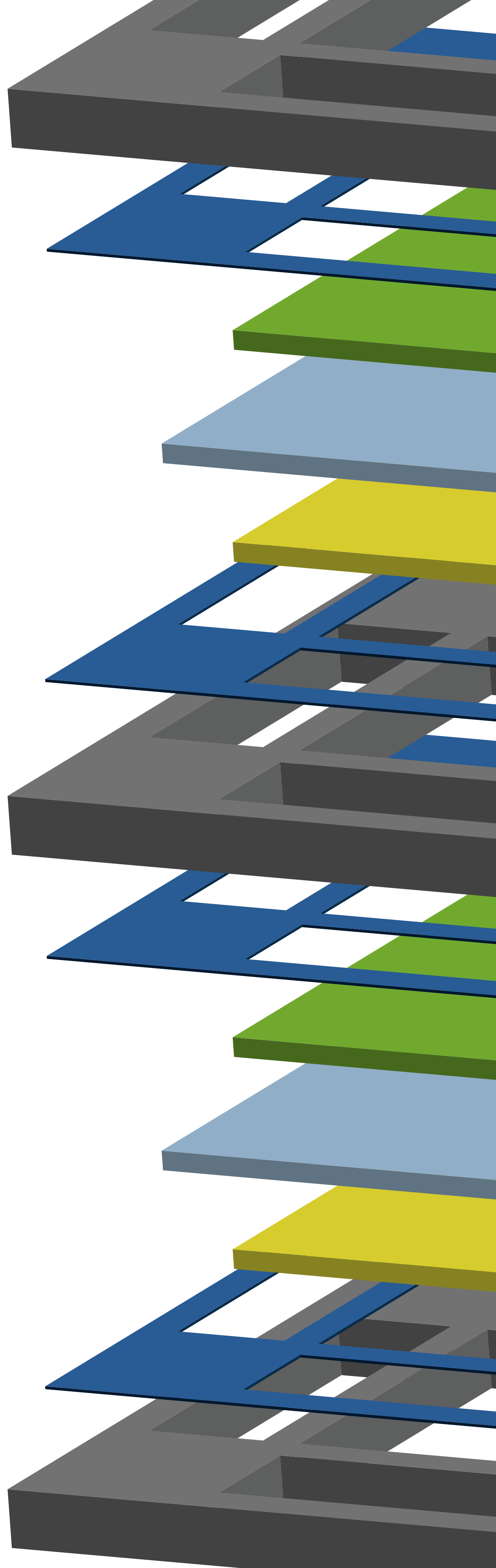
Sealing Glass Selection Guide

by **Cheol-Woon Kim, PhD**
Senior R&D Engineer
MO SCI



mo•sci

Introduction

Many thermal or energy devices, such as lighting headers, high temperature sensors, thermocouple and heater components, solar cells, molten sodium batteries, and solid oxide fuel cells, require the formation of seals between glasses and other glasses, metals, or ceramics for high temperature applications. Glasses are widely used as hermetic sealants due to their superior hermeticity, high temperature stability, and compositional flexibility to tailor for specific properties. Compatibility in thermal expansion is the most critical parameter for selection of such glasses because seals will undergo thermal cycling between the operational temperature and room temperature. Thermal stresses will develop and cause seal failure unless good thermal expansion/contraction matches exist between the materials to be sealed or joined. The softening temperature of the glass must also be compatible with the characteristics of the material to which it is joined.

Matched Seals

The coefficient of thermal expansion (CTE) of the glass must be matched as closely as possible (within 10%) to those of the sealing components to prevent glass seal cracking. The strength of the matched seal comes mainly from the chemical bonding at the glass to material (e.g., glasses, metals, and ceramics) interface. For matched glass to metal seals, pre-heating the metal can enhance the chemical bonding by forming an oxide film on the metal surface. MO SCI provides sealing glasses with various and/or customized CTE values to enable seals with a wide variety of materials.

