Materials Innovation Case Study:
Corning's Gorilla Glass 3 for Consumer Electronics

SUMMARY

Corning's Gorilla Glass 3 is a notable materials innovation that occurred over a compressed, 22-month time period—an achievement facilitated by Corning's depth of modeling capability, experience with prior Gorilla Glass products, and direct control over the major elements of the innovation process. The following case study explores the specific actions that led to this success through the development of a "reverse roadmap," which captures and classifies the key activities that either accelerated or inhibited the innovation process.

BACKGROUND

While it is now a household name, Corning's Gorilla Glass has only been used in consumer applications for less than 10 years. In fact, the first generation of the glass—which resists breakage and scratching thanks to a chemical treatment applied by an ion exchange process[1]—was developed for Apple's first iPhone, launched in 2007. When Gorilla Glass 2 was introduced in 2012, it achieved the market's desire for a thinner product at a size 20% thinner than its predecessor.[2]

In its third iteration, Gorilla Glass 3 is even stronger, thinner, and more scratch resistant. In addition to the chemically strengthened surface, bulk composition tailoring has been employed to create Native Damage Resistance (NDR), which has resulted in a glass three times more damage resistant than Gorilla Glass 2.[3] The glass is also provides the additional advantage of being more resistant to deep scratches that might otherwise initiate breakage.

Gorilla Glass has indeed been a commercial success for Corning—recently, Gorilla Glass 4 was introduced to extend the product line. At the end of 2015, Corning's Gorilla Glass had been used in over 4.5 billion devices, including smartphones, tablets, notebook computers, and smartwatches,[4] as well as extended applications such as interior architecture and design, markerboards, and automotive glass and touch panels.

