

Influences on the Polishing Process of Optical Glasses Using Synchrospeed-Kinematics

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Background

The polishing of optical components results in a complex system consisting of the polishing pad, the suspension and the work piece material. Minor changes to one of these components can cause major irregularities in the polishing results. This complexity, meaning the interaction between the system components, has still not been fully understood to the present day. A comprehensive quantitative model describing the abrasion mechanisms does not exist.

In the past numerous efforts have been made to increase the transparency and thereby the predictability of the polishing process. The **hypothesis of abrasion** is based on purely mechanical processing which generates abrasion by inducing fine cracks. This hypothesis can at best be significant in the first phase of polishing when the peaks of surface roughness left by pre-machining operations are removed. The **flow hypothesis** finds the basic mechanism in a ductile displacement of material made possible by local softening of the surface due to frictional heat. The **chemical hypothesis** is based on the theory, that within the subsurface of the glass a gel layer is developed. This film created by an incorporation of water is thereupon removed. The **friction-wear hypothesis** finds its motivation in the mechanical stressing of the polishing grains, which uncovers faults in the crystal structure. The faults' reactivity cause a joining of the glass material and the polishing grain.

All of these hypotheses have something in common which is that they do not offer a quantifiable model of abrasion and also that the influence of the glass type is not taken into consideration. There are though combined hypotheses which have been developed in recent years, which focus particularly on the effects on the surfaces between glass and the polishing grain. Izumitani [IZU79] chose 18 different borate- and silicate glasses and put them into a 0.01 molar solution of HNO_3 . Afterwards these controlled corroded glasses showed a correlation between the polishing rate and the Vickers hardness determined after the corrosion (Fig. 1). This hypothesis can therefore be seen as a combination between the abrasion- and the chemical hypothesis.

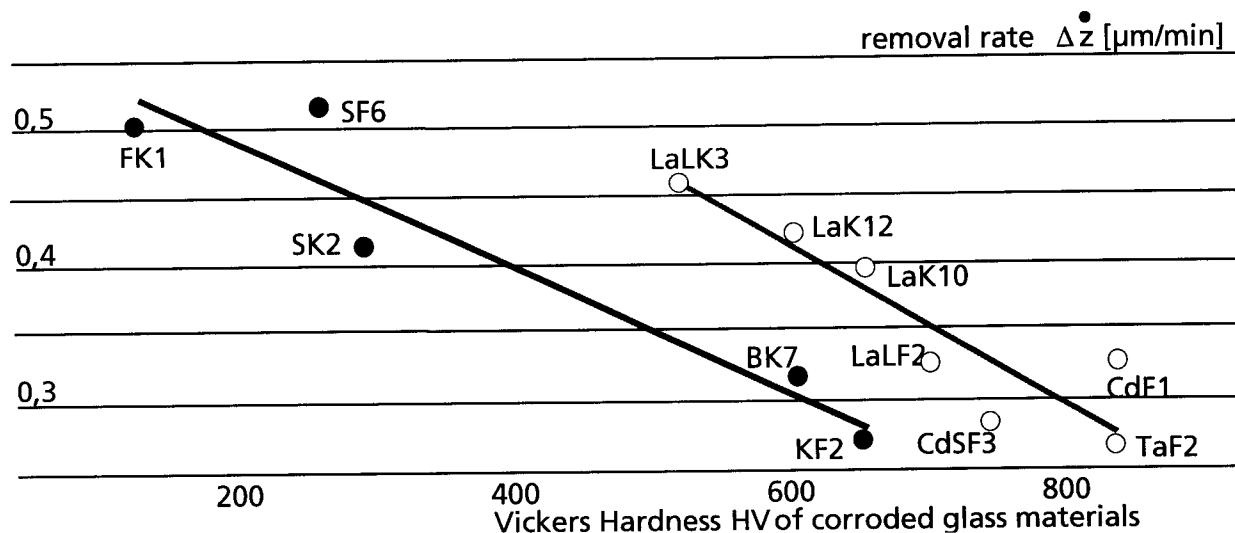


Fig. 1: Influence of corroded samples [IZU79]

However this hypothesis considers neither the polishing suspension nor the influence of the polishing pad. In addition, it should be mentioned that the theories presented here are based on experiments conducted with pitch as a carrier of the polishing agent. This particular polishing pad results in an abrasion one order of magnitude smaller than what would be expected with a common polyurethane foam. There has been to date no success in achieving the development of a comprehensive approach for the description of the complex tribochemical process occurring within the polishing gap.

