Mechanical Reliability of AMLCD Glass Substrates

Technical Information Paper

TIP 204
Issued: November 2004
Supercedes: February 2003

S. T. Gulati and J. D. Helfinstine

Corning Incorporated, Corning, NY 14831
Paper presented at SID 1996 – San Diego, CA

Abstract

Strength, fatigue, and toughness data for five different AMLCD glass substrates are used, together with the Power law fatigue model, to compute their threshold stress intensity K_{I0}. The relative robustness of LCD displays is assessed by measuring the flaw depth and computing the safe allowable in-service stress from K_{I0}, which ensures the long-term reliability of AMLCD glass substrates.

Objectives and Background

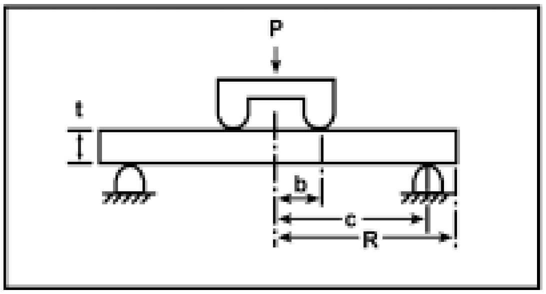
AMLCD displays are exposed to mechanical, thermal, and vibrational stresses during manufacturing, packaging, and in-service[1,2]. Depending on stress-time history and fatigue properties of AMLCD glass, surface flaws introduced during manufacturing and handling may or may not grow thereby impacting the long-term reliability of displays. Since fatigue models[3-5] have proven valuable in reliable design of space windows[6], optical fibers[7], telescope mirrors[8], CRT panels[9], and automotive windshields[10], it is prudent to apply the same model to AMLCD glasses and estimate their threshold stress intensity which plays a critical role in designing LCD displays from long-term durability point of view. Several AMLCD glasses were evaluated with respect to their biaxial strength, dynamic fatigue behavior, fracture toughness, and flaw severity.

These data, when applied to Power law fatigue model, provide the safe allowable tensile stress which, if not exceeded in day-to-day service, would ensure the long-term mechanical reliability of AMLCD displays. These data are also useful in comparative evaluation of different AMLCDglasses from reliability point of view.

Results

Table 1 lists the key physical properties of five different AMLCD glasses which were investigated from mechanical reliability point of view. Bocko and Allaire[1] and Dumbaugh et al[11] have recently compared their thermal, chemical, dimensional stability and edge integrity characteristics. We extended their work by focusing on mechanical properties of these glasses, namely biaxial strength, fracture toughness, stress corrosion constant, Young's modulus and Poisson's ratio.

Figure 1. **Concentric ring flexture test**



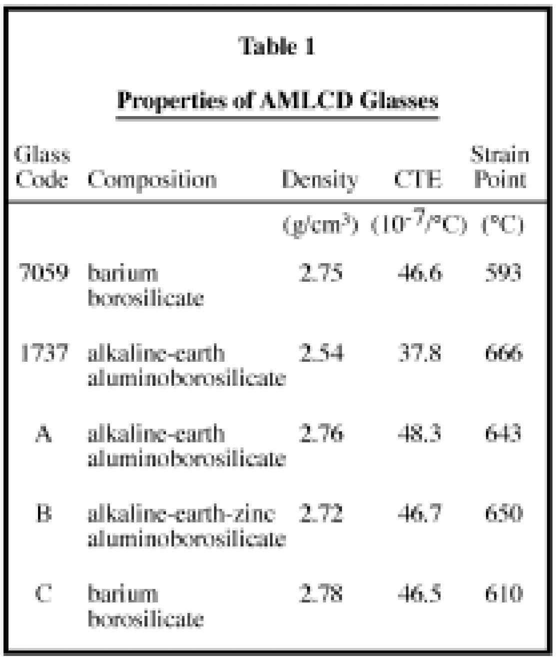


Table 1

Properties of AMLCD Glasses

Glass Code	Composition	Density (g/cm^3)	CTE (10^{-7}/°C)	Strain Point (°C)
7059	barium borosilicate	2.75	46.6	593
1737	alkaline-earth aluminoborosilicate	2.54	37.8	666
A	alkaline-earth aluminoborosilicate	2.76	48.3	643
B	alkaline-earth-zinc aluminoborosilicate	2.72	46.7	650
C	barium borosilicate	2.78	46.5	610

