Product design for strong cover glass

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Abstract — Strength is one of the most important properties of cover glass. In this study, fracture analysis is used to classify the breakage mode of cover glass into four typical modes. Moreover, the mechanism and evaluation method of each mode are investigated. Consequently, a chemical strengthening design with high compressive stress (CS) and low center tension (CT) is obtained. In addition, processing design is determined to be an important factor. Fining of edge processing and surface polishing after chemical strengthening are shown to enhance the edge and surface strength, respectively.

Keywords — *glass, cover glass, chemical strengthening.*

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1 Introduction

Chemically strengthened glass is widely used as cover glass for electronic devices such as cellular phones, tablet PCs, laptop and desktop computers, and televisions. Chemical strengthening is used to increase the strength and reliability of glass by forming a compressive stress layer under the glass surface through ion exchange.[1] The back surface of the cover glass will not be damaged in use; therefore the initial strength is important. On the other hand, the front surface will be damaged by contact or scratch with something hard such as sand; therefore both the initial and retained strength are important.

The compressive stress of the glass surface, depth of the compressive stress layer, and tensile stress in the center of the glass are known as CS, DOL, and CT, respectively. CT can be calculated by

$$CT = (CS \times DOL)/(t - 2 \times DOL), \tag{1}$$

where t is the thickness of the glass.

As is well known, glass strength is described by Griffith's theory.[2] In the case of chemically strengthened glass, CS and CT are related as

$$\sigma = K_{IC}/\left(Y \times c^{1/2}\right) + CS, \text{ when DOL} > c \tag{2}$$

$$\sigma = K_{IC}/\left(Y \times c^{1/2}\right), \text{ when DOL}=c \tag{3}$$

$$\sigma = K_{IC}/\left(Y \times c^{1/2}\right) - \text{CT}, \text{ when DOL}<c, \tag{4}$$

where σ is the stress at the fracture, K_{IC} is the fracture toughness of the glass, Y is the geometric parameter of the flaw tip, and c is the depth of the flaw.

On the basis of fracture analysis of cover glass, the breakage mode of cover glass can be classified into four typical modes,[3] as shown in Table 1.

This paper focuses on the strength of chemically strengthened glass used for cover glass and describes the product design for strong cover glass.

2 Experiments

2.1 Edge Front breakage mode

The Edge Front breakage mode typically occurs when devices are dropped on the ground with a relatively small curvature, resulting in contact stress and local bending stress on the edge front (the edge along the glass surface touched by fingers) of the cover glass. It can also occur because of damage introduction to the edge creating a new flaw. If the hardness of the material which strikes the glass is higher, the glass will be easy to be damaged. Small curvature and sharp shape of the material which strikes the glass will be prone to damage the glass. The four-point bending (4 PB) test is generally used to evaluate this mode; however, the cylinder impact test[4] can be also applied. In the cylinder impact test, a pendulum tester with a cemented carbide cylinder strikes the glass edge. In this paper cover glasses are evaluated by the cylinder with the smooth surface like a mirror, and it directly strikes glass edge. The angle of the glass and the cylinder is 10°, and the glass is fixed on the stainless steel base. Impact by the cylinder generates tensile stress on the edge front; glass breakage occurs when the tensile stress exceeds the edge strength. Each experimental setup is shown in Fig. 1.

2.2 Edge Back breakage mode

The Edge Back breakage mode typically occurs when devices are dropped on the ground with a relatively large curvature,

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