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TECHNICAL DATA SHEETS

Pyro-LD80™

CELLULAR
OPAQUE FUSED QUARTZ

LD80N
08/30/01

Pyro-LD80™
TECHNICAL DATA SHEETS

Sections

1. Overview and Highlights
2. Purity
3. Bubble Content
4. Radiant Heat Transfer Properties
5. Conductive Heat Transfer Properties
6. Mechanical Properties
7. Electrical Properties

Pyro-LD80™
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Section 1 - Overview and Highlights

Pyro-LD80™

Overview

Pyro-LD80 is a unique, high purity opaque fused quartz material containing microscopic bubbles that are engineered to a specific size and quantity. This novel grade retains many of the desirable properties of conventional fused quartz. At the same time, Pyro-LD80 provides superior performance where heat transfer needs to be minimized or where the transmission of radio-frequency energy needs to be maximized. In addition to its unique properties, Pyro-LD80 can be molded into useful net and near-net shapes. Subsequently, it is an optimal grade for applications where thermal management is critical, such as in semiconductor processing furnaces.

Pyro-LD80 is being manufactured under patents granted and pending.

Highlights

- Pyro-LD80 is a semiconductor grade of fused quartz that is 99.998% SiO_2.
- The density of the material is 1.76 g/cm^3, (80% of theoretical density).
- The average bubble diameter in Pyro-LD80 is less than 20 μm.
- The bubbles in Pyro-LD80 are closed cells. Subsequently, the material is impermeable to gases and liquids, even after the surfaces have been machined.
- Just like conventional fused quartz, Pyro-LD80 is chemically inert, can be used at temperatures up to 1200°C and has tremendous thermal shock resistance.
- Pyro-LD80 reduces the transmittance of infrared heat by 85%, as compared to conventional opaque fused quartz.
- Thermal conductivity is reduced by 40% when using Pyro-LD80, as compared to conventional opaque fused quartz.
- Pyro-LD80 can be welded to any other fused quartz grades (clear or opaque), using conventional techniques.
- Pyro-LD80 surfaces can be fire polished flat and smooth, as opposed to the irregular, “orange-peel” surfaces found after fire polishing the surfaces of conventional opaque fused quartz.
- A diffusion tube furnace is an example of a Pyro-LD80 application:
  - Pyro-LD80 is near-net shaped, then finish ground into a flange;
  - The Pyro-LD80 flange is welded on to a clear fused quartz tube;
  - The Pyro-LD80 surfaces are fire polished to a smooth finish;
  - Because of its superior thermal management properties, the Pyro-LD80 flange prevents deterioration of the polymer o-ring.
  - Also, because of its smooth surface, the Pyro-LD80 flange forms a tight seal against the o-ring.

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Section 2 - Purity

TYPICAL CHEMISTRIES

(all values in parts per million)

Element			NitroSil	NSG	NSG
Name	Symbol	Pyro-LD80	PT-77	OP-1	OP-3
Aluminum	Al	12	12	120	12
Calcium	Ca	3	3	5	0.5
Copper	Cu	<0.1	<0.1	0.03	0.03
Iron	Fe	0.8	0.8	1.4	0.8
Lithium	Li	<1	<1	3.7	0.2
Magnesium	Mg	<0.2	<0.2	0.3	0.2
Potassium	K	<1	<1	7.6	0.2
Sodium	Na	0.9	0.9	4	0.9
Zirconium	Zr	<1	<1	0.6	0.6
Hydroxyl	OH-	<10	<10	160	160

Notes

1) "NSG" stands for Nippon Silica Glass Co., Ltd.
2) OP-1 and OP-3 are opaque fused quartz grades produced by NSG.
3) The NSG data was taken from a technical brochure on OP-1 and OP-3