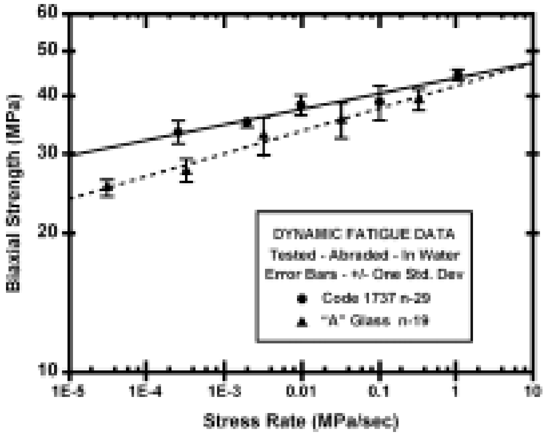
The biaxial strength σ_f was measured in a concentric ring flexure test, Figure 1, using 50 x 50 x 1.1 mm thick square plates and equation 1:

$$\sigma_f = \frac{3P}{4\pi t^2}\left[2\cdot(1+\nu)\cdot\ln\left(\frac{c}{b}\right)+(1-\nu)\cdot\left(\frac{c}{b}\right)^2\left(1-\frac{b^2}{c^2}\right)\right] \qquad (1)$$

In equation 1, *P* denotes load at failure, ν is Poisson's ratio of glass, and other terms are defined in Figure 1. The fracture toughness K_{Ic}, which is relatively insensitive to glass composition, was measured using the Chevron notch short bar test. The stress corrosion constant *n*, which is a strong function of glass composition, surface flaws, and test environment, was obtained by measuring the biaxial strength σ_f at five different stress rates σ' . The *n* value is estimated from the slope of ln (σ_f) vs. ln (σ') plot, Figure 2, and equation 2:

$$n = \left\{\frac{\ln\sigma'_1 - \ln\sigma'_2}{\ln(\sigma_{f1}) - \ln(\sigma_{f2})}\right\} - 1 \qquad (2)$$

Figure 2. **Biaxial strength vs. stress rate plot of two different AMLCD glass substrates with sandblasted surface**.



Similar plots were used for other AMLCD glasses. A Weibull plot of unabraded biaxial strength of Code 1737 vs. "A" glass is shown in Figure 3. Similar plots help compare the strength distribution of other AMLCD glasses which is a strong function of surface quality of substrates. The Young's modulus *E* and Poisson's ratio n were measured by sonic resonance technique[12]

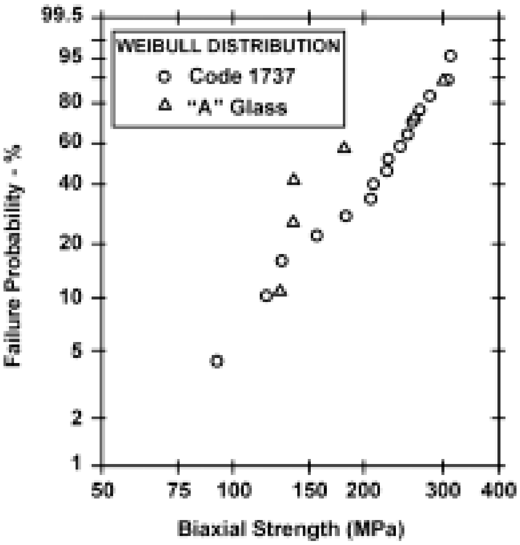
Table 2 summarizes the mechanical properties of AMLCD glasses listed above. The higher the n value is, the more robust and fatigue resistant the glass will be. It is clear in Table 2 and Figure 3 that Code 1737 glass has the highest strength and stress corrosion constant. Moreover, the surface flaws, in fusion-drawn Code 1737 glass, have the lowest depth due to absence of grinding and polishing flaws. The flaw depth α was measured from the fracture surface of 50 x 50 x 1.1 mm square plates and verified from equation 3, which relates fracture toughness K_{Ic}, biaxial strength σ_f and flaw depth α for scratch type flaws representative of grinding damage[5]:

$$K_{Ic} = 1.98\cdot\sigma_f\sqrt{a} \qquad (3)$$

Figure 3. **Biaxial strength of two different AMLCD glass substrates with unabraded surfaces.**

Table 2
Mechanical Properties of AMLCD Glasses

Glass Code	Biaxial Strength (MPa)	Flaw Depth (μm)	Stress Corrosion Constant	Fracture Toughness (MPa√m)	Young's Modulus (GPa)	Poission's Ratio
7059	135	9.0	19.4	0.80	66.3	0.25
1737	217	3.7	29.0	0.83	72.1	0.22
A	191	4.7	19.0	0.82	75.4	0.20
B	182	5.2	20.0	0.82	70.0	0.17
C	153	7.0	18.1	0.80	64.9	0.23



The threshold stress intensity K_{Io} and safe allowable stress σ_o were then estimated from K_{Ic}, and σ_f using equation 4[7]:

$$\frac{K_{I0}}{K_{Ic}} = \frac{\sigma_o}{\sigma_f} = \left[0.75 \cdot 10^{-12} \cdot \left(\frac{n}{2} - 1\right)\right]^{1/n} \qquad (4)$$

Table 3 summarizes K_{Io} / K_{Ic}, σ_o / σ_f values for the five AMLCD glasses. It should be noted that,once again, Code 1737 glass permits the highest safe allowable stress in service, i.e. its long-term mechanical reliability and robustness are the best among the five glasses studied here. A static stress equal to 42% of biaxial strength can be applied to Code 1737 AMLCD substrate with little or no risk of long-term degradation, compared with only 26% for glass "A". Experiments to verify these predictions of Power law fatigue model, which have proven correct for other applications[7-10], are currently in progress.