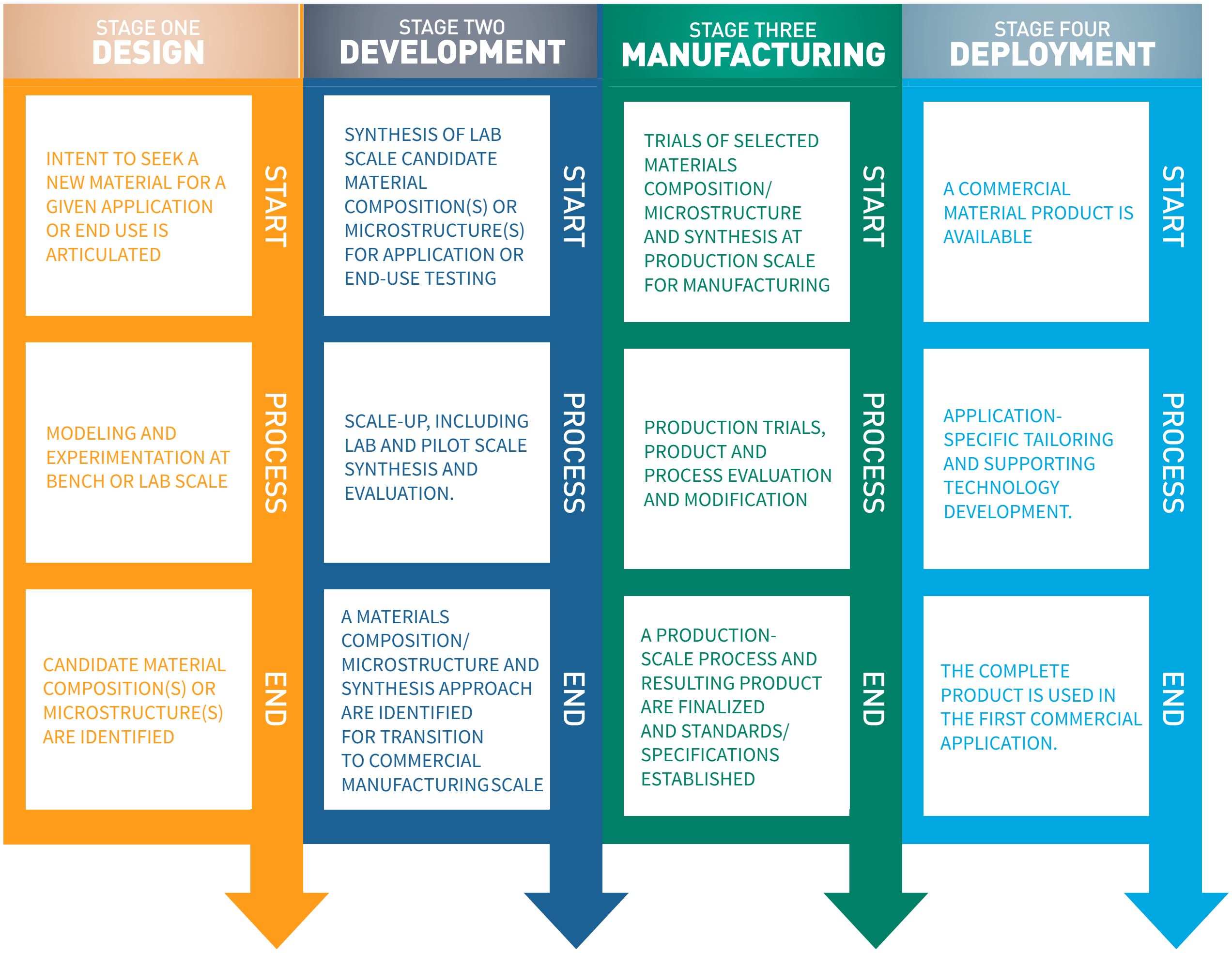
REVERSE ROADMAP

The materials innovation process employed to develop Gorilla Glass 3 is outlined in a "reverse roadmap," which captures events that have already occurred, as compared with a traditional forward-looking roadmap. The reverse roadmap is presented on a time scale divided into four major categories: Design, Development, Manufacturing, and Deployment. The analytical framework in Figure 1 outlines the general structure of the reverse roadmap and can be applied to materials innovation processes across a broad range of materials, applications, and markets.[5]

---

[1]Walton, D, Amin, J, and N. Shashidhar. 2010. "Specialty Glass: A New Design Element in Consumer Electronics."
[2]Guglielmo, C. 2013. "Corning, After Thinning out Gorilla Glass, Makes New Generation Tougher." Forbes. http://www.forbes.com/sites/conniegug lielmo/2013/01/10/corning-after-thinning-out-gorilla-glass-makes-new-generation-tougher/#4938a9373d223a2bf3ea3d22.
[3]Corning. http://www.corninggorillaglass.com/en/glass-types/gorilla-glass-3-with-ndr, accessed 01/20/16.
[4]Corning. http://www.corninggorillaglass.com/en/products-with-gorilla, accessed 01/20/16.
[5]"Quantitative Benchmark for Time to Market (QBTM) for New Materials Innovation", Report by Nexight Group and Energetics, Inc., January 2016.

Figure 1. Analytical Framework for Time to Market for Materials Innovation



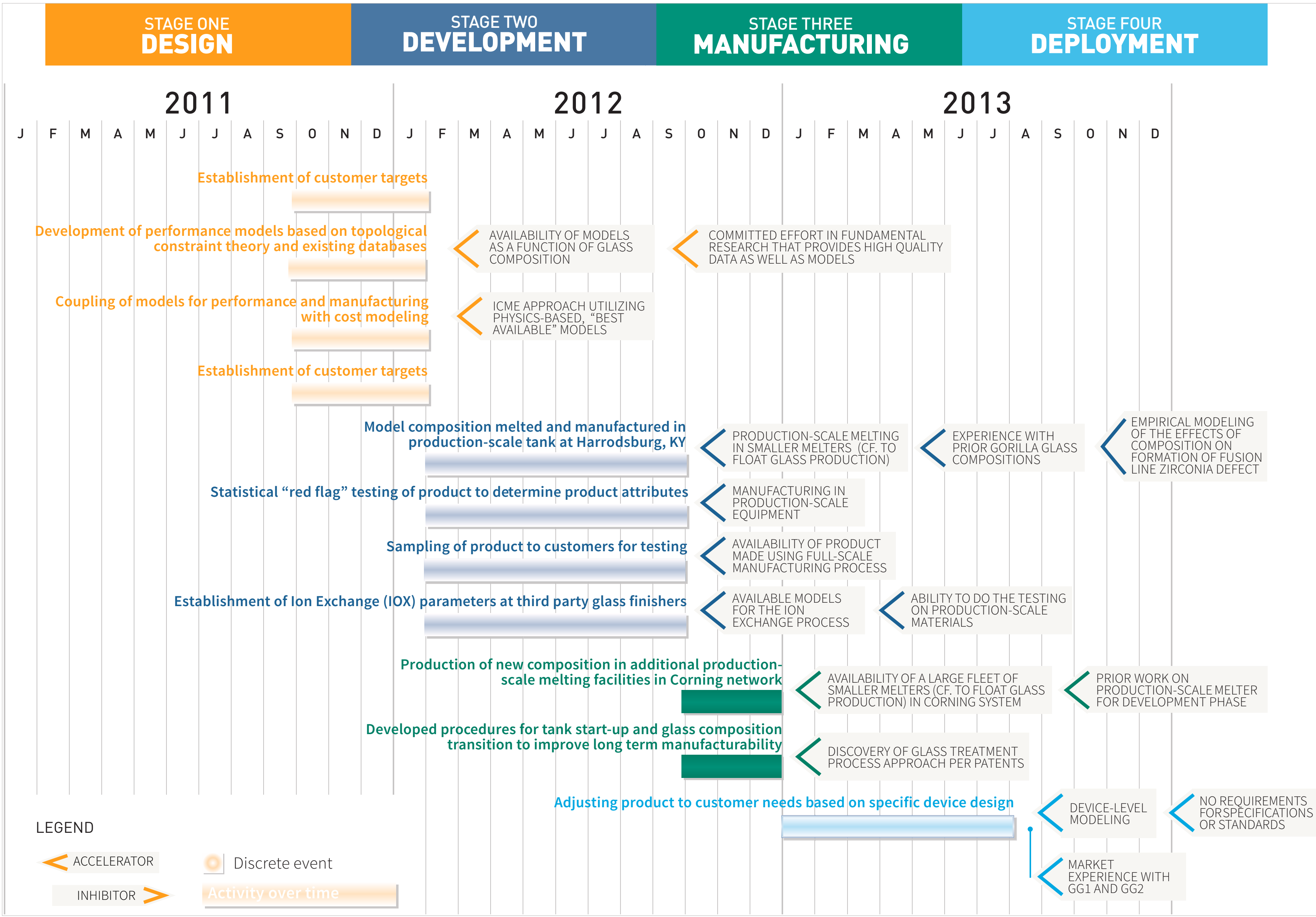
The reverse roadmap includes four primary elements:

