

Using glass for passivation in semiconductor applications



A silicon wafer used in semiconductor processing.

By Cheol-Woon Kim

With its unique properties and versatility, glass is a compelling choice in semiconductor manufacturing to prevent degradation and ensure long-term reliability of components.

In the fast-paced world of semiconductor manufacturing, where precision and reliability are paramount, choosing a suitable passivation material is critical to ensuring the optimal performance of electronic devices.

Among the library of viable materials, glass has gained significant attention for its unique properties and versatility. This article looks at how glass is used for passivation and what properties make it highly suitable for the job.

Understanding passivation in semiconductors

Before unpacking the specifics of glass as a material for passivation, it is essential to understand the concept of passivation in semiconductor manufacturing. Passivation involves depositing a protective material onto the surface of metals or metal alloys to enhance their resistance to environmental factors.

The layering material can be organic or inorganic and should exhibit excellent electrical insulation and strong substrate adhesion, as well as block the ingress of chemical species. In the case of semiconductors, passivation is crucial to preventing degradation and ensuring long-term reliability.^{1,2}

Why glass is used for passivation

Glass has emerged as a compelling choice for passivation due to its unique combination of properties. For example, glass can be formulated in numerous ways, with common types including lead aluminosilicate, zinc borosilicate, lead zinc borate, and bismuth zinc borate. This compositional diversity allows manufacturers to produce glass capable of meeting low- and high-voltage electrical specifications; matching the coefficient of thermal expansion of semiconductor materials; and meeting the low-temperature processing requirements.^{3,4}

Glass is chemically durable and thus can provide an inert barrier against external elements, such as moisture and contaminants, which might otherwise compromise the semiconductor's performance. Moreover, the high transparency of some glasses, such as borosilicate glass, makes them ideal for applications with critical optical properties, such as photovoltaics. This transparency enables efficient energy transmission and absorption, contributing to the overall performance of semiconductor devices and solar cells.^{5,6}

How semiconductors are passivated

Glass is deposited onto semiconductors in a variety of ways. Choosing methods for passivation depends on factors

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such as the semiconductor device's specific requirements, the passivation layer's desired properties, and the overall manufacturing process. Methods for achieving glass passivation in semiconductor manufacturing include⁷

- Chemical vapor deposition, including plasma-enhanced deposition;
- Physical vapor deposition, including E-beam deposition;
- Sputter coating; and
- Atomic layer deposition.

In manufacturing, the process of glass passivation is frequently followed by chemical procedures, such as the etching of contact windows or the electrolytic deposition of contacts. These procedures may pose a threat to the integrity of the glass.

The chemical resistance of different passivation glasses varies significantly and serves as a crucial factor in determining the suitable glass type and the accompanying etching process.⁸

Comparing glass to other materials

While various materials can be used for passivation, glass stands out for its exceptional stability over temperature, humidity, and time. Literature searches reveal a lack of head-to-head comparisons with other common passivation materials; however, general comparisons can be drawn.⁶

Amorphous silicon films used in solar cells present numerous advantages. These advantages include a lower deposition temperature, in contrast to the temperatures commonly employed in cell manufacturing. However, it is essential to note that amorphous silicon films exhibit sensitivity to subsequent high-temperature processes, which are frequently necessary in industrial manufacturing technology.⁹

Similarly, AlO_x passivation films can be applied at relatively low temperatures, but they can be limited by slow deposition speeds when using specific application methods. This slowdown can generate problems for high-throughput techniques, such as solar cell production.⁹

Polyimide, a common passivation material lauded for its strength and thermal stability, is also susceptible to moisture absorption. This characteristic can impact the strength and dielectric properties of the protective coating, risking the integrity of the semiconductor.¹⁰

Applications of glass passivation

Passivation glasses demonstrate outstanding performance in wafer passivation and encapsulation processes, providing advantages to a diverse range of semiconductor devices,⁸ including thyristors, power transistors, diodes, rectifiers, and varistors.

Glass also has applications in solar cell passivation. In a recent study, researchers developed a method for enhancing borosilicate glass passivation using high temperatures before lowering the temperature to accommodate the metallization process. In doing so, they notably improved the solar cell's efficiency.¹¹

In another study, phosphosilicate glass was found to significantly enhance the practical lifetime of minority carriers and improve the overall performance of solar cells, particularly in structures involving nanocrystalline silicon and crystalline silicon.¹²

MO-SCI's expertise in glass thin films

Fueled by the increasing prevalence of smart devices and advancements in the automotive and aerospace sectors, the semiconductor passivation glass market is anticipated to grow consistently in the next few years.³

The expertise of MO-SCI, LLC (Rolla, Mo.) lies in leveraging the unique properties of glass to create tailored solutions, ensuring the reliability and performance of many applications, including glass seals and glass coatings. For more information, contact MO-SCI at <https://mo-sci.com/contact-us>.

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References

- ¹Pehkonen, S.O., et al., "Chapter 2—Self-assembly ultrathin film coatings for the mitigation of corrosion: General considerations," *Interface Science and Technology* 2018, 23: 13–21.
- ²Lu, Q., et al., "Chapter 5—Polyimides for electronic applications," *Advanced Polyimide Materials* 2018, 195–255.
- ³Reliable Business Insights, "Semiconductor passivation glass market—global outlook and forecast 2023–2028." Accessed 14 March 2024. <https://www.reliablebusinessinsights.com/semiconductor-passivation-glass-market-r1365249>
- ⁴Schott, "Passivation glass." Accessed 14 March 2024. <https://www.schott.com/en-hr/products/passivation-glass-p1000287/technical-details>
- ⁵Zhong, C., et al., "Properties and mechanism of amorphous lead aluminosilicate passivation layers used in semiconductor devices through molecular dynamic simulation," *Ceramics International* 2022, 48(21): 32455–32463.
- ⁶Hansen, U., et al., "Robust and hermetic borosilicate glass coatings by E-beam evaporation," *Procedia Chemistry* 2009, 1(1): 76–79.
- ⁷Korvus Technology, "The revolution of PVD systems in thin film semiconductor production." Published 9 May 2023. Accessed 14 March 2024. <https://korvustech.com/thin-film-semiconductor>
- ⁸Schott, "Technical glasses: Physical and technical properties." Accessed 14 March 2024. <https://www.schott.com/-/media/project/onex/shared/downloads/melting-and-hot-forming/390768-row-schott-technical-glasses-view-2020-04-14.pdf>
- ⁹Bonilla, R.S., et al., "Dielectric surface passivation for silicon solar cells: A review," *Physica Status Solidi* 2017, 214(7): 1700293.
- ¹⁰Babu, S.V., et al., "Reliability of multi-layer copper/polyimide," Defense Technical Information Centre, 1993. Accessed 14 March 2024. <https://apps.dtic.mil/sti/citations/ADA276228>
- ¹¹Liao, B., et al., "Unlocking the potential of borosilicate glass passivation for industrial tunnel oxide passivated contact solar cells," *Progress in Photovoltaics* 2021, 30(3): 310–317.
- ¹²Imamura, K., et al., "Effective passivation for nanocrystalline Si layer/crystalline Si solar cells by use of phosphosilicate glass," *Solar Energy* 2018, 169: 297–301. ■