EFFECT OF THERMAL CONDITIONING OF THE SODIUM SILICATE GLASS ON THE VALUE OF ZETA POTENTIAL OF THE SOLUBLE SODIUM SILICATE

WPŁYW KONDYCJONOWANIA TERMICZNEGO SZKLIWA KRZEMIANOWO-SODOWEGO NA WARTOŚĆ POTENCJAŁU ZETA UWODNIONEGO KRZEMIANU SODU

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Abstract

Problems connected with a change of Zeta potential values of soluble sodium silicate are presented. Soluble sodium silicate was made from sodium-silicate glass to thermally conditioned at a temperature of 1350°C for 60, 90 and 120 minutes. It was found that particles in all types of the soluble sodium silicate have similar electrokinetic properties. In the soluble sodium silicate made from the sodium-silicate glass subjected to thermally conditioned for 120 minutes, particles with the highest value of the Zeta potential were present. They provide the most intense laser light scattering.

<u>Key words</u>: *soluble sodium silicate, sodium silicate glass, Zeta potential*

Streszczenie

Przedstawiono zagadnienia związane ze zmianą wartości potencjału Zeta uwodnionego krzemianu sodu. Uwodniony krzemian sodu był wykonany ze szkliwa krzemianowo--sodowego poddanego kondycjonowaniu termicznemu w temperaturze 1350°C przez 60, 90 i 120 minut. Stwierdzono, że we wszystkich rodzajach uwodnionego krzemianu sodu występują cząstki o zbliżonych właściwościach elektrokinetycznych. W uwodnionym krzemianie sodu wykonanym ze szkliwa krzemianowo-sodowego poddanego kondycjonowaniu termicznemu przez 120 minut, cząstki o największej wartości potencjału Zeta są źródłem największej intensywności rozpraszania światła laserowego.

<u>Słowa kluczowe</u>: *uwodniony krzemian sodu, szkliwo krzemianowo-sodowe, potencjał Zeta*

Introduction

High demands and rising costs related to environmental protection have increased interest in inorganic binders and technologies that will help to reduce the consumption of organic binders, causing the emission of toxic gases in the foundry [1–4, 6–16, 18, 20–21].

On the surface of insoluble metal oxides in an electrolyte solution, the electric charge accumulates as a result of acid-based reactions of surface hydroxyl groups (OH⁻) or ions, H⁺. The reactions give rise to the formation of groups with the surface charged either positively or negatively [17–18, 23]. An increase in the solution pH value increases the surface concentration of negatively charged groups and decreases in the concentration of positively charged groups.

It was found that with increasing carrier concentration of the electrolyte increases the surface charge density at the "metal oxide - electrolyte solution" interface, while the value of Zeta potential is decreasing. According to the theory of "binding site" electrical double layer (*edl*), the charge on the surface of the metal oxide is formed by both ionization reaction, and as a result of reaction with the carrier electrolyte ions.

The reaction of the surface oxide accumulates a positive charge that is compensated by the adsorbed anion charge in the inner *Helmholtz plane* (*IHP*). Cation adsorbed on the surface creates a negative charge, which is compensated by the cation charge in *IHP*. An increase in *pH* will increase the level of groups and decrease the concentration. Increasing the electrolyte concentration leads to increased concentration of complexed groups.

Surface charge density is proportional to the algebraic sum of the concentration of ionized groups and complexed groups. Surface charge density at the "metal oxide - electrolyte solution" interface is usually determined by potentiometric titration suspension. In the case of metal oxides, the ions forming potential are H⁺ ions, therefore, this point refers to the *pH* scale and is referred to as *pH_{pzc}*. In *pH_{pzc}* total charge density is zero, which means that the concentration of positively charged groups is equal to the concentration of negatively charged groups. As mentioned above, the carrier electrolyte ions occupy positions in the inner *Helmholtz plane*. A part of the surface charge originating from the ionizing groups is compensated in the diffusion of the electrical double layer. The diffusion layer accumulates the adsorbable ions through electrostatic interaction. The adsorption of these ions is referred to as "nonspecific adsorption".