Compression Seals

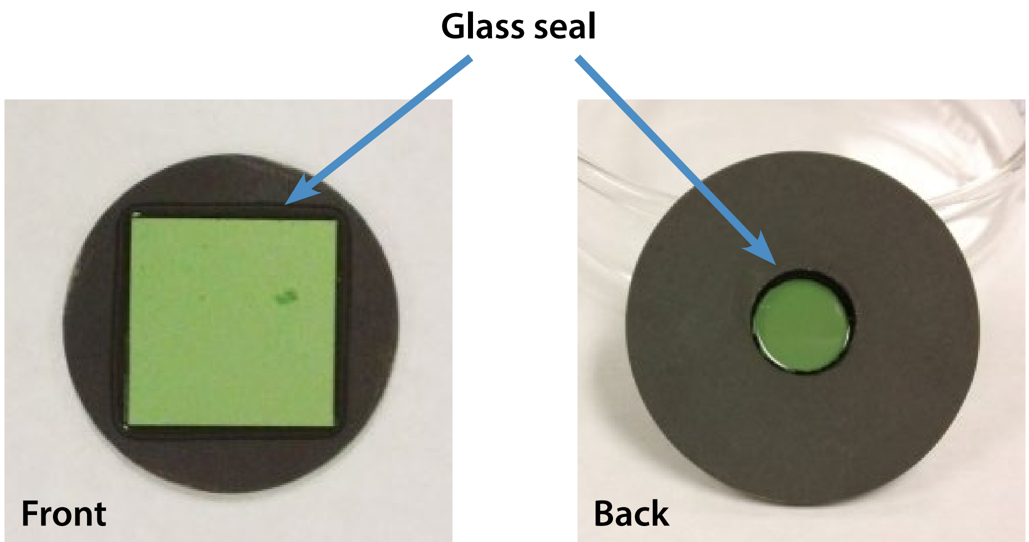
For certain seal geometries, it is possible to make seals which have large differences in the coefficients of thermal expansion between the glass and other components (especially metals), provided the glass is under compression after firing/cooling. These seals are formed by placing a higher CTE component around a lower CTE glass. The shrinkage of the outer component during cooling places the glass in compression. Compression seals are often used for isolating electrical feedthrough metal pins from steel or stainless steel housings. Compression seals can withstand extremely high pressures and physical stresses because glass is strong in compression.

Glass-Ceramic Seals

Glass-ceramic seals are commonly used in many applications as matched seals or compression seals. Upon firing, the glass flows and partially crystallizes into a stable phase(s), forming a glass-ceramic that strongly bonds to seal components. The thermal properties of the crystalline phase(s) and residual glass are designed to be stable over time at the operational temperature. For higher temperature applications, glass-ceramic seals are good candidates but there are products available for low temperature applications as well. MO SCI formulates glass-ceramic seal compositions to provide requisite CTE values, softening temperatures, or flow characteristics for custom applications.

Compliant Viscous Seals

Compliant viscous glass seals are a new class of seal [1-4] and are designed to be vitreous at the operational temperature. Viscous seals reduce the risk of catastrophic seal failure through viscous healing of cracks formed during thermal cycling. Viscous seals are made of glass compositions that resist crystallization and remain in an amorphous, viscous state during their operation. If a crack occurs, the surrounding glass spreads to occupy the new gap and heals itself. It also reduces the necessity for an exact CTE match as the glass can flow to fill any gaps as components expand and contract upon heating and cooling. Viscous sealing glasses are appropriate for use in devices undergoing frequent thermal cycling.



A viscous glass seal between a yttria-stabilized zirconia (YSZ) substrate and stainless steel

Glass Selection Criteria

Below are the main criteria to be considered when selecting a sealing glass:

Coefficient of Thermal Expansion	Softening/ Firing Temperature	Operating Temperature	Operating Environment	Sealing Glass Form

1. CTE matching: What are the materials to be sealed?

Identify the coefficient of thermal expansion (CTE) values of the materials of interest that need to be sealed or joined. Look for candidate glasses (e.g., from https://mo-sci.com/products/sealing-glass/) possessing similar CTE values as those of the sealing component materials, if matched seals are required. Select candidate glasses with CTE values lower than those of the housing materials, but the same as those of the pin components, if compression seals are sought.

2. What is the required firing temperature for sealing?

Identify the softening temperatures of the materials of interest that need to be sealed or joined. The firing temperature cannot be higher than the softening temperatures of the sealing component materials. From the candidate glasses satisfying the CTE requirements, look for glasses with a softening temperature lower than those of the sealing components. If firing (sealing) has to be conducted at a low temperature, look for low softening temperatures among the candidate glasses to provide glass flow at the desired temperature. The ultra-low temperature (e.g., 250°C) sealing glasses are available from lead-free, non-silicate glasses.

