

Correlations of the multicomponent oxidic melt viscosity with other properties

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Correlations between the viscosity of iron yttrium garnet solutions in the melted $PbO–B_2O_3–BaO–BaF_2$ solvent and the solution-melt specific volume and conductance have been investigated. To study the structure of that system, it is possible to use the Bachinsky equation and the "hole" model of the liquid structure.

Изучены соотношения вязкости растворов железо-иттриевого граната в расплаве растворителя $PbO–B_2O_3–BaO–BaF_2$ с удельным объемом и электропроводностью растворов-расплавов. Для изучения строения этой системы можно использовать уравнение Бачинского и "дырочную" модель строения жидкостей.

Among the ways to the bulk and film garnets crystals, there is the crystallization from solution-melts. In this work, the object of investigations is the iron-yttrium garnet (YIG) solution in $PbO–B_2O_3–BaO–BaF_2$ solvent. The qualitative composition of the solvent is indicated in [1]. The growing process of garnet single crystals of depends on many factors, including the physicochemical parameters of the crystallization medium. The main physicochemical properties of that system were investigated before [2, 3]. As is shown in [4], in melted mixtures of alkali metal halides, an interrelation is observed between the melt viscosity and specific volume as well as conductance. In this work, similar correlations in the multicomponent oxidic melt will be studied.

The dynamic viscosity (η) of a liquid can be connected with its specific volume (V_{sp}) by the interrelation [5]

$$\eta = \frac{A}{V_{sp} - w}, \quad (1)$$

where A and w are stationary values for each liquid. To the quantity w, assigned is usually the sense of volume occupied by the liquid particles, and the difference ($V_{sp} - w$) can be identified as the liquid "free volume".

After investigation of viscosity and density of garnet solutions, the interrelation between those was studied. Fig. 1 illustrates correlations between the reciprocal viscosity value and specific volume of pure solvent melt and garnet solutions. Linear correlations with high correlation factors (above 0.97) were obtained between these physicochemical parameters. The gradient of the viscosity dependence on the melt specific volume increases with the garnet concentration. The obtained volume dependence is a formal one. The increasing garnet concentration results in increasing operating temperatures of the solution-melt and temperature gradient of viscosity. This statement is confirmed by the temperature dependences of viscosity. Thus, it is just the temperature that is the objective reason for the viscosity gradient increase in Figure.

Using Eq.(1), it is possible to obtain the following expression for the activation energy of viscous flow (E_η) [4, 5]

$$E_\eta = RT\ln\left[\frac{A}{\eta_0(V_{sp} - w)}\right]. \quad (2)$$

This equation relates formally the energy to the liquid "free volume". The activation energies of a viscous flow calculated from Eq.(2), coincide essentially with activation energy values determined from temperature dependences of viscosity (to within ±2 %).

In is shown [6] that the viscosity of melted salts can be related to another physicochemical property of system, equivalent electric conductance (Λ_{eq}). To that end, the following relationship was used

$$\lg\eta = f - n\lg\Lambda_{eq}, \quad (3)$$

where f and n are coefficients [5]. For salt melts, the values of those coefficients remain constant within accuracy limits of viscosity and conductance measurements in rather wide temperature intervals [4]. In this work, the interrelation between these physicochemical parameters has been studied, too, except for the molar conductivity values were used instead of equivalent conductivity.

Using Eq.(3), the correlations between viscosity and molar conductivity of the system have been obtained. Within the studied concentration range, the rectilinear dependences between these parameters are observed (at high correlation factors). The coefficients f and n are constant within the temperature interval of up to hundred degrees. The dependences of viscosity on conductance have no physical sense, therefore, the graphic material is not represented in this work.

The viscosity is rather sensitive to presence of large ions in the system, in this case, of yttrium and iron complex ions. It is just the smaller particles that are responsible for electric conductance to the greatest extent [3, 4]. However, it is impossible to find any correlation between the particle sizes of structural moieties in the solutions (elementary and complex ions) and the viscosity or conductance values. Therefore, the viscosity and conductance can be connected formally using Eq.(3).

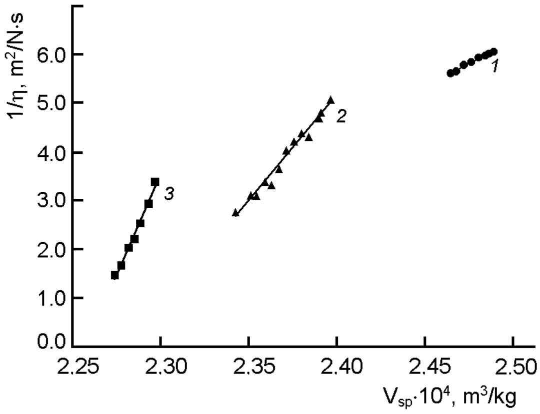

Fig. 1. Viscosity correlations with specific volume of YIG solution-melts: pure solvent (*1*), 14 mol. % YIG (*2*); 17 mol. % YIG (*3*).

The results of calculations have shown that in YIG-($PbO–B_2O_3–BaO–BaF_2$) systems, the correlations between viscosity and specific volume or conductance are observed. To study the structure of this system, it is possible to use the equations 1–3, so the "hole" model of the fluid structure is valid.

References

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Співвідношення в'язкості багатокомпонентного оксидного розплаву з іншими властивостями

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Досліджено співвідношення в'язкості розчинів залізо-ітрієвого гранату у розплаві розчинника $PbO–B_2O_3–BaO–BaF_2$ з питомим об'ємом та електропровідністю розчинів-розплавів. Показано, що для вивчення будови цієї системи можна використовувати рівняння Бачинського та "діркову" модель будови рідин.