The diffusion layer is characterized by the potential of the diffusion layer and the charge density of the diffusion layer. The potential of the diffusion layer in the electrical double layer can be determined from measurements of the Zeta potential, taking into account the distance of an *x* plane of slip (delineating the value of Zeta potential) from the outer *Helmholtz plane* (*OHP*), which is related to the potential of the diffusion layer. To determine the potential value of the diffusion layer, it is necessary to know the distance from the *OHP* slip plane. In the literature, this distance is not determined in a uniform manner and, depending on the tested system (for example on the porosity of system), is from 0.4 nm to 2.0 nm [19]. The concentration of ions at which Zeta potential is equal to zero is called isoelectric point, which in the case of metal oxides is also referred to the *pH* scale. At the isoelectric point, the charge density in the diffusion layer is equal to zero. This means that the surface oxide concentration of the positively ionized groups is equal to the concentration of the negatively ionized groups.

The Zeta potential of colloidal systems with liquid phase as the disperse phase is usually determined by electrophoresis. The latest laser technology *LDV* (*Laser Doppler Velocimetry*) has replaced the microscopic method. The measurement consists in measuring the velocity of particles under the influence of an electric field. The specified velocity

divided by the intensity of the applied electric field is a direct measure of the electrophoretic mobility of the particles studied.

Experimental setup

In order to compare the physical properties, such as the Zeta potential and the binding properties of soluble sodium silicate formed from sodium silicate glass, subjected to conditioning at a temperature of 1350°C for a period of 60, 90 and 120 minutes, the three types of soluble sodium silicate with silica module M = 2.0, and a density of 1.5 ±0.04 g/cm^3 were prepared.

The following symbols were used to denote the investigated types of the soluble sodium silicate:

- *SW-60*: soluble sodium silicate made from sodium silicate glass undergoing the process of conditioning for 60 minutes.

- *SW-90*: soluble sodium silicate made from sodium silicate glass undergoing the process of conditioning for 90 minutes.

- *SW-120*: soluble sodium silicate made from sodium silicate glass undergoing the process of conditioning for 120 minutes.

The distribution of Zeta potential in the examined [5–6] types of hydrated sodium silicate, i.e. *SW-60*, *SW-90* and *SW-120,* and in the ethylene glycol diacetate, as a function of the intensity of laser light scattering, is illustrated in figures 1–4.
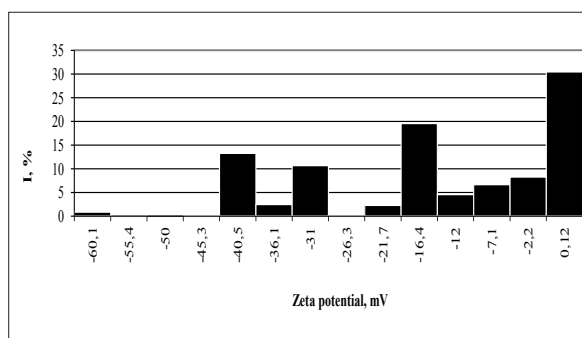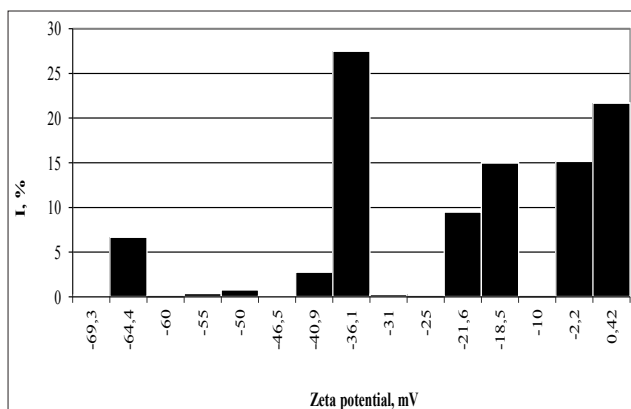

