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Specialty Glass:
A New Design Element in Consumer Electronics

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In the best mobile electronics designs, the interaction with the hardware or software fades away, immersing users in the experience. The mobile device becomes an invisible conveyance, or window, into the content. Two technologies are bringing this immersive experience closer to reality: broadband connectivity and touchscreens.

Broadband enables users to always be connected, with information and entertainment always at their fingertips. As multitouch technologies continue to improve, this experience advances further so the user only becomes aware of the appliance's presence when it isn't functioning optimally.

As consumers gain greater access to rich media content such as pictures and videos, displays play an increasingly pivotal role. Consumers have little tolerance for scratches and damage that distort images and tarnish device usage. The paradox is that as devices become more display-centric, touch interfaces make the display the primary input avenue, subjecting it to smudging, scratching, and other flaws.

Multitouch technologies predominantly consist of capacitive touch sensors, which typically mount to the underside of a display cover lens so user contact is via the top surface of the cover lens. If the mobile touchscreen device is supposed to "disappear" as the user is immersed in the experience, the display cover lens has to possess special intrinsic and extrinsic properties.

Intrinsically, the material needs to be scratch resistant, impact resistant, and transparent. These ensure, respectively, a pristine appearance throughout the device's lifetime, providing a continually pleasurable viewing experience as well as allowing for the inputs to the touchscreen to remain consistent. These qualities also enable the device to survive drops and other physical abuse. And, they prevent the cover from obstructing the viewing experience.

SOLUTIONS UNDER GLASS

Increasingly, tempered specialty glass is becoming the material of choice for display covers, rapidly replacing traditional plastics employed as a cover media in units where the user does not directly use the screen as an input medium. Tempered glass is more transparent and scratch resistant than plastic.

These key attributes enable tempered glass to play a critical role in the immersive experience offered by the combination of broadband technologies and touch sensors. Also, tempered glass is more transparent and scratch resistant than plastic.

It's possible to make tempered glass highly damage resistant and therefore more likely to survive significant user abuse. Applying anti-reflective, anti-glare, anti-splinter, hydrophobic, and oleophobic coatings to the glass surface enhances viewing and allows for easier-to-clean surfaces.

The glass also is moldable into non-planar shapes that are aesthetically pleasing and ergonomically effective, if so desired. Moreover, specialty glasses that meet green standards—i.e., devoid of any heavy metals with a glass-making process that's significantly more environmentally friendly than that used for plastics—are possible as well.

GLASS VERSUS OTHER SOLUTIONS

Glass is a relatively new material in the consumer-electronics designer's toolkit. Unlike typically used plastics and metals, glass is a brittle material that requires its own design guidelines to maximize its utility.

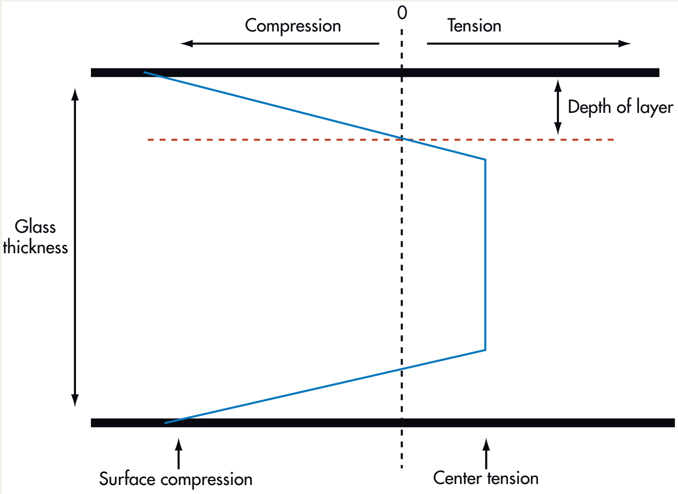

Figure 1. The compressive stress developed in the surface decreases with depth until it is zero over a depth denoted as the depth of a layer. A tensile stress generated within the glass balances this stress.