1. Activities that occurred over time
2. Discrete events occurred at a specific point in time (e.g., milestone)
3. Factors that decreased the time needed to complete an activity (or, “accelerators”), which are shown to the right of an activity pointing backwards in time
4. Factors that increased the time needed to complete an activity (or, “inhibitors”), which are shown to the left of an activity pointing ahead in time.

DISCUSSION

The value chain for this materials innovation was largely within Corning, which has the capability for the production or at least simulation of all of the necessary processes to move through all four stages outlined in Figure 2. External work by other companies that perform the ion exchange treatment to impart compressive surface stresses as well as end-use customers involved in evaluating material samples is important for commercial realization, but did not markedly influence the innovation process and timeline. Additional detail on the activities that occurred in each of the four stages is included in the text that follows.

Figure 2. Reverse Roadmap for Corning's Gorilla Glass 3 Materials Innovation



Design Stage

In the Design stage, a series of parallel activities occurred over a period of approximately four months. This stage was facilitated by the experience gained from the development of the previous two versions of Gorilla Glass. In addition, the breadth of data and models available to Corning as a result of the company's strong and ongoing commitment to fundamental research served as an accelerator. For example, the availability of models—specifically, performance models based on topological constraint theory[6]—enabled Corning to more quickly determine which materials compositions could best meet the specific customer requirements identified.

Also critical to the efficiency of this stage was the use of an integrated computational materials engineering (ICME) approach that incorporated both materials design for performance and manufacturing-related models. This ICME approach used the best available models, which, despite varying degrees of precision and accuracy, were effective in identifying >50 candidate compositions. In the Design stage, the candidate compositions were produced in the form of crucible melts for screening. The output of the Design stage was a model composition that could then be moved to the Development stage.

Development Stage

The Development stage involved a series of overlapping processes that were carried out in seven months at Corning's manufacturing facility in Harrodsburg, Kentucky, using a production-scale melter. Significant accelerators at this stage included Corning's experience in producing prior Gorilla Glass products as well as the availability of empirical modeling that informed the operating conditions, especially with regard to the suppression of fusion line zirconia defects in the fusion draw process used in glass manufacturing. Sample materials were tested both internally and by customers, with effective customer engagement enabled by the fact that the samples had been produced using commercial-scale equipment and processes. Also included in this stage was work on establishing the parameters for the ion exchange (IOX) process that is employed to impart the compressive surface stresses that contribute to the damage resistance of Gorilla Glass. This activity was accelerated by having models in place for the ion exchange process.

Manufacturing Stage

The Manufacturing stage occurred over a short timeframe of approximately three months. It was greatly accelerated by the use of the production-scale melter during the Development process, and essentially involved implementation of the process developed in the prior stage at other production facilities with similar melting equipment. The procedure for tank start-up as well as transitions between glass composition were also developed in this stage, which helped facilitate the incorporation of Gorilla Glass 3 production into the production flow of different glass compositions within Corning. The invention of a process for minimizing the potential for fusion line zirconia formation[7] also assisted in this smooth transition.

Deployment Stage

Gorilla Glass 3 was announced at the Consumer Electronics Show in January 2013, which initiated the Deployment stage. The main activity during this stage was adjustment and adaptation to specific customer designs based on the particular device, which occurred over the ensuing seven months. Corning's device level modeling capability accelerated this stage.

The ability to rapidly deploy Gorilla Glass 3 into the marketplace was aided by the lack of requirements for material certification and standards development that can be an important element of many structure-critical materials applications. Often the certification step can take a year or more to accomplish, and the fact that

[6] J. C. Mauro, et al., "Modeling of Chemically Strengthened Glass", presented at MS&T15, October 2015.
[7] A. J. Ellison et al., "Method for Reducing Zirconia Defects in Glass Sheets", U.S. Patent 8,746,010 B2, June 10, 2014.

it was not necessary in this consumer products application eliminated this potential slow-down.

CONCLUSION

Corning's Gorilla Glass 3 was completed in a very short time period of approximately 22 months, from the start of the Design stage to the completion of Deployment. Corning's strong knowledge of prior products and fundamental research and its ability to conduct all primary activities in-house, as well as a lack of requirements for material certification and standards development, all contributed to the accelerated pace. This functional materials innovation is an excellent example of the application of modeling coupled with commercial experience to rapidly produce a material product with enhanced capabilities.

ACKNOWLEDGEMENT

The helpful inputs from Dr. John Mauro of Corning to develop the materials innovation timeline are greatly appreciated.