The rapid development of new techniques and new production processes constantly demands the development of new structural materials. Such materials should work reliably when exposed to corrosive media, intense wear, high and low temperatures, and a deep vacuum.

To manufacture materials with such properties, powder metallurgy methods which permit synthesizing materials with special properties, using metallic and nonmetallic constituents, are being applied ever more frequently. Examples of such materials are cermets with a metallic binder, metal-oxide materials of the SAP type, etc. Reports on the use of metal-glass materials manufactured by the powder metallurgy methods have recently appeared in the literature.

Metal-glass materials usually have mechanical properties which are determined by the metallic phase with consideration of its porosity and good corrosion resistance since the open pores are filled with glass which eliminates access of corrosive reagents into the material.

With the proper selection of the composition of the metallic constituent and the material of the mate, metal-glass materials can have a high wear resistance, since in this case it is easy to fulfill the basic rule of developing a wear-resistant material—the combination of a soft metallic matrix with hard vitreous inclusions.

In view of the importance which the vitreous state has acquired in metal-glass materials, we need examine the main information on the nature of the vitreous state, properties of glass, and the processes of the interaction of metal with molten glass.

Structure of Glass and Its Properties

Vitreous materials are amorphous, metastable, and isotropic substances. A characteristic feature of molten glass is the increase in viscosity upon a drop of temperature, the process of solidification occurring without the formation of a new phase. The structure of glass can be examined as the accumulation of an enormous number of extremely small (12-15 A) appreciably deformed crystals or crystallites. It is assumed that in the central part the crystallite has a structure which is closest to the structure of a crystal lattice and on moving to the periphery it has an amorphous structure.

An extremely important characteristic of glass is its viscosity. During founding the viscosity of glass should be no more than 100 poise, when pressing parts no more than 4·10^8 poise, and when sintering no more than 10^9 poise [12]. Experience has established that SiO_2, Al_2O_3, ZrO_2, MgO increase viscosity and Na_2O, K_2O, Li_2O, PbO, BaO, and ZnO lower it.

Boron anhydride B_2O_3 appreciably increases the viscosity of glass at a high temperature. Its effect on viscosity at low temperature depends on the content; up to 15% B_2O_3 increases viscosity and at a higher content it decreases viscosity. Calcium oxide CaO at a low temperature increases the viscosity of glass. At a high temperature it lowers the viscosity of glass when the content is less than 10% and increases the viscosity at a higher content. The dependence of the viscosity of industrial glass (based on the data in the literature), is shown in the figure.

An important characteristic of glass is its thermostability which is determined by the linear coefficient of expansion, elasticity, and heat capacity. Glasses with a low linear coefficient of expansion (for example, quartz and borosilicate glasses with a low content of alkali oxides) have the greatest thermostability. Glasses containing a high content of alkali oxides have a higher linear coefficient of expansion and, accordingly, a low thermostability.
Temperature dependence of the viscosity of certain industrial glasses: 1) "Standard glass" of composition Na₂O · 2SiO₂ [13]; 2) Zs-4 [13]; 3) 152/34 [13]; 4) electric-bulb glass [15]; 5) No. 23 [15]; 6) plate [13]; 7) bottle [19]; 8) Zs-5K [13]; 9) No. 25 [15]; 10) Ts-32 [15]; 11) pyrex [13].

Chemical resistance is an important characteristic of glass. According to current concepts [2], silicates on a glass surface react with water or moisture, forming caustic alkalis and silicate gel. The caustic alkali is washed off the surface and the gel remains on the surface of the glass, forming a dense film. The rate of destruction of glass is determined by the rate of hydrolysis of the silicates and the rate of diffusion of water and of the decomposition product through the protective film. The highest rate of hydrolysis is for alkali silicates, a lower rate for silicates of Ba, Pb, Ca, Mg, and the lowest rate for aluminosilicates and borosilicates.

To increase the chemical resistance of glass it is necessary to diminish the content of alkali oxides, which leads to an extreme increase of the viscosity of glass and complicates its founding. In view of this alkali oxides are replaced by oxides which increase the chemical resistance of glass without increasing its viscosity very much (B₂O₃, TiO₂, ZrO₂, TeO₂). An analysis of the effect of oxides on the properties of glass shows that by changing the composition of the vitreous phase of metal-glass materials we can appreciably change the properties of the vitreous phase and, accordingly, those of the entire metal-glass material.

Thus, to manufacture corrosion-resistant metal-glass materials we can recommend the use of glasses No. 23, No. 846, No. 29, TsL-32, No. 36, No. 40, No. 46, etc. To manufacture thermostable metal-glass materials we can recommend glasses No. 17, Zs-9, Zs-11, No. 46, zircon glass, etc., and to produce heat-resistant materials, pyrex, P-15, 13-13, No. 40, quartz glass, etc. The composition and properties of certain industrial glasses are shown in Table 1.

Reaction of Molten Glass with Metal

When sintering cermet materials in the presence of the liquid glass phase the processes occurring at the interface between the solid and liquid phases are of decisive importance. It has been established [3] that in the transition zone of the glass-metal junction the free silica reacts with the metal oxides.

The many years of experience in electrovacuum production has shown [4] that molten glass wets all metal very well if the following conditions are observed:

a) An oxide film is on the surface of the metal;

b) The metal and glass are heated to the soldering temperature;

c) The melting point of the metal is higher than the soldering point.

The formation of a soldered joint between the glass and metal is most accurately described by the theory of the Soviet School of Physical Chemistry. Other theories of the formation of the soldered joint—the oxide, dendritic,