation as a glass former, and replaces toxic lead oxide. In this work, the SiO_2-B_2O_3-Bi_2O_3-BaO-ZnO system was studied.

As shown by experimental data, with an increase in temperature brew glass from 1300 ° C (the first series of glasses) to 1430 ° C, brew glass properties are significantly improved. If in the first series were obtained opaque milky color glasses, then with an increase in the melting temperature to 1430°C, the area of transparent glasses increases.

The research results showed that glasses containing boron oxide concentration from 5 to 15 mol% partially crystallize, forming a crystal crust (fig.2).

Fig.2. Surface of a nanocomposite film in the presence of a crystal crust on the surface. Increase -500.

An increase in the concentration of B_2O_3 in the glass composition enhances the crystallization ability. The measured softening temperature of the studied glasses is within 440-635⁰C. To reduce the softening temperature of the glasses, CdO was introduced into the above system, and BaO was replaced with MgO.

Thus, the SiO_2-B_2O_3-Bi_2O_3-ZnO-CdO-MgO system was obtained, a part of which, namely $xSiO_2$-yB_2O_3-$30Bi_2O_3$-zZnO-10CdO-2.5MgO, was studied.

Experimental data have shown that glasses well boiled and clarify under experimental conditions, although on the surface of the molten glass they have an insignificant floating crust in the form of a gray bloom. The cooking temperature does not exceed 1000 ° C. Cadmium oxide provides a beneficial effect on the improvement of glass formation processes (lowering the cooking temperature to 900°C). It was established by preliminaries that in a given section the glasses are resistant to crystallization and remain transparent during heat treatment in the entire temperature range (fig.3).

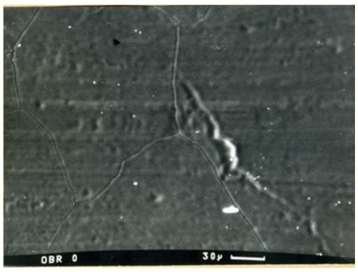

Fig.3. Surface of a crystallization-resistant nanocomposite film. Increase -500.

Analysis and generalization of the results of studying of the SiO_2-B_2O_3-Bi_2O_3-ZnO-MgO-CdO system glasses properties made it possible to suggest that an increase in the softening onset temperature and a decrease in LTEC of these glasses depend on their chemical composition and are determined by the characteristics of the cations included in the glass structural network.

` Studies have shown that the tested glasses are resistant to water. The weight loss of the powder upon boiling for five hours in water ranged from 0.01 to 0.05% of weight. Zinc oxide is most effective in increasing the chemical resistance to water. It has been established that the water resistance of glasses mainly depends on boron and zinc and increases in inverse proportion to the increase in the content of B_2O_3.

Conclusion

We found that the glass component of nanocomposites provides the distribution of particles of the functional material and adhesion to the substrate. When choosing a glass composition, it is necessary to take into account the dependence of its viscosity on temperature, substrate wetting, chemical activity, thermal expansion coefficient, and crystallization features. These properties of glass affect the modes of heat treatment of nanocomposites, the formation of mechanical bonds between the grains of the functional material and the resistivity of the film. It was found that an increase in the softening temperature and a decrease in the LTEC of glasses depend on their chemical composition and are determined by the characteristics of the cations included in the structural glass network.

It has been established that the water resistance of glasses mainly depends on boron and zinc and increases in inverse proportion to the increase in the content of B_2O_3. The composition of the material is protected by a patent of Ukraine.

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