The Polishing Characteristics of Different Glass Types

The experiments on polishing characteristics of different optical glasses have been carried out on a polishing machine called SPS 120 by LOH OPTIKMASCHINEN AG. This type of polishing machine is suitable for the polishing of spherical lenses in a diameter range from 20 to 120 mm. The concept is based on the synchrospeed theory. Using this method of polishing, it is almost possible to reach a constant relative velocity between tool and workpiece on spherical lenses with small aperture angles; which according to the Preston-hypothesis leads to constant rate of abrasion [PRE27]. As polishing pads, polyurethane foams are used because their mechanical stability allows higher pressures and rotation speeds compared to pitch.

During the experiments different glass types were observed. Cerium oxide with deionized water (DI-water) was used as polishing agent. In advance of each series, a new suspension was mixed. The polishing time was varied, single workpieces were polished for 2, 3, 5, 10 and 20 minutes. Afterwards, the series was repeated with new suspension (Fig. 2).

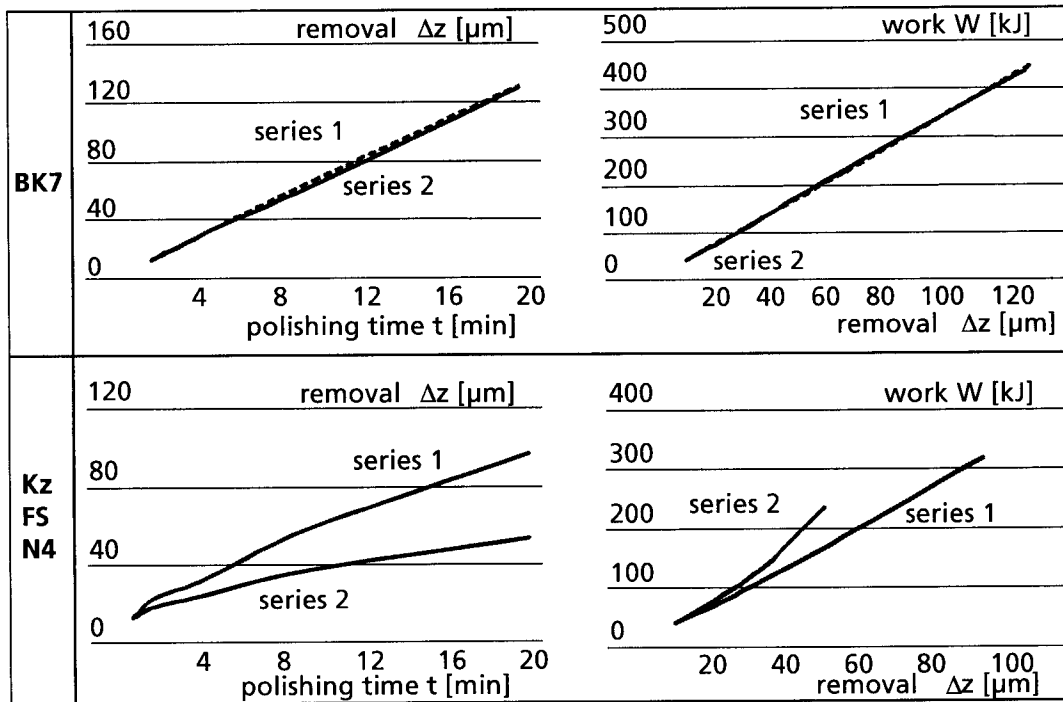


Fig. 2: Polishing characteristics of different glass types

What draws attention is, that while polishing certain glasses, e.g. BK7, there is a linear relation between the polishing time and material removal, even after the second series. However, when polishing KzFSN4 the removal rate evidently decreases during the second series. Obviously, a reaction between the glass surface and the polishing medium occurs. However when the polishing pad is dressed once again, this results in roughening the surface of the pad and the pores are thereby opened, the condition of series 1 is reached after a third series.