Conclusion

Pyro-LD80 is of much higher purity than OP-1 and is equivalent to OP-3

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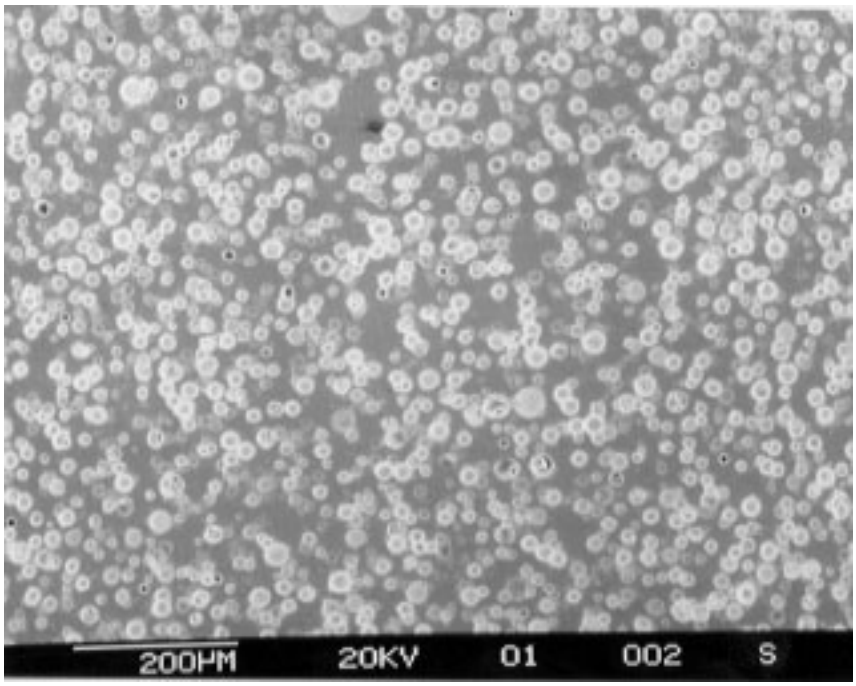
Section 3 - Bubble Content

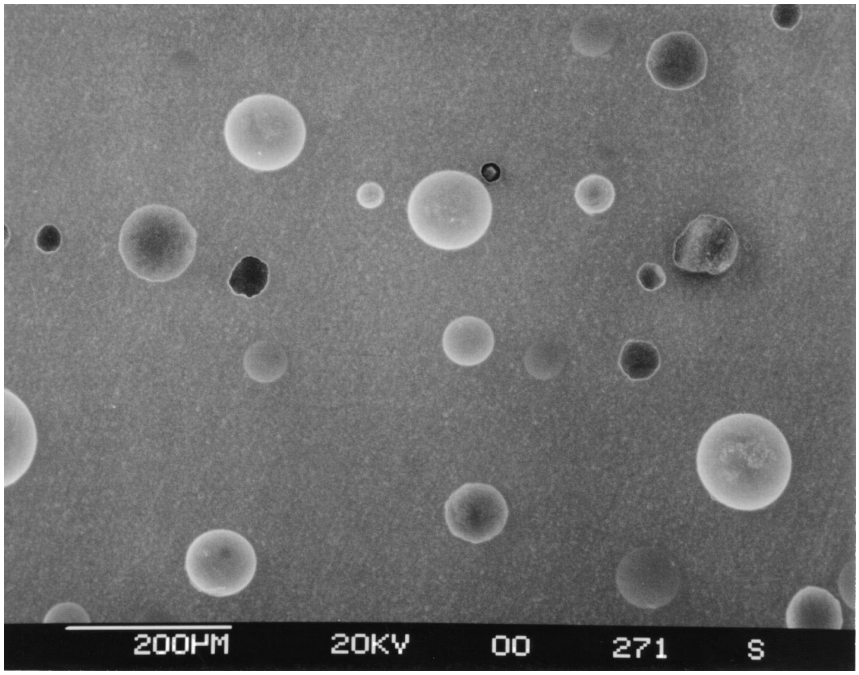
- **Photomicrographs**

Bubble Structure

Pyro-LD80
100x

