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ELECTRONIC PROCESSING OF MATERIALS

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Size of gas bubbles forming during electroflotation

Dispersity and type of gaseous medium are of great importance in the course of flotation of minerals. Available techniques of air dispersion can produce 0.8-0.9 mm air bubbles (impeller flotation machines), 0.1-0.2 mm (vacuum flotation), and in certain cases – 0.06-0.08 mm (compression type units). Producing fine dispersed gas bubbles is important, since these bubbles penetrate the hydrate layer of the surface of mineral particles more actively. Smaller bubbles attach to mineral particles much faster than larger ones.

Electrolytic technique is one of the methods for producing fine dispersed gas bubbles. Electrolytic water decomposition process produces very fine bubbles of hydrogen and oxygen. In alkaline solutions, hydrogen bubbles formed near the cathode are so fine that the solution becomes milk-white. Bubbles forming near the anode are much larger. The situation is reverse in acid conditions.

B.N. Kabanov, A.N. Frumkin [1] studied the conditions causing a gas bubble to break away from the electrode it was attached to. They determined that the size of a bubble attached to an electrode in equilibrium is defined by contact angle of wetting. Bubbles with larger contact angle are attached to the electrode more tightly, therefore growing larger in size.

Electrode potential is an important factor affecting the contact angle [1].

Maximum contact angle is observed at the electrode potential close to the point of zero charge. Shift of potential to either side (both + and -) results in change (reduction) of contact angle. Gas bubbles are therefore decreasing in size as well.

Electrochemical polarization, both cathodic and anodic, caused by shift of potential, may produce significant effect on the size of bubbles breaking away from the electrode.

The amount of shift of cathodic polarization is greatly affected by current density [2], pH value of the medium, cathode material, [2--9], temperature [10], etc.

Current density dependence of overvoltage is described by Tafel equation

$$\eta = a + b \ln i,$$

where η is hydrogen overvoltage; i is current density; a is a coefficient defined by cathode material, ion composition of slurry, temperature; $b = \frac{RT}{\alpha F}$, $\alpha \approx 0,5$.

For most metals, as pH value increases, cathodic polarization initially increases and then decreases. Maximum overvoltage occurs in neutral or mild alkaline conditions [3-6]. Anodic polarization [7] decreases as pH value increases.

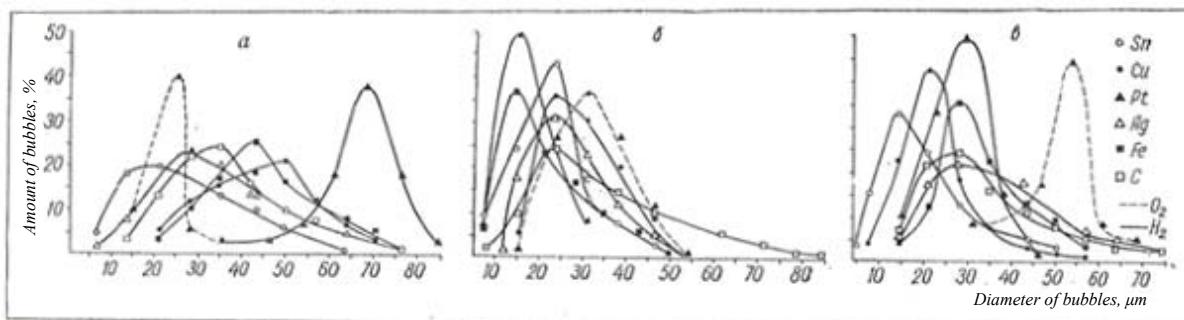


Fig. 1. Effect of electrode material on the size of electrolytic bubbles. Current density 25 ma/cm^2 , electrode diameter 0.4 mm , temperature 20° . pH 2 (a), 7 (b) and 12 (c)

Dependence of size of electrolytic gas bubbles on the factors affecting the overvoltage of oxygen and hydrogen release was studied by high speed shooting method, using SKS-16 movie camera (800 -1200 fps).

Size of bubbles was measured using MPS-1 microscope. The electrodes used included platinum, copper, tin, silver, stainless steel wire and graphite bar, dia. 0.2 to 1.0 mm. Current density varied from 10 to 40 ma/cm^2 , temperature varied from 5 to 75° . The required pH was achieved by using H_2SO_4 , NaOH and Na_2SO_4 solutions. In the course of analysis of the effect produced by a single variable, all other variables remained unchanged. The electrodes were prepared as follows: thorough mechanical polishing, chemical degreasing with strong organic solvents, rinsing in distilled water, 1.5-2 h electrochemical cleaning.

Fig. 1 shows variation of the size of bubbles with respect to pH value and electrode material. Variation of the size of bubbles is inversely related to the overvoltage variation, i.e. hydrogen bubbles are larger in acid conditions (Fig. 1, a) compared to neutral (b) and alkali (c) conditions. The smallest bubbles are observed in neutral conditions (for all cathode materials) and alkali conditions (for copper and tin), i.e. pH values corresponding to the maximum hydrogen overvoltage.