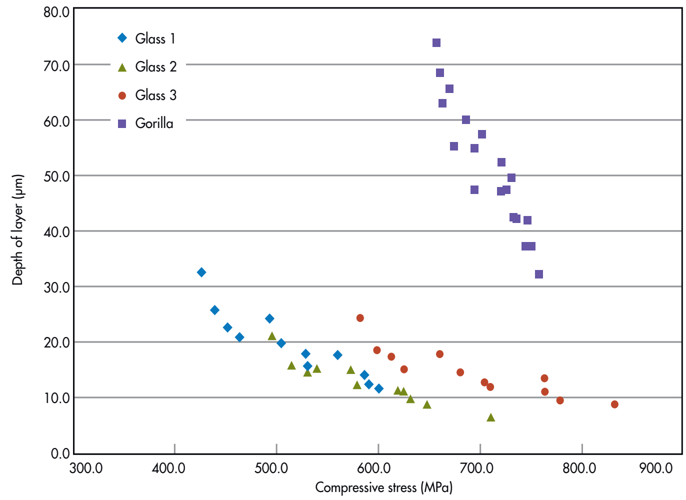

Figure 2. Comparing the magnitude and thickness of the compression layer for various glasses, the diamond and triangles represent common (soda-lime) glasses while the circle represents a modified soda-lime glass.

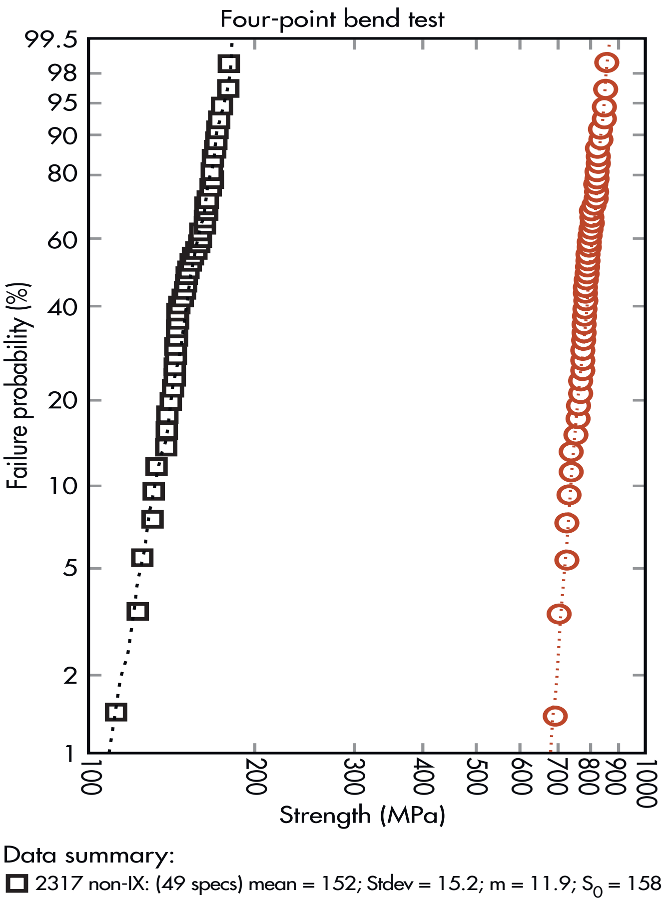

Figure 3. The strength of a glass is measured by a four-point test before and after chemical tempering.

As a brittle material, glass is strong under compression, but weak under tension. Once a crack forms in glass, it will propagate, in most circumstances, to failure. To avoid such catastrophic consequences, the key is to prevent the initial crack from forming, accomplished by tempering the glass.

This involves generating a layer of compressive stress on the surface. For a crack to start, it will have to first overcome this compressive stress. Inducing compressive stress on the glass surface entails one of two methods: thermal tempering and chemical tempering.

In thermal tempering, the glass is cooled very quickly in air or oil. This process is typically suitable for glass found in household appliances, automotive glass, and other applications. Glass subjected to these processes carries tempered-glass label.

The chemical-tempering process immerses the glass in a molten alkaline salt bath, such as potassium nitrate. The alkaline ions in the bath exchange for other alkaline ions already in the glass, resulting in a compressive stress developing in the surface of the glass.

Chemical tempering is more suitable for cover glasses in electronic devices for several reasons. The compressive stress layer is uniform throughout the article, which results in little shape distortion due to warping and little optical distortion due to birefringence. The magnitude of compressive stress developed is also several times higher than thermal tempering. Chemical tempering is more suitable for the thinner glasses commonly used in lightweight consumer electronics as well.

The compressive stress layer acts as an armor that protects the glass, the magnitude of which is comparable to the toughness of the armor. The depth of the compression layer is analogous to the thickness of the armor. Thus, a glass capable of generating deep and high compressive stress will be more effective for use as a cover in mobile devices. Figure 1 shows a profile of a chemically tempered glass with the surface compression layer enveloping a tensile region within the glass.

