Effect of high temperature ambience during sharp indentation on the residual contact site properties in glass

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Introduction

Why high temperature indentation?

- To understand the nature of process-derived contact flaws and simulate product handling damage.

- To study these strength-controlling sites at room temperature.
Outline

- Material / mechanical test
- Macroindentation and temperature
- Macroindentation/microindentation and residual stresses
Material – Mechanical test

Window Glass: Planilux (Saint-Gobain)
air side

49 N Vickers
0.1 mm/s no hold

2 °C/min ->100 °C

2 h
Change of contact site characteristics

Michel et al, JNCS, 2004
Hardness as a function of temperature

This study
Watanabe et al
Michel et al
Shang et al

Michel et al, JNCS, 2004
Shang Rouxel, JACS, 2005
$E/H$ ratio as a function of temperature

Indentation temperature, $\circ C$

- Dwell time = 60 s, Michel et al
- Dwell time = 0 s, this study,

Roussel Sangleboeuf, JNCS, 2000
Crack length as a function of temperature

\[ c = \left( \alpha P \right)^{\frac{2}{3}} \left( \frac{E}{H} \right)^{\frac{1}{3}} K_c^{\frac{2}{3}} \]

Fitting measured crack length gives \( \alpha = 0.020 \)

\[ 0.028 < \alpha < 0.034 \]


Rouxel Sangleboeuf, JNCS, 2000
Vickers microindent on stress-free surface of glass

(a) 20 °C

200 μm
Influence of Vickers residual stress field on indentation cracking

Macroindent 49 N

Microindent 2.94 N

$\sigma_c$  

$\sigma_T$

$C_r > C_o$

$C_t < C_o$
Calculate stresses from crack lengths

\[ \sigma_c = K_c \frac{1 - \left( \frac{c_o}{c_t} \right)^{3/2}}{\sqrt{\pi c_t}} \]

\[ \sigma_T = K_c \frac{1 - \left( \frac{c_o}{c_r} \right)^{3/2}}{\sqrt{\pi c_r}} \]

Crack length as a function of position

Length of radial/median cracks

- 500 °C, Radial crack
- 500 °C, Tangential crack

Crack length μm

2a

C₀

y/a

y
Contact site transformation

500 °C

(a) 100 μm

(b) 500 μm

(c) 200 μm

Microindents

Radial cracks

Subsurface lateral crack

Delayed radial crack
Lateral crack dependence on radial crack
Shape of lateral crack dependence on radial crack position
Layout of microindentations around macroindent
Residual stress as a function of temperature

Stresses are tensile in the tangential direction, and compressive in the radial direction.

The spatial extent of the stress field decreases as a function of temperature: relaxation process.

Abrupt change in magnitude close to the radial crack front.
• The nature of contact site can change from a fully cracked imprint at room temperature to a crack-free imprint at higher temperatures.

• The crack-free indent can transform into a fully cracked indent when the residual stress field is mechanically disturbed, as for example by another micro indent.

• The lateral cracks obtain their shape as a result of their coupled growth with that of the radial cracks.

• Stresses are tensile in the tangential direction, and compressive in the radial direction

• The spatial extent of the stress field decreases as a function of temperature