Physics

1957

SovietRxiv

Abstract

Full Text

Physics

E. S. TREKHOV

STUDY OF THE OPTICAL CONTACT OF MICA WITH GLASS

(Presented by Academician P. A. Rehbinder, 12 XII 1955)

The contact of glass with glass, as well as the contact of mica with mica, has been studied fairly well ([2,3]). The phenomenon of contact between the cleavage surface of mica and the surface of polished glass has long attracted attention ([1]). However, the possibility of optical contact (“adhesion”) of mica with glass was rejected ([4]).

We have established that mica sheets can be brought into optical contact with glass provided that they are sufficiently thin (about 5 μ) and are placed into contact immediately after being split in air. The condition of the polished glass surface substantially affects not only the character of the contact, but also the very possibility of its formation. The best results in bringing the surfaces into contact are obtained if the glass surfaces have been cleaned by a glow (corona) high-frequency discharge and, after cleaning, have remained in contact with atmospheric air for not less than 15 min.

The contact of mica with glass never gives large areas of continuous contact. It should be noted that a freshly split mica sheet, when placed on a glass surface that has just been treated by an electric discharge, does not enter into optical contact even under very strong pressure ([5]). When such a sheet slides over the glass surface, the contacting surfaces catch strongly and irregularly. The phenomenon occurs as though very rough surfaces were sliding over one another ([6]). The mica surface is then severely scratched.

All cases of contact of mica with glass observed by the author can be assigned to two different types.

The first type includes cases of optical contact with large contact areas. The boundary of separation of the contact into microregions is, as a rule, rectilinear; when observed in reflected monochromatic light, the width of the interference zero band is constant. From the character of the interference pattern, such a boundary of separation is difficult to distinguish from that observed when mica is split. All this indicates a high constancy of the molecular adhesion forces between the contacting surfaces. Such a contact may be called homogeneous. The characteristic appearance of the interference pattern of a homogeneous contact is shown in Fig. 1. The photograph gives an idea of the shape of the boundary

Fig. 1. Segment of the rupture boundary of optical contact of mica with glass. Homogeneous contact. Moment of formation of a membrane spot. $\lambda = 0.53\,\mu$. 40×

Figure 1: Fig. 1. Segment of the rupture boundary of optical contact of mica with glass. Homogeneous contact. Moment of formation of a membrane spot. $\lambda = 0.53\,\mu$. 40×

of separation of the contact.

The second type of contact is characterized by an irregular shape of the separation boundary, by inconstancy of the curvature of the sheet being separated, and by inconstancy of the width of the zero band. This type of contact, which we have called heterogeneous, occurs more often than the homogeneous one. Bringing the surfaces into contact in this case is accomplished with greater difficulty. All this indicates that the magnitude of the contact forces for this type varies strongly from point to point over the contact surface, which, in my opinion, corresponds to a microheterogeneous structure of the glass surface.

By varying the process of cleaning the surfaces of the glasses, one can vary the type of their contact with mica. Thus, for example, cleaning with alcohol, distilled water, and a glow (corona) high-frequency discharge followed by holding for 15-20 min in contact with air gave, as a rule, the first type of contact. Treatment with a sharp flame or a corona discharge with immediate bringing into contact gave the second type of contact, if it could be obtained at all*.

Similarly to the case of mica-mica contact, the degree of reproducibility of mica-glass contact was established. As was to be expected, in the case of heterogeneous contact it proved impossible, by merely reducing the separating force, to restore the contact after separation. When the splitting wedge is withdrawn from the separation region, the curvature of the mica sheet decreases very strongly; the interference fringes become blurred, distorted, or disappear altogether, but optical contact does not arise. The transition from the contact region to the separation region remains in its old place. It proves possible to restore the contact only to a very small extent and only under the influence of strong pressure on the mica sheet from outside.

Fig. 1. Segment of the rupture boundary of optical contact of mica with glass. Homogeneous contact. Moment of formation of a membrane spot. $\lambda = 0.53\,\mu$. 40×

In the case of homogeneous contact we obtained directly opposite results. Optical contact was often restored completely by simply reducing the separating force. The boundaries of separation could be moved repeatedly over the contact surface, and neither the width of the O-fringe nor the curvature of the sheet underwent any sharp changes. This indicates that in the contact region neither macro- nor micro-displacements occur.