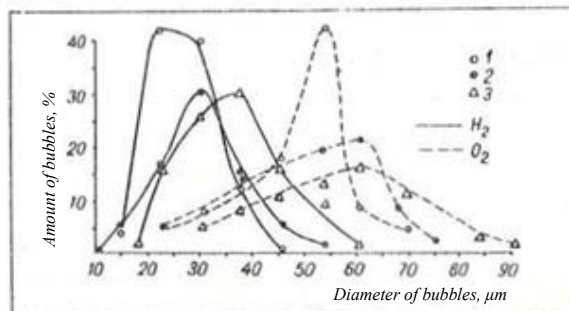
The effect of cathode material on the size of produced bubbles is especially pronounced in acid conditions. Average diameter of bubbles varies from 20 to $70 \mu\text{m}$.

Order of metals in this area in terms of bubble size corresponds to their order in terms of overvoltage [8, 11]. In alkaline conditions (Fig. 1, c) the size of hydrogen bubbles is to a lesser extent affected by the cathode material, average diameter of bubbles varies from 15 to $30 \mu\text{m}$. In neutral conditions (Fig. 1, b) the size of produced hydrogen bubbles is virtually not affected by the cathode material. Average diameter of bubbles varies from 15 to $20 \mu\text{m}$.

The minimum size of oxygen bubbles formed on the platinum electrode (other materials were not used for anodes) is observed in acid conditions ($25 \mu\text{m}$). The size of bubbles increases when shifting to neutral and then to alkaline conditions (30 and $55 \mu\text{m}$ respectively).

Fig. 2. Variation of the size of bubbles with respect to the diameter of electrode.

Material - platinum, current density 25 ma/cm^2 , temperature 20° , pH 12.. Electrode diameter, mm: 0.2 (1), 0.5 (2) and 1(3)



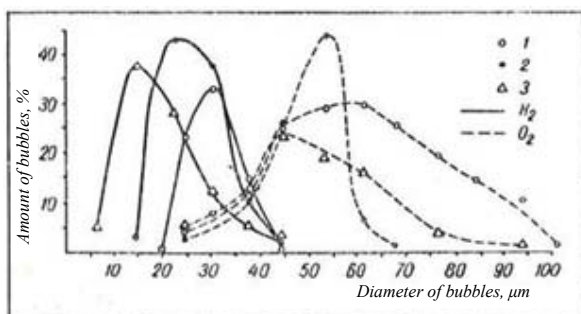


Fig. 3. Effect of current density on the size of bubbles
Material – platinum, electrode diameter 0.2 mm, pH 12, temperature 20°. Current density, ma/cm²: 12 (1), 25 (2) and 40 (3)

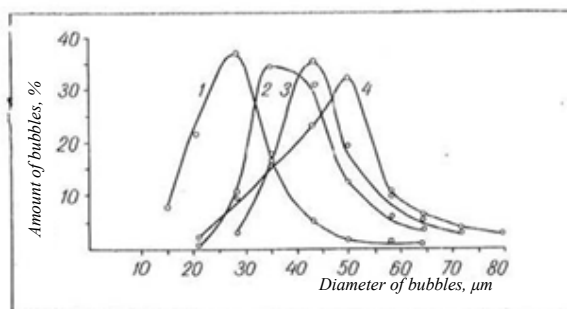


Fig. 4. Effect of temperature on the size of hydrogen bubbles.
Material – platinum, electrode diameter 0.5 mm, current density 25 ma/cm², pH 7. Temperature °C. 5 (1), 25 (2), 55 (3) and 75 (4)

Fig. 2 shows the variation of size of the produced bubbles with respect to the electrode surface curvature at pH 12. As electrode diameter increases, average diameter of the hydrogen and oxygen bubbles increases only slightly. Noticeable increase of variation of diameters of bubbles is also observed. With 0.2 mm dia. electrode, at pH12, diameter of the major portion of bubbles ranges from 15 to 40 μm, whereas with 1 mm dia. electrode the variation of diameter extends to 60 μm. Diameter of oxygen bubbles ranges from 40 to 60 μm (with 0.2 mm dia. electrode) and from 30 to 90 μm (1 mm dia. electrode).

Fig. 3 shows the effect of current density on the average diameter of bubbles. Within the specified shift of current density (10 to 40 ma/cm²), average diameter of bubbles demonstrates only slight change in acid and neutral conditions. In alkaline conditions, average diameter of bubbles varies from 15 to 30 μm; as current density increases, the variation of diameter of bubbles increases as well, especially for oxygen in alkaline conditions*.

Fig. 4 shows the distribution of diameter of bubbles against temperature. Within the temperature interval under consideration, it was found that as the temperature increases, average diameter of hydrogen bubbles shifts towards increasing as well. Thus, the minimum diameter of bubbles (30 μm) is observed at 5°, while the maximum diameter (50 μm) is observed at 75°.

* The effect of current density and electrode surface curvature is not significant in neutral and acid conditions; therefore the corresponding data is not provided.

Compared with the nature of variation of overvoltage with respect to temperature in neutral conditions [10], it was found that though temperature only slightly affects the overvoltage, the effect of temperature on the size of produced bubbles within this interval is quite significant.

Therefore, electrode diameter and current density only slightly affect the size of hydrogen and oxygen bubbles within the interval under consideration. Temperature dependence is more significant, but pH value of media and electrode material produce the maximum effect on the size of bubbles forming in the course of electrolytic decomposition of water.

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