A COLD VITREOUS COMPOUND WITH FINE PURIFICATION OF THE SURFACES

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A new effect is reported, i.e., the development of strong molecular adhesive forces betwen plane glass surfaces, which had been cleaned using jets of water. In this case, the greatest amount of attention has been paid to the elimination of microscopic contaminants which prevent the approach of the surfaces to small distances.

The experiments were carried out using glass discs produced industrially, polished to the third optical class of purity in accordance with GOST [All-Union State Standard] 11141-65. The dimensions of the discs were ϕ 40 mm and thickness 1.5 mm.

1. In the preliminary cleaning of the surfaces, the following washing agents were tested: aqueous soap solutions, potassium bichromate, trisodium phosphate, ethyl and isopropyl alcohols. Purification in the above media was also carried out in combination with ultrasonic treatment. In all cases, the final washing of the discs was carried out in a stream of distilled water.

To prevent possible subsequent contamination, the surfaces of two discs were brought into contact under a layer of water, after which, joined together, they were dried in air at a temperature of 40°C.

The degree of purity of the contacting surfaces was monitored under an MIM-7 microscope in a dark field, at a magnification of 500.

It was found that, after purification using the above-listed agents, the surfaces were uniformly contaminated by solid particles with a diameter generally less than 2 μm, with an average distance between particles on the order of 100 μm. Individual particles attained values of 10-30 μm.

2. It was decided to carry out an intermediate treatment using jets of water. Now, the surfaces of the glasses were first washed in an aqueous soap solution, which eliminated the main mass of contaminants, and which weakened the adhesion of the microscopic particles to the glass. Then, all parts of the surface of the discs were subsequently cleaned using jets of tap water, supplied from a nozzle with a diameter, at a velocity of ~20 m/sec. The angle of inclination of the jet to the surface of the glass was ~30°. Immediately after cleaning by the jet (so that the disc was not able to become uncovered by water) the discs were transferred into a stream of distilled water, in which they were rinsed for a peiod of ~1 min, and then, as before, were brought into contact under water. Drying before determination of the purity of the surfaces was carried out in air. No special measures were taken to remove dust from the air or to filter the tap water.

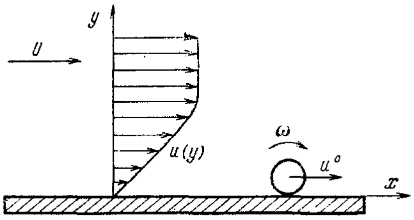

Fig. 1

With use of the jet method, the number of solid particles on the treated surfaces was sharply reduced. In individual cases, pairs of discs were completely without contaminants, visible with a magnification of 500. Interference bands were observed only on the periphery (due to the nonplanar nature of the edges of the discs, arising during polishing), which permitted evaluating the gap between the surfaces of the glasses, from the upper side, at a value of 2000 Å.

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The effectiveness of jet purification can be explained by the fact that all the particles are simultaneously attracted by the boundary layer, arising with flow around the disc. The boundary layer is characterized by a large velocity gradient, as a result of which the particles acquire an appreciable angular velocity and slide off toward the periphery of the surface, without damaging it (Fig. 1). An evaluation of the velocity of the removal of a particle (see below) shows that the particles are washed off quite rapidly. Thus, a particle with a diameter of 1000 Å is displaced along the surface with a velocity on the order of 20 mm/sec.

The purest samples were dried at a temperature of 40°C, with a pressure on the order of ~300 kg/cm^2 applied to the outer surfaces of the discs. It was found that after drying under pressure the discs adhered with such force that attempts to separate the samples along the contact surface led to spallation fragments along the monolith. With observation of the surfaces of a fragment under a microscope, no traces of the piece were observed between the discs. The pairs of discs broke down like a solid body. This fact made it possible to evaluate the forces of adhesion between the discs, starting from the tensile strength of the glass, a value on the order of 500 kg/cm^2.

3. Such great adhesive forces can arise only with very small distances between the surfaces. An evaluation on the basis of molecular interaction, without a layer of water, gives a magnitude of the gap of not more than 20 Å. If it is assumed that the adhesion is due to the capillary forces of a thin film of water remaining between the discs, the size of the gap must not exceed 30 Å, which corresponds to a thickness of several molecular layers. It is evidently impossible to use an evaluation based on a model of capillary interaction, since water located in such a narrow gap differs in its properties from water in the volumetric phase [1, 3].

It is not possible to draw quantitative conclusions with respect to the effect of the film of water on the development of large adhesive forces, since the properties of thin layers of water have not been studied with sufficient completeness.

4. With jet purification, flow around the disc takes place at a Reynolds number not higher than 5×10^5. It can be assumed that the boundary layer is everywhere laminar and, with a high degree of accuracy, the velocity distribution (Fig. 1) near the surface can be assumed to be linear [4]. Therefore, from the relationship

$$\tau = \mu \left(\frac{\partial u}{\partial y}\right)_{y=0} = c\,\frac{\rho U^2}{2}$$

approximately replacing

$$\frac{\partial u}{\partial y} \approx \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

we obtain

$$u \approx \frac{c\rho U^2}{2\mu}\,y$$

and, assuming that a particle moves with the velocity of the flow at the height of its center, we have the evaluation

$$u^\circ \approx \frac{c\rho U^2}{4\mu}\,d$$

Here u is the velocity in the boundary layer; y is the distance from the surface; μ is the dynamic viscosity coefficient; τ is the tangential stress at the surface; c is the local friction coefficient; ρ is the density of water; U^2 is the velocity of the oncoming flow; u° is the velocity of a particle; d is the diameter of a particle;

The numerical value of the velocity with $R = 10^5$ for a particle with a diameter of 1000 Å is equal to 20 mm/sec.

LITERATURE CITED

1. P. A. Rebinder, Summary of a General Course on Colloid Chemistry from Lectures [in Russian], Izd. MGU, Moscow (1949).
2. B. V. Deryagin and M. M. Kusakov, "Experimental investigation of the solvation of surfaces with application to the construction of a mathematical theory of the stability of lyophilic colloids (anomalous properties of thin layers of liquids), V," Izv. Akad. Nauk SSSR, Ser. Khim., No. 5 (1937).
3. A Frumkin, "Phenomena of wetting and adhesion of bubbles, I," Zh. Fiz. Khim., 12, No. 4 (1938).
4. H. Schlichting, Boundary-Layer Theory, McGraw-Hill (1968).