When the separation boundary was moved in the region of homogeneous contact, we discovered an interesting phenomenon of "memory" of the contacting surfaces; there occurred not merely restoration of the contact, but its identical reproduction in all stages of separation and bringing together. It was noteworthy that it was almost impossible to distinguish the topography of the contact surface before the beginning of separation and after the return of the separation boundary to its former position.

An interesting formation on the surface of contact of mica with glass is represented by the so-called "membrane" spots. These formations are gas bubbles, the mica film separating them being stretched like a thin elastic membrane. The membrane spots observed in homogeneous contact have regular, round shapes and a constant width of the O-fringe. The region of heterogeneous contact is speckled with membrane spots of different sizes, often of irregular shape, with a nonconstant width of the O-fringe even within a single spot.

It is of interest to determine whether the membrane spots are purely air bubbles or whether they are formed on some irregularity or speck of dust. Investigation of the shape of the transverse section of a spot confirmed the similarity to the shape of a round membrane, clamped at the edge, loaded by a force concentrated at its center. The calculated and experimental forms of the cross section (7) agree well. This made it possible to carry out a number of calculations.

Using the known formula for the deflection of a thin circular membrane when a concentrated load is applied at its center, the following conclusions can be drawn.

Table 1

Calculation of membrane spots

$$f = k\frac{Pa^2}{Eh^3}$$

(f—deflection, in numbers of fringes; a—diameter of the spot, in arbitrary units). Mica—glass. (Experiment No. 86—87)

Photograph No.	f	a	$\frac{f}{a^2}$
18	6.5	13.0	0.038
18	2.5	8.0	0.039

---

* According to the author' s observations, confirmed by an oral communication from E. P. Osmolovskaya, cleaning by this method achieves very strong adhesion of glass to the polished surface of steel in air.

Photograph No.	f	a	$\frac{f}{a^2}$
10	2.5	8.0	0.039
10	0.5	3.5	0.041
19	6.0	12.5	0.038
19	16.0	21.0	0.036

$$\left(\frac{f}{a^2}\right)_{\text{av}} = (38.0 \pm 0.7) \cdot 10^{-3}.$$

For homogeneous contact the ratio of the square of the visible diameter of the "membrane" spots to the height (deflection) is a constant quantity (see Table 1). For a heterogeneous form of contact these ratios are different even for two neighboring spots, which, undoubtedly, also indicates inhomogeneity of the contact surface. The homogeneous form of contact is apparently always connected with a high degree of cleanliness of the surface, which, moreover, has been in contact with atmospheric air for a sufficiently long time.

The calculation shows that, in the case of homogeneous contact, the work of formation of a unit area of the spot is a constant quantity, which agrees well with all the other facts.

The work of rupture of the optical contact was measured by the method described in [2]. The calculation was carried out according to the formula

$$Q = \frac{1}{24}\frac{Ey^2h^3}{x^4},$$

where E is the modulus of bending; h is the thickness of the plate; y is the deflection at a distance x from the zero fringe.

The work of separation under our conditions was equal to 13 erg/cm^2 for the initial separation of the mica—glass boundary and changed only slightly. After prolonged action of the separating deformation, the separation boundary shifts, the separating force decreases, and the work of separation becomes established at the level of 9 erg/cm^2. The scatter of values was insignificant (for a quantity of this type), reaching ±50% of the measured value.

I consider it my duty to express my deep gratitude to Corresponding Member of the Academy of Sciences of the USSR I. V. Obreimov for suggesting the topic and for his guidance.

Moscow Engineering-Physics Institute

Received
10 XII 1955

CITED LITERATURE

1. N. K. Adam, *Physics and Chemistry of Surfaces*, 1947.

2. I. W. Obreimoff, *Proc. Roy. Soc.*, (A) **127**, 290 (1930).

3. E. S. Trekhov, Dissertation, Moscow Engineering-Physics Institute, 1954.

4. V. D. Kuznetsov, *Physics of the Solid State*, **5**, 1950.

5. V. V. Karasev, G. I. Izmailova, *ZhTF*, **24**, no. 5, 871 (1954).

6. A. Strong, *Technique of the Physical Experiment*, 1952.

7. L. D. Landau and E. M. Lifshitz, *Mechanics of Continuous Media*, 1954.

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.