3. What is the operating temperature?

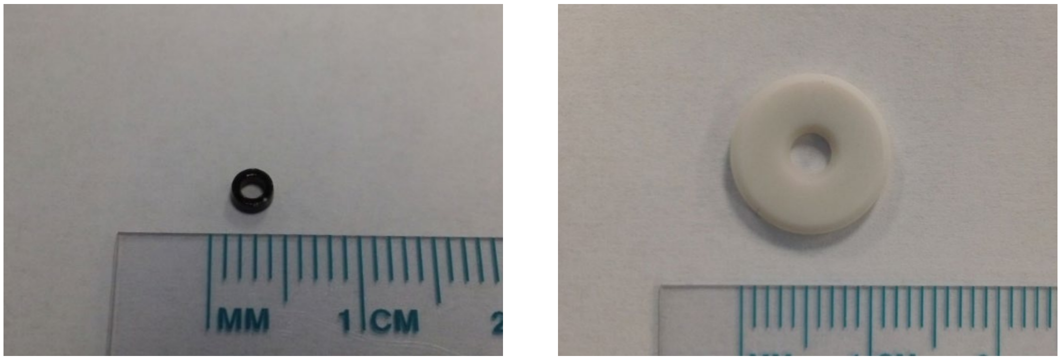
The device/seal operating temperature cannot be higher than the softening temperature of the seal. Certain glass-ceramic seals can operate at temperatures higher than their firing temperatures. From the candidate glasses satisfying the CTE and firing requirements, look for glasses with appropriate working temperature ranges. If the device seal requires moderate strength, good adhesion and undergoes frequent thermal cycling, viscous sealing glasses are good candidates.

4. What is the environment of the application?

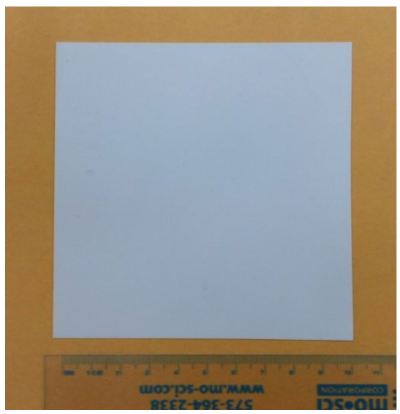
Most glass seals provide good electrical insulation (e.g., 1011 to 1015 Ω·m at 20°C) and are chemically durable under normal conditions. Custom sealing glasses with specific dielectric constants and loss tangent values can be made. These electrical properties can be affected by the absorption of water to the glass, which is dependent upon the chemical durability of the sealing glasses. If the device/seal operates in a harsh environment (e.g., molten salt batteries), sealing glass compositions are specially formulated to withstand the chemical corrosion while maintaining the electrical properties. If volatile components (e.g., alkali metals) are not allowed for certain applications, sealing glasses without such elements are also available.

5. What form of sealing glass do you need?

Sealing glasses are available in powders, pastes, preforms, or tapes. Users should choose a form that works best for their applications depending upon the sealing methods, geometry and size of the sealing area. For the use of pastes or tapes, a step holding at the decomposition temperature of the binder material for 1 to 2 hours has to be added in order to remove the binder before the peak firing temperature for sealing.



Examples of sealing glass preforms



Sealing glass tapes are available in various sizes (Pictured: 10 cm × 10 cm tape)

Selecting a correct glass particle size is very critical for all of the forms above because the particle size controls the surface crystallization, the rheology (e.g., viscosity) of pastes for screen printing or dispensing, the rheology of slurries for tape casing, and the bubble issues in seals after firing. In general, a glass particle size of d90=45µm works for all of the forms. A particle size of d90=20µm is also commonly used for making screen printing pastes. A particle size smaller than d90=10µm is not recommended. If the particle size is too small, it causes surface crystallization of glass-ceramics seals and hinders the glass flow for wetting. It increases the viscosity of the pastes or slurries and the glass loading in the pastes or slurries has to be reduced. It also generates bubbles especially in viscous seals after firing.

References

1. C. W. Kim and R. K. Brow, “Viscous sealing glass compositions for solid oxide fuel cells”, U.S. Patent 9,530,991B2; Japan 6,328,111B2; Europe 13823847.2; India 1487/DELNP/2015; South Korea 10-1972632.

2. J. H. Hsu, C. W. Kim, R. K. Brow, J. Szabo, R. Crouch, and R. Baird, “An alkali-free barium borosilicate viscous sealing glass for solid oxide fuel cells”, Journal of Power Sources 270 (2014) 14-20.

3. J. H. Hsu, C. W. Kim, and R. K. Brow, “Interfacial interactions between an alkali-free borosilicate viscous sealing glass and aluminized ferritic stainless steel”, Journal of Power Sources 250 (2014) 236-241.

4. C. W. Kim, J. H. Hsu, C. Townsend, J. Szabo, R. Crouch, R. Baird, and R. K. Brow, “Viscous sealing glass development for solid oxide fuel cells”, Ceramic Engineering and Science Proceedings 34[4] (2013) 123-132.

MO SCI, LLC
4040 Hypoint North • Rolla, MO 65401
Phone: 573-364-2338 • Fax: 573-364-9589

www.mo-sci.com

© 2025 MO SCI, LLC