Characteristics of Dynamic Elastic Modulus Of Chemically Ion Exchanged Glass

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1. Introduction

Glasses are widely used in components requiring high performance with high resistance to impact and superior optical characteristics. Especially increased use of cellular phone requires the development of thin glasses with high strength and permeability through various physical and chemical strengthening. Chemical strengthening is obtained by formation of compressive stress layer which is produced by exchange of large K+ ion with small Na+ ion at glass surface through temperature and time control of molten KNO3 as shown in Fig. 1.

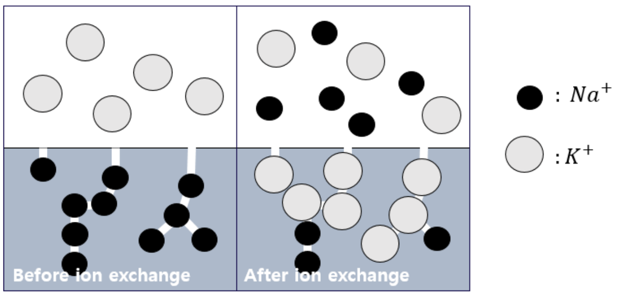

Fig. 1 Chemical ion exchange concept of glass for compressive surface stress

Elastic modulus and Poisson's ratio of various chemically strengthened glasses for display by classical static 3-point bending test and dynamic ultrasonic pulse echo overlap technique(UPET) and impulse excitation technique(IET) to understand the change in physical characteristics.

2. Test methods

Display glass used in this study is gorilla I type of Corning before and after chemical strengthening with dimension 75*50*0.7mm. Mechanical characteristics of a material such as elasticity, bending and fracture strengths can be measured by applying load at the center of specimen in 3-point bending test. Bending test was conducted based on ASTM C 1161, ISO7438 test method[1]. 3-point bending test was conducted by standing glass specimen at A and B points and applying loads at the center using test equipment shown in Fig.2, and 3-point bending tests were conducted under 0.1mm/sec of speed and 30mm of distance between standing points to obtain the most stable slope, and elastic modulus and shear modulus could be obtained through these bending tests.

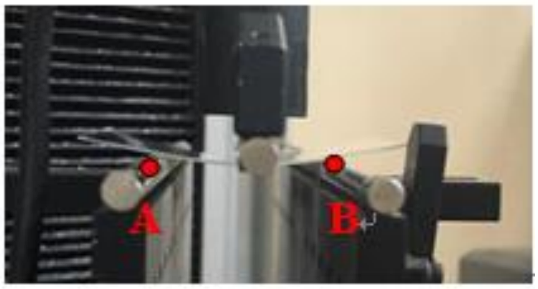

Fig. 2 Three-point bending test

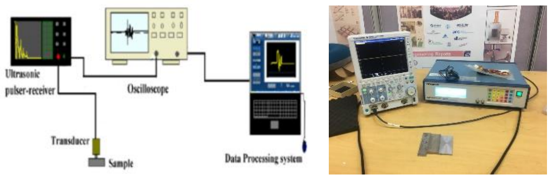

Fig. 3 Schematic representation of ultrasonic pulse echo overlap technique

Fig. 3 shows basic measuring system and equipment of ultrasonic pulse echo method, and velocities of ultrasonic reflected sound (V_ℓ , V_t) are obtained using two ultrasonic transducers. V_ℓ is longitudinal wave velocity and V_t is transverse wave velocity. Velocity of ultrasonic wave is obtained by measuring round trip distance of ultrasonic sound wave produced in ultrasonic transducer divided by round trip time (t_ℓ, t_t) measured by oscilloscope, and elastic modulus, shear modulus and Poisson's ratio can be obtained. And impulse excitation technique can produce elastic modulus through finding resonance frequency by applying impact on specimen. Fig. 4(a) shows how to measure flexural frequency by analyzing the signals through microphone after striking the specimen at impulse point using impulse tool by setting the test specimen with parallel node line. Shear modulus is measured by setting the node line crossed as in Fig. 4(b), and flexural frequency and torsional frequency are determined. And thickness, length, area and weight of test specimen are substituted into related equation to obtain dynamic elastic modulus and dynamic shear modulus[2-4].

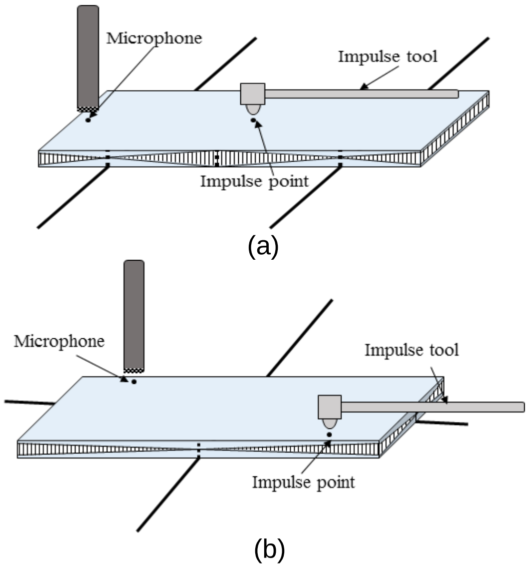

Fig. 4 Flexural test in IET (a), Torsional test in IET (b)

3. Results and discussion

Table 1 summarizes the results of each test, and dynamic UPET and IET methods showed about 1GPa and 3GPa higher elastic modulus and shear modulus compared to static bending test result, respectively. And bending test and dynamic methods of UPET and IET showed Poisson's ratio of 0.22 and 0.19, respectively. This can be explained by difference in static bending test where flexure and shear stress mode against external loads are measured at the same time and dynamic UPET and IET methods where interatomic cohesion energy and spring model theory are applied[5-6].

Table 1. Test results of E, G, μ

Methods	BT	UPET	IET
E [GPa]	71.40	72.41	72.52
G [GPa]	27.00	30.23	30.43
μ	0.220	0.197	0.191

Table 2. Results of Stress in IET test

Specimen	F1 [Hz]	F2 [Hz]	E [GPa]	G [GPa]	μ
Non	1386	1862	72.52	30.43	0.19
KNO_3 420℃ 1h	694	665	69.25	30.73	0.13
KNO_3 420℃ 2h	693	665	68.16	30.45	0.12
KNO_3 420℃ 3h	690	664	67.69	30.31	0.12

Table 2 shows results of dynamic elastic modulus by IET method under various chemical strengthening conditions with about 3~5GPa less than before chemical strengthening. And elastic modulus showed decreasing tendency with increasing strengthening time. Physical meaning of elastic modulus is potential energy related with interatomic force. There might be difference in elastic wave based on spring mode by K^+ ion exchange by chemical strengthening, and this can be identified by K^+(0.231nm, 63℃) ion with large atomic radius and lower melting point than Na^+ (0.186nm, 98℃) ion. It was intended to explain that mechanical bending strength increased after chemical strengthening but physical elastic modulus related with potential energy and spring mode related with interatomic force decreased[7-8].

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