KINETICS OF THE ETCHING OF QUARTZ GLASS IN HYDROFLUORIC ACID

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Quartz glass has extremely high chemical resistance to acid and alkali solutions. The only acid that reacts comparatively rapidly with quartz glass is hydrofluoric acid, but the resistance of the glass to this reagent is still high.

Solution of quartz glass proceeds by the reaction

$$SiO_2 + 6HF \rightleftarrows H_2SiF_6 + 2H_2O.$$

Treatment in hydrofluoric acid is widely employed when it is necessary to clean the surface of quartz-glass articles.

In practice, it is often necessary to remove the surface layer of quartz glass to a definite depth. For this purpose, one must know the rate at which quartz glass is etched in hydrofluoric acid solutions of different concentrations.

Our investigation of the etching kinetics of quartz glass at HF concentrations between 10 and 45 mass % was conducted at room temperature. We studied the temperature function of the etching rate at 20-80°C for 20% HF solution. The temperature was measured with a glass thermometer placed in a sheath fabricated from thin polyethylene film. Etching was carried out without agitation of the solution. A fresh acid solution was used for each experiment.

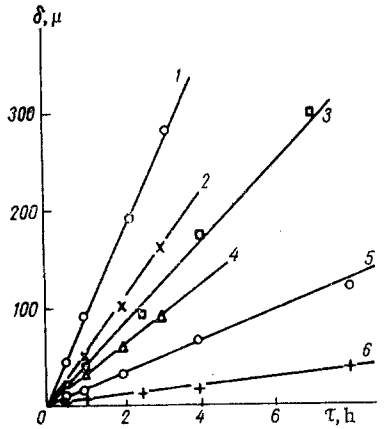

Fig. 1

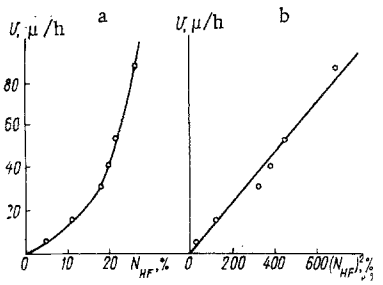

Fig. 2

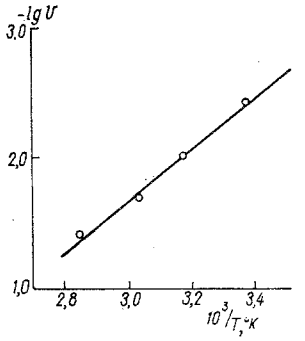

Fig. 3

Fig. 1. Etching kinetics of quartz glass in hydrofluoric acid solutions with different concentrations: 1) 45% HF; 2) 38% HF; 3) 35% HF; 4) 32.5% HF; 5) 20% HF; 6) 10% HF.

Fig. 2. Dependence of etching rate of quartz glass on: a) hydrofluoric acid concentration; b) square of hydrofluoric acid concentration.

Fig. 3. Etching rate of quartz glass in hydrofluoric acid (20%) as a function of temperature.

State Scientific-Research Institute of Quartz Glass. Translated from Steklo i Keramika, No. 11, p. 15, November, 1973.

The quartz–glass specimen, in the form of a ball about 10 mm in diameter, was placed on a platinum-wire grid and immersed in a Teflon beaker containing the acid solution. The specimen diameter before etching was measured with a micrometer (the results were the averages of 10 measurements). When the thickness of the dissolved layer was small, it could not be determined with high accuracy by using a micrometer. The layer thickness was therefore calculated from the loss of specimen mass. Weighing was conducted with VLT-1 microanalytic scales, to within 0.00001 g.

The difference in the specimen masses before and after etching Δp was calculated from the formula

$$\Delta p = \frac{4\pi}{3}[R_0^3 - (R_0 - \delta)^3]\rho,$$

where R_0 is the radius of the original specimen, δ is the thickness of the dissolved layer, and ρ is the density of the quartz glass. Hence,

$$\delta = R_0 - \sqrt[3]{R_0^3 - \frac{3\Delta p}{4\pi\rho}}.$$

The results of our experiments are presented in Figs. 1-3.

It can be seen from these graphs that:

1) the thickness of the dissolved layer was proportional to the time with a given acid concentration;

2) the etching rate of quartz glass at room temperature increases in direct proportion to the square of the hydrofluoric acid concentration;

3) the etching rate increases exponentially with temperature.

Using Figs. 1-3 as a guide, one can thus calculate the acid concentration and etching time necessary to remove a glass layer of desired thickness.