Fig. 1. The distribution of Zeta potential values of the colloidal particles in SW-60 soluble sodium silicate as a function of the intensity of laser light scattering (I)

Rys. 1. Rozkład wartości potencjału Zeta cząsteczek koloidalnych w rozpuszczalnym krzemianie sodowym SW-60 w funkcji intensywności rozpraszania światła laserowego (I)

Fig. 2. The distribution of Zeta potential values of the colloidal particles in SW-90 soluble sodium silicate as a function of the intensity of laser light scattering (I)

Rys. 2. Rozkład wartości potencjału Zeta cząsteczek koloidalnych w rozpuszczalnym krzemianie sodowym SW-90 w funkcji intensywności rozpraszania światła laserowego (I)
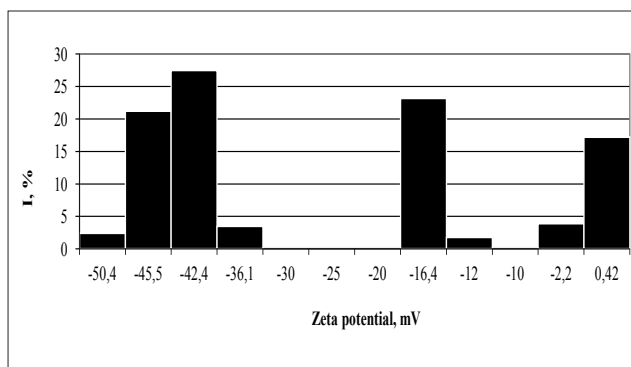

Fig. 3. The distribution of Zeta potential values of the colloidal particles in SW-120 soluble sodium silicate as a function of the intensity of laser light scattering (I)

Rys. 3. Rozkład wartości potencjału Zeta cząsteczek koloidalnych w rozpuszczalnym krzemianie sodowym SW-120 w funkcji intensywności rozpraszania światła laserowego (I)
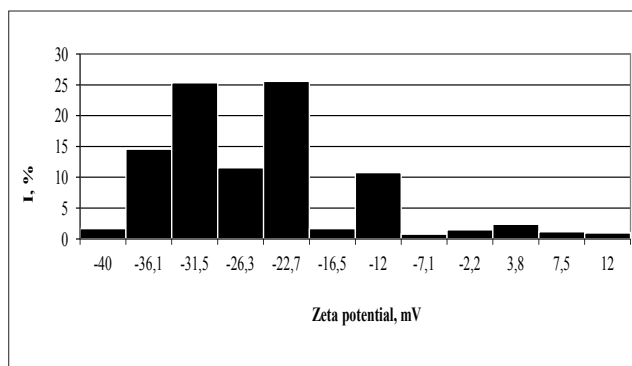
Fig. 4. The distribution of Zeta potential values of the colloidal particles in ethylene glycol diacetate as a function of the intensity of laser light scattering (I)

Rys. 4. Rozkład wartości potencjału Zeta cząsteczek koloidalnych w dwuoctanie glikolu etylenowego w funkcji intensywności rozpraszania światła laserowego (I)

Results and discussion

Based on the obtained results can be stated that in all types of the soluble sodium silicate there are particles of similar electrokinetic properties. However, in the soluble sodium silicate, grade *SW-120*, a group of particles with the largest Zeta potential is the source of the highest intensity of laser light scattering. The cause of this high intensity of laser light scattering on the surface of these particles can be both their large size and large diameter, or a complex geometric shape. The Zeta potential of the *SW-60 s*oluble sodium silicate differs from that of the *SW-120* soluble sodium silicate, occurring in the form of colloidal particles. It is easy to find that it contains in its composition the smallest particles with the dominant Zeta potential. The *SW-90* soluble sodium silicate is characterized by properties intermediate between the soluble sodium silicate *SW-120* and *SW-90*. If not engaged as condensation centres, certain groups of particles may occur during the electrokinetic measurements of gel formed by the reaction of hydrated sodium silicate and ethylene glycol diacetate.

Acknowledgement

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