High Edge Strength Glass for Mobile Devices

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Abstract

A new evaluation method of the "Edge Impact Test" has been developed. Breakage of cover glass from the edge is enabled to evaluate quantitatively by this method. It is found that resistance to edge impact damage has a correlation with the CT of glass, and a high CS is more effective to improve resistance to the edge impact damage than deep DOL.

Author Keywords

Chemically strengthened glass; Cover glass; Edge strength; Ion-exchange property; High strength

1. Objectives and Background

Touch panel manufacturers utilize chemically strengthened glass as cover glass for mobile devices, in order to keep their mechanical durability. Chemical strengthening is a well-known process to improve the fracture strength of glass. This process generates compressive stress layers on glass surfaces and tensile stress on the inside of glass (Fig. 1). [1], [2] Compressive stress value and depth of compressive stress layer are abbreviated to "CS" and "DOL", respectively.

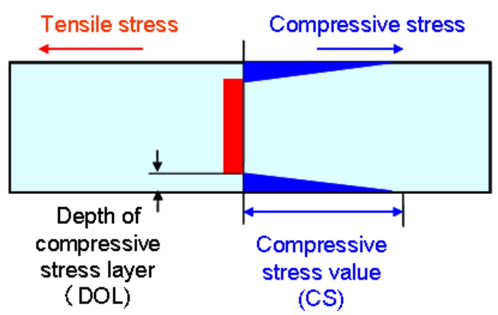

Figure 1. Compressive stress layer schematic illustration.

The cover glass of mobile devices demands to be unbreakable, but breakage sometimes occurs in daily use. Various types of glass have been proposed [3] [4]. However, the issue of breakage of cover glass is not yet solved. That is because the main reason for the breakage of cover glass of mobile devices has been misunderstood. After our research into the causes of the breakage of cover glass of mobile devices, it has been found that, breakage from the edge is dominant. Breakage from the edge is caused by the drop impact to the edge of mobile devices. Therefore, it is important for cover glass to improve resistance to edge impact damage.

Generally, fracture strength of glass is evaluated by the Ball Drop Test, 3-Point Bending Test and other methods. Fig.2 (a) (b) show crack patterns of breakage caused by these general tests. The tests are applied to cover glass. Fig2 (c) shows crack patters of breakage caused by dropping impact. The test is applied to cove glass on simulated mobile device. Crack pattern of breakage caused by these general tests is different from the typical crack pattern of breakage from drop impact. Previously, tests to make an impact to edge have not been carried out so much.

Therefore, Nippon Electric Glass Co., Ltd. devised an evaluation method for the edge strength of glass, to develop a new chemically strengthened glass having high edge strength. In this study, a new evaluation method "Edge-Impact Test" is introduced and the direction of development of next generation chemically strengthened glass is reported.

2. Experimental procedure

2-1 Specimens

T2X-1(Alkali-alumino-silicate glass produced by Nippon Electric Glass Co., Ltd.) with a thickness of 0.55mm manufactured by the overflow-down-draw method and glass in current development were prepared for measurement. The properties of T2X-1 are listed in Table 1.

Specimens of dimensions 22×30×0.55mm were prepared and their edges were chamfered with a #800 diamond wheel. Specimens were ion-exchanged using $KNO_3/NaNO_3$ mixed molten salt. The temperature of molten salt, ion-exchange time and concentration of K^+ ion in molten salt were adjusted to obtain the target CS and DOL. CS and DOL were determined using a surface stress meter (Orihara Seisakujo, FSM-6000).

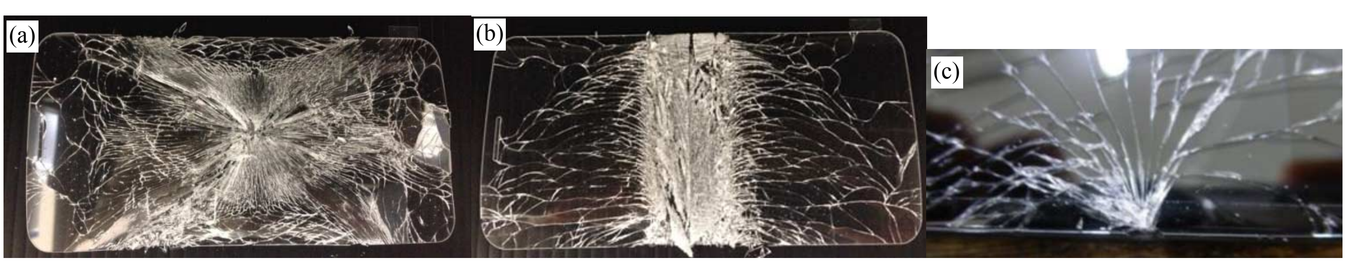

Figure 2. Crack patterns of breakage by (a) Ball Drop Test, (b) 3-Point Bending Test and (c) Typical Dropping Impact.

