

**TABLE 1.1 SEALS - PROS AND CONS**

RIGID CHEMICAL	SLIDING MECHANICAL	COMPLIANT WET
<p><b>Glass - Pros</b></p> <ul style="list-style-type: none"> <li>• Lowest leakage</li> <li>• Inexpensive</li> <li>• Glasses not limited to stoichmetric</li> <li>• Excellent thermal and environmental stability</li> <li>• Processing flexibility (automatable) in-expensive</li> <li>• Successful experience “short-term”</li> </ul> <p><b>Glass - Cons</b></p> <ul style="list-style-type: none"> <li>• Constrains cell movement during thermal excursions</li> <li>• Accommodation of CTE mismatch</li> <li>• Increases strength requirement on PEN</li> <li>• Increases tendency for cracking</li> <li>• Metal to ceramic delamination</li> <li>• Different materials thermal capacitance compositions (tailorable)</li> <li>• Application temperature</li> <li>• Migration of species</li> <li>• Assembly tolerances and compensation</li> <li>• Seal/cell surface debonding, cell component debonding, interface stream</li> <li>• Durometer u/mils</li> <li>• Increases time of heating and cooling (fabrication)</li> <li>• Changing material structure with cycling</li> </ul> <p><b>Cements</b></p> <ul style="list-style-type: none"> <li>• Con: CTE – coefficient thermal expansion</li> <li>• Pro: No requires loading</li> </ul> <p><b>Organo precursor cements - Cons</b></p> <ul style="list-style-type: none"> <li>• Steam?</li> <li>• CTE mismatch</li> <li>• Porosity or density</li> <li>• Hydrogen</li> </ul> <p><b>Nonconductive braze system</b></p> <p><b>All - Con</b></p> <ul style="list-style-type: none"> <li>• Interfacial reactivity</li> </ul>	<p><b>Pros</b></p> <ul style="list-style-type: none"> <li>• Tolerance for CTE mismatch</li> <li>• Less demanding on strength of cell</li> <li>• Easier to disassemble - repairable</li> </ul> <p><b>Cons</b></p> <ul style="list-style-type: none"> <li>• Requires pressure</li> <li>• Surface preparation &amp; finish</li> <li>• Limitations on location for usage</li> <li>• Larger mechanical structure + seal volume</li> <li>• Leak rate degradation (cycling)</li> <li>• Degradation &amp; seal material (corrosion)</li> <li>• Creep wear/products others</li> <li>• Problems with external loads in plane of cells</li> <li>• Electrical insulation for metallic seals</li> <li>• Stacking issues &amp; assembly</li> <li>• Operational procedure</li> <li>• Stack height dimensional changes &amp; long-term operation</li> <li>• How big of load needed and applied</li> <li>• Need for flexibility to seal YSZ variations</li> <li>• Dimensional tolerance</li> <li>• Compliance vs. spring back</li> </ul>	<p><b>Pros</b></p> <ul style="list-style-type: none"> <li>• Allows CTE mismatch</li> <li>• Potential for low leakage</li> <li>• Accommodate irregularities in surface</li> <li>• Low interfacial stresses</li> <li>• Self-healing</li> </ul> <p><b>Cons</b></p> <ul style="list-style-type: none"> <li>• Molten glass - volatilization</li> <li>• Molten glass - continuous change in properties</li> <li>• Need for reservoir to replenish</li> <li>• Possible wicking</li> <li>• What liquid?</li> <li>• Reactivity</li> <li>• Possibility of migration and lead formation</li> <li>• Containment stop</li> <li>• Proper viscosity over operational temperature range</li> </ul>

**TABLE 1.2 NOVEL R&D APPROACHES PLUS REQUIREMENTS**

COMPLIANT WET	RIGID	SMART MATERIALS	GRADED SEAL STRUCTURES	FLEXIBLE MECHANICAL SEALS	REQUIREMENTS
<ul style="list-style-type: none"> <li>• Impregnated materials, e.g., felt, fabric</li> <li>• Self-healing materials</li> <li>• Porous/dense reservoir/hard stop wet seal</li> </ul>	<ul style="list-style-type: none"> <li>• Microcracking toughened glasses</li> <li>• Particle reinforced glasses</li> <li>• Development of organo precursors</li> </ul>	<ul style="list-style-type: none"> <li>• Adaptive</li> <li>• Magneto strictive</li> <li>• Electro rheologic material</li> <li>• Piezo electric</li> <li>• SMA - shape memory alloys</li> <li>• "MEMS" inspired manufacturing approach</li> <li>• Magneto-elastic materials</li> </ul>	<ul style="list-style-type: none"> <li>• Multi-layered/Graded microstructures, e.g., porosity, nested Vs</li> <li>• Chemical modification of mica</li> <li>• Multi- functional layered structure</li> <li>• Engineered materials, e.g., macor</li> </ul>	<ul style="list-style-type: none"> <li>• Zr O-ring</li> <li>• Compliance with rigid tubes 3YSZ</li> <li>• Glass coated bellows</li> <li>• High temperature RTV</li> <li>• Nano ceramic springs</li> </ul>	<ul style="list-style-type: none"> <li>• Voltage effects on seal</li> <li>• Standardized testing protocols</li> <li>• Strain management</li> <li>• Seal design methodology</li> </ul>