Table 3

Threshold Stress Intensity K_{Io} and Safe Allowable Stress σ_o for AMLCD Glasses

Glass Code	K_{Io}/K_{Ic}	σ_o/σ_f
7059	0.27	0.27
1737	0.42	0.42
A	0.26	0.26
B	0.28	0.28
C	0.24	0.24

Summary

The measurement and comparison of key mechanical properties of five different AMLCD glass substrates, in conjunction with the Power law fatigue model, have demonstrated the superiority of Code 1737 glass over other candidates from long-term reliability point of view. These data show that Code 1737 glass is not only stronger, it can sustain 80% higher stress over its lifetime than other candidates due to its higher fatigue resistance and strength.

References

1. Bocko, P.L. and Allaire, R.A.; *"Glass Contribution to Robustness of Displays for Automotive Applications;"* 1995 Symposium on Vehicle Displays sponsored by Detroit Metropolitan Chapter of Society for Information Display, Ypsilanti, MI, November 2, 1995.

2. Ghosh, A.; Gulati, S. T; and Helfinstine, JD.; *"Review of Requirements of Glass for AMLCDs for Vehicle Display Applications and Fatigue Behavior of LCD Glass;"* 1995 Symposium on Vehicle Displays sponsored by Detroit Metropolitan Chapter of Society for Information Display, Ypsilanti, MI,- November 2, 1995.

3. Wiederhorn, S.M. and Boiz, L.H.; *"Stress Corrosion and Static Fatigue of Silicate Glass,"* J. Am. Ceram. Soc.; 53, 10 (19 70).

4. Ritter, JE. and Sherburne, CL.; *"Dynamic and Static Fatigue of Silicate Glasses;"* J. Am. Ceram. Soc.; 54, 12 (1971).

5. Evans, A.G.; *"Slow Crack Growth in Brittle Materials under Dynamic Loading Conditions;"* Int. J Frac.; 10 (1974).

6. Wiederhorn, S.M.; Evans, A.G. and Roberts, D.E.; *"A Fracture Mechanics Study of the Skylab Windows,"* Proc. Conf Fract. Mech. Ceramics; Penn State Univ. (1973).

7. Glaesemann, G.S. and Gulati, S. T; *"Design Methodology for Mechanical Reliability of Optical Fiber;"* Opt. Engg., 30, 6 (1991).

8. Gulati, S.T and Powell, W.R.; *"Mechanical Reliability of 8m Class ULE^{TM} Glass Telescope Blanks during Manufacturing;"* SPIE Proc. 2536 (1995).

9 Gulati, S. T; *"Stress Corrosion in Silicate Glasses and Its Impact on CRT Panel Design;"* SID Digest (1993).

10 Gulati, S. T; *"Delayed Cracking in Automotive Windshields;"* Proc.7th Nondest. Charact; Prague (1995).

11 Dumbaugh W.H.; Bocko, P.L. and Fehlner, F.P; *"Glasses for Flat Panel Displays;"* in High Performance Glasses, ed. M. Cable and JM. Parker, Chapman and Hall, New York (1992).

12 ASTM Designation C-623-92; Am. Soc. Test. and Mat., Vol 15.02 (1995).

North America and all other Countries
Corning Display Technologies
MP-HQ-W1
Corning, NY 14831
United States
Telephone: +1 607-974-9000
Fax: +1 607-974-7097
Internet: www.corning.com/displaytechnologies

Japan
Corning Japan K.K.
Main Office
No. 35 Kowa Building, 1st Floor
1-14-14, Akasaka
Minato-Ku, Tokyo 107-0052 Japan
Telephone: +81 3-5562-2260
Fax: +81 3-5562-2263
Internet: www.corning.co.jp

Nagoya Sales Office
Nagoya Bldg., 7 F
4-6-18, Mei-eki, Nakamura-ku
Nagoya-shi, Aichi 450-0002 Japan
Telephone: +81 52-561-0341
Fax: +81 52-561-0348

China
Corning (China) Ltd., Shanghai Representative Office
31/F, The Center
989 Chang Le Road
Shanghai 200031
P.R. China
Telephone: +86 21-5467-4666
Fax: +86 21-5407-5899

Taiwan
Corning Display Technologies Taiwan Co., Ltd.
Room #1203, 12F, No. 205
Tun Hua North Road,
Taipei 105, Taiwan
Telephone: +886 2-2716-0338
Fax: +886 2-2716-0339
Internet: www.corning.com.tw

Korea
Samsung Corning Precision Glass Co., Ltd.
20th Floor, Glass Tower Building
946-1 Daechi-Dong
Kangnam-Ku, Seoul 135-708
Korea
Telephone: +82 2-3457-9846
Fax: +82 2-3457-9888
Internet: www.samsungscp.co.kr