Table 1. Properties of T2X-1.

Glass code	T2X-1
Density [g/cm^3]	2.45
C.T.E (30-380^{o}C) [x10^{-7}/K]	91
Young's Modulus [GPa]	71
Refractive Index (587.6 nm)	1.50
Photo-Elastic Constant [nm/cm/MPa]	29.5
Dielectric Constant (1MHz)	7.7
Softening Point [^{o}C]	860
Annealing Point [^{o}C]	610
Strain Point [^{o}C]	560

2-2 New evaluation method of "Edge Impact Test"

The Edge Impact Test method was newly developed to evaluate resistance to edge impact damage. A schematic illustration of the evaluation system is shown in Fig. 3. Specimens of glass are fixed in a holder in a state where the edge is exposed. A pendulum arm tip, impact head fitted with a SUS cylinder (φ5mm), is lifted up to a predetermined position. And it is released and hits on the edge of specimen. If the specimen does not break, the position of the arm is raised step by step. The test continues until the breakage of the specimen, then the height of the impact head when the specimen broke is recorded. The results are treated by Weibull plot. The fracture height in the 63rd percentile, B63, is calculated and this decides the edge strength of the glass. The crack pattern of breakage by Edge Impact Test is investigated.

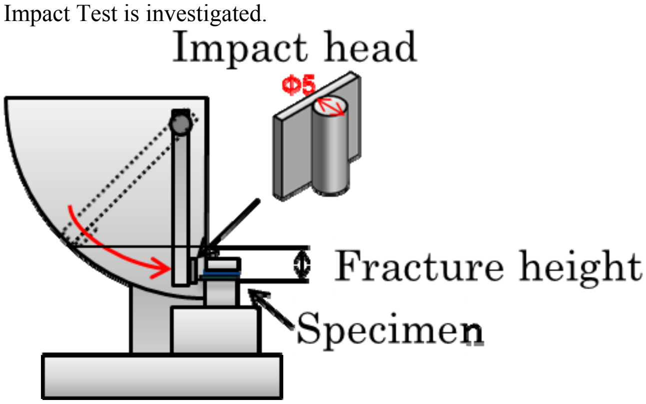

Figure 3. Schematic illustration of Edge Impact Test.

2-3 Edge Impact Test

The following specimens are prepared to investigate the relationships between chemical strengthening characteristics and fracture height.

Relationship between the fracture height and DOL: On the premise of actual production, specimens were ion-exchanged using KNO_3/$NaNO_3$ mixed molten salt to obtain 2 different CS (1000MPa and 700MPa) and various DOL. The CS and DOL of the specimens are shown in Table 2 (No. 1~8).

Relationship between the fracture height and CS: Specimens were ion-exchanged using KNO_3/$NaNO_3$ mixed molten salt to obtain various CS and 35μm of DOL. The CS and DOL of the specimens are shown in Table 2 (No. 3, 9~12).

3. Results

3-1 Confirming the reproducibility of breakage / Breakage after Edge Impact Test

Fig. 4 shows a crack pattern of breakage from the edge of glass by Edge Impact Test. Compared with a typical crack pattern of breakage from dropping impact (Fig. 2 (c)), both crack patterns are very similar. This result indicates that the Edge Impact Test can reproduce practical breakage.

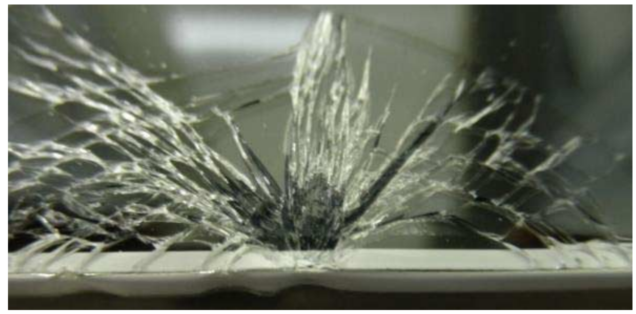

Figure 4. Crack pattern of breakage after Edge-Impact Test.

3-2 Resistance to the edge impact damage

Relationship between the fracture height and DOL: Fig. 5 shows the B63 fracture height of the Edge Impact Test versus DOL. It is clear that the B63 fracture height of specimens were increased with increasing DOL.