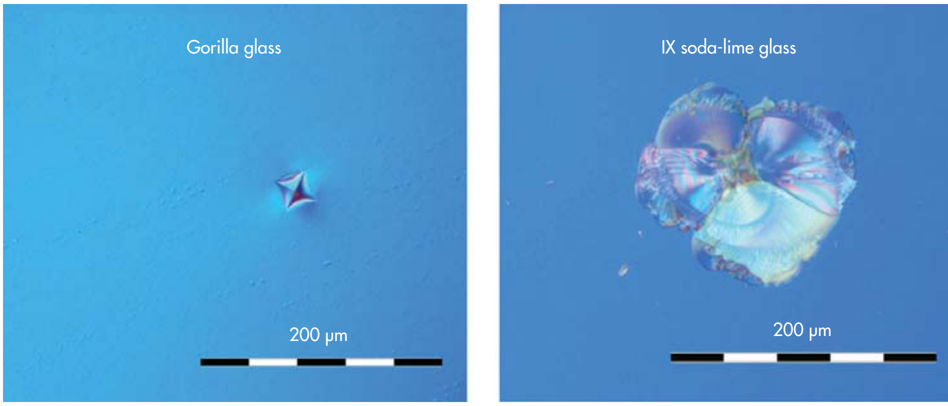

Figure 4. In common glass, cracks and chips are generated when a 500-g load is applied to the glass with a diamond tip. In alkalinalumino-silicate glass (Gorilla glass), these cracks are not generated until 4000-g loads are applied.

WHAT'S AVAILABLE

Window glass, also known as soda-lime silicate glass, has been used as a protective cover in mobile devices. Although capable of strengthening, soda-lime silicate glass generates a relatively thin and flimsy armor layer on the glass due to the lower magnitude and shallower depth of its compressive stress layer.

Several glasses are available for use in electronic devices. The easiest way to compare them is to look at the strength and thickness of the armor. Figure 2 compares four types of glass. The triangles and diamonds represent common glass types, while the circles represent a modified soda-lime glass developed to provide a higher compressive stress. The squares represent Corning's Gorilla alkalinalumino-silicate glass.

The chemical armor in chemically tempered glass serves several purposes. The induced compressive stress increases the strength of the glass as measured by the standard strength tests. This is because any tensile stress that is applied to cause fracture first needs to overcome the compressive stress. The higher the compressive stress, the higher the strengthening we observe. Figure 3 shows the strength in a Weibull plot in which the strength of non-tempered glass (squares) shifts to higher strengths upon chemical tempering.

The compressive stress resists breakage when a device with a glass cover drops onto pavement, which is the most common reason why glass covers on mobile phones break. The sharp impact generates several well-studied crack systems in common glass. We can characterize the response of the glass to sharp contact by studying its response to a load in the form of a well-defined, sharp tip such as Vicker's diamond.

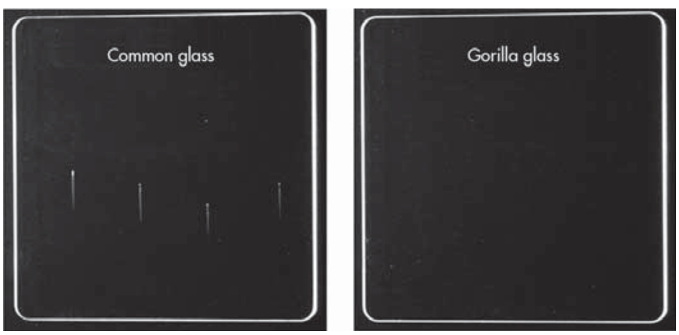

Figure 5. Under test, controlled scratches are visible to the naked eye in common glass while such scratches are not visible in Gorilla glass.

In a common glass, several cracks and surface chips are observable with a 500-g load even after chemical tempering. With Gorilla glass (Fig. 4), cracks do not appear until loads greater than 4000 g are in play.

Another benefit of chemical tempering is that the resultant armor enables the glass to resist scratches. To understand this concept, one needs to understand the scratch process. Typically, the scratch on a glass is a multi-phenomena process where a combination of micro-plastic deformations, micro-cracking, and chipping occurs.