While performing the polishing series, it is noticeable that there is a correlation between the energy input and the material removal. However if wear to the polishing pad occurs, as observed when polishing KzFSN4, the amount of energy put in is reduced. Since the curve characteristic is a measure of how much energy is needed to generate material removal («activation energy»), one can conclude that the activation energy rises with an increasing wear of the polishing pad.

This wear of the polishing pad is obviously related to the type of glass. The interesting question therefore is, which characteristics of the glass leads to the different polishing characteristics.

Pad Wear

The ideal situation is that during the polishing a stable liquid film builds up between the polishing pad and the workpiece. Pad and glass are therefore either divided by the fluid or by polishing grains. These conditions prevent abrasive wear to the pad. However if the film is torn open the soft pad gets in contact with the hard glass material and pad wear occurs. The wear to the polishing pad is thus directly related to the interaction between the polishing fluid and the glass material.

The polishing fluid is DI-water. Water is bound to the surface by physisorption. Consequently, the power of the adhesion between water and the surface is characterized by the polar fraction of surface of the individual glasses. This means that also the wear of the pad is influenced by the polar fraction of surface of the individual glasses when polishing optical glasses.

During the experiments it was identified that the interaction between glass and polishing fluid increases with a rising fraction of polar surface energy. This immediately leads to a stabilization of the liquid film and thus to a reduction of wear.

The resulting question is therefore which measures have to be taken in order to optimize the polishing of »critical« glasses such as KzFSN4? For that purpose the previously mentioned model for the description of the wear of the pad is used.

The wear can only occur once the pad gets in contact with the glass. Polishing grains between pad and glass prevent this contact. An increase of the concentration of the polishing agent therefore reduces the tendency of the pad to wear out (Fig. 3).

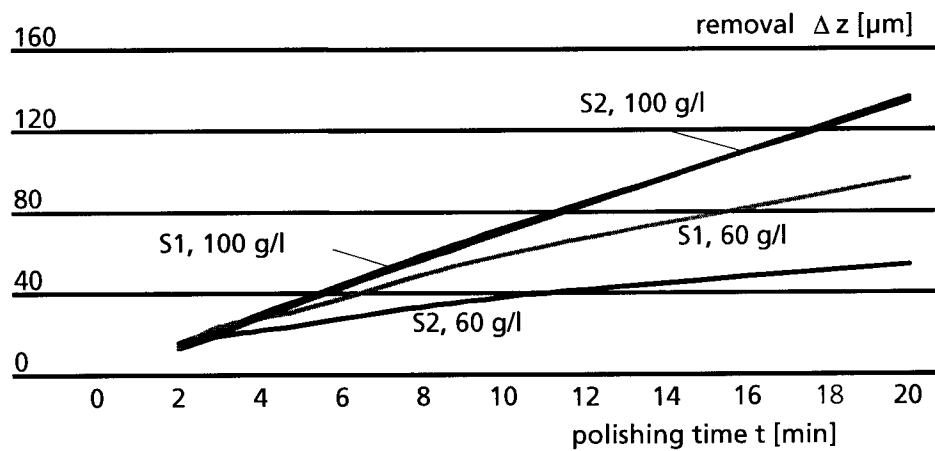


Fig. 3: Technological means to reduce wear (glass type: KzFSN4)

In this example, the concentration was increased from 60 g/l to 100 g/l during the polishing of KzFSN4. Throughout the following polishing, the same characteristics as in the first series could be observed. Wear to the pad does obviously not occur [HAB01].

Literature

- [IZU79] Izumitani, T.: Treatise on Material Science and Technology. Academic Press. New York, 1979, pp. 115
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- [HAB01] Hambücker, S.: Technologie der Politur sphärischer Optiken mit Hilfe der Synchrospeed-Kinematik. Dissert. an der RWTH Aachen (2001)