Relationship between the fracture height and CS: Fig. 6 shows the B63 fracture height of the Edge Impact Test versus CS. It is clear that the B63 fracture height of specimens were increased with increasing CS.

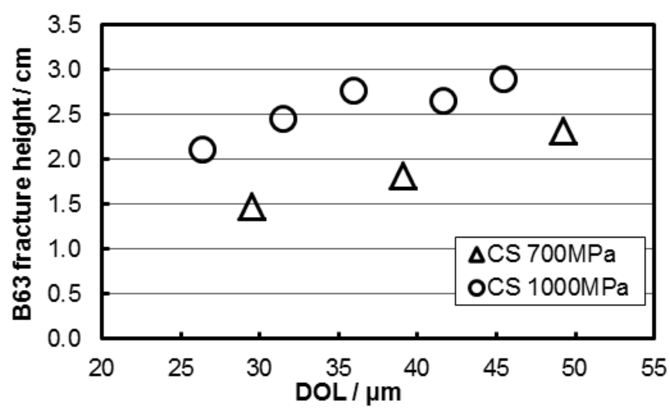

Figure 5. Relationship between B63 fracture height and DOL of specimens.

Table 2. CS and DOL of Specimens.

No.	1	2	3	4	5	6	7	8	9	10	11	12	13
CS [MPa]	1000	995	990	995	1005	695	690	700	990	850	750	650	560
DOL [μm]	26	31	36	42	45	30	40	49	36	36	35	33	32

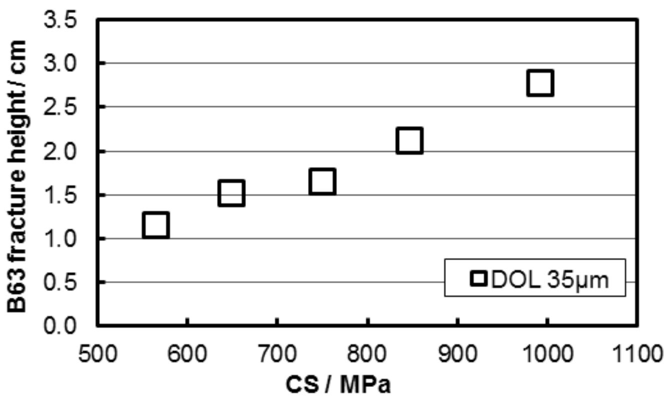

Figure 6. Relationship between B63 fracture height and CS of specimens.

4. Discussion

The experimental results indicate that resistance to edge impact damage will be improved by increasing CS and DOL of glass. Central tension, CT, on the inside of glass is increased with increased CS and DOL. CT is a function of CS, DOL and the thickness of the glass substrate, t, as expressed in equation (a).

$$CT = \frac{CS \times DOL}{(t - 2 \times DOL)} \quad (a)$$

Therefore, the effective to improve resistance to edge impact damage of either CS or DOL was investigated. Fig. 7 shows the B63 fracture height of the Edge Impact Test versus CT. The B63 fracture height of cover glass increased with increasing CT. However, excess CT of glass can cause disadvantages to self-destruction and weakness against surface damage.. Comparing the same CT samples, the higher CS samples were found the stronger resistance to edge impact damage. From this result, the direction of development of high edge strength glass for mobile devices is founded.

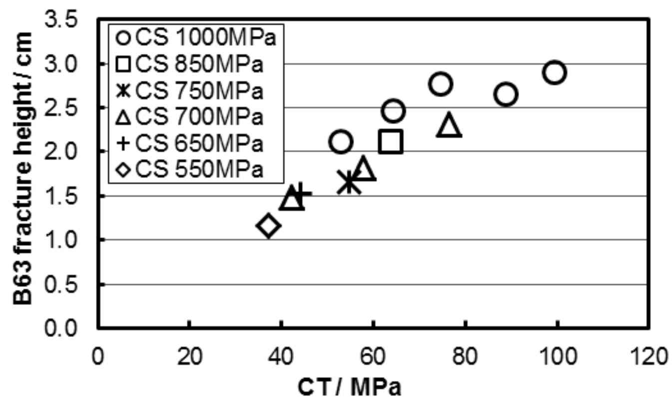

Figure 7. Relationship between B63 fracture height and CT of specimens.

5. Summary

A new evaluation method of "Edge Impact Test" is devised and breakage of cover glass from the edge can be quantitatively evaluated by the method. Resistance to edge impact damage has a correlation with the CT of glass. High CS of glass, when compared with deep DOL, is more effective to improve resistance to edge impact.

Now, Nippon Electric Glass Co., Ltd. is developing new glass which is able to obtain a high CS.

6. References

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