Micro-cracking and chipping occur at a higher scratch load where there is adequate residual stress left due to the scratching process, which must be relieved by the generation of secondary damage. With Gorilla glass, secondary damage occurs at two to three times the load level that scratches common glass. Figure 5 outlines a situation where controlled scratches were applied using a known material and tip geometry and ramped load.

A scratch in the glass may form a flaw from which the glass may ultimately break. In other words, the strength of the glass decreases when scratched. Failure analysis of devices broken in the field shows that cracks originating from scratches are the second most common reason why glass in mobile devices breaks during use. Figure 6 shows the decrease in strength upon a controlled scratch event.

TESTING

Obviously, product design engineers prefer the least expensive alternative. Every product usually goes through rigorous testing, which is proprietary to each manufacturer and involves a combination of drop, tumble, and other tests.

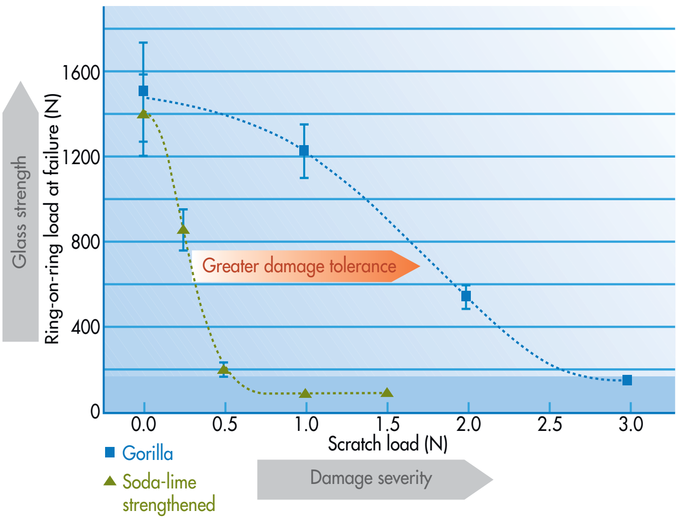

Figure 6. The strength of glass in general decreases when its surface is damaged, though Gorilla glass can retain its original strength to a much greater degree than common glass.

During drop testing, testers release the device from a set height onto steel, granite, or a Portland cement concrete surface in select orientations. The tumble test involves tumbling the device in a closed tube that rotates about its center along its length. The tube may contain other objects such as keys and coins. To design a different glass into a device, the glass must prove itself by performing better than the common glass in these tests.

How can a designer select the right glass for an application? The attributes will depend on the application, model, and requirements. For instance, a device in which the screen closes up after use, like a notebook or netbook computer, may not need sharp impact protection since.

However, the fact that the unit is mobile means the device may be dropped, requiring high glass strength. If the device performs a video application or if the display is a high-resolution type, then scratch resistance figures prominently in the requirements.

Ball-drop strength is conspicuously missing from the list because the ball-drop test is a simple pass-fail test, measuring the height from which a ball drops onto a glass sample and causes breakage. Once a de-facto criterion for evaluating materials, some device manufacturers are finding inconclusive or non-existent correlations between device performance and ball-drop height.

Further investigation reveals that this test measures the surface strength of the material with five-times higher variability than standard surface-strength tests described in ASTM C1499 and does not show any unique advantage in being a more accurate impact test.

CONCLUSION

While durability is a primary attribute affecting the survivability of the glass in mobile devices, designers are demanding other attributes such as anti-fingerprint characteristics, textures that limit specular reflections, and textures that have superior tactile response for stylus and finger operations. Also desirable is the ability to creatively shape the cover glass.

Glass is an excellent material. As a design language, it communicates precision, quality, and longevity. With the consumer electronics trend of thinner, lighter devices that feature ever-greater functionality, the properties of strengthened glass help to meet these needs. For example, the Dell Adamo is the first laptop computer to employ Gorilla glass (Fig. 7) as a part of its enclosure. Also, many brands are investigating formed glass, which allows for the creation of unique shapes.

Figure 7. As an example of glass forming to create custom shapes, the Dell Adamo is the first laptop computer to employ Gorilla glass as a part of its enclosure.

As the market increases for smart devices with touchscreens and for devices design-driven devices that aim to create an enhanced viewing experience, strong glass will continue to offer many unique design features, enabling this exciting material to be more widely used in the future.

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Jaymin Amin, program director for complex glass components specialty materials, first joined Corning in July 1997 as a senior research scientist and since has held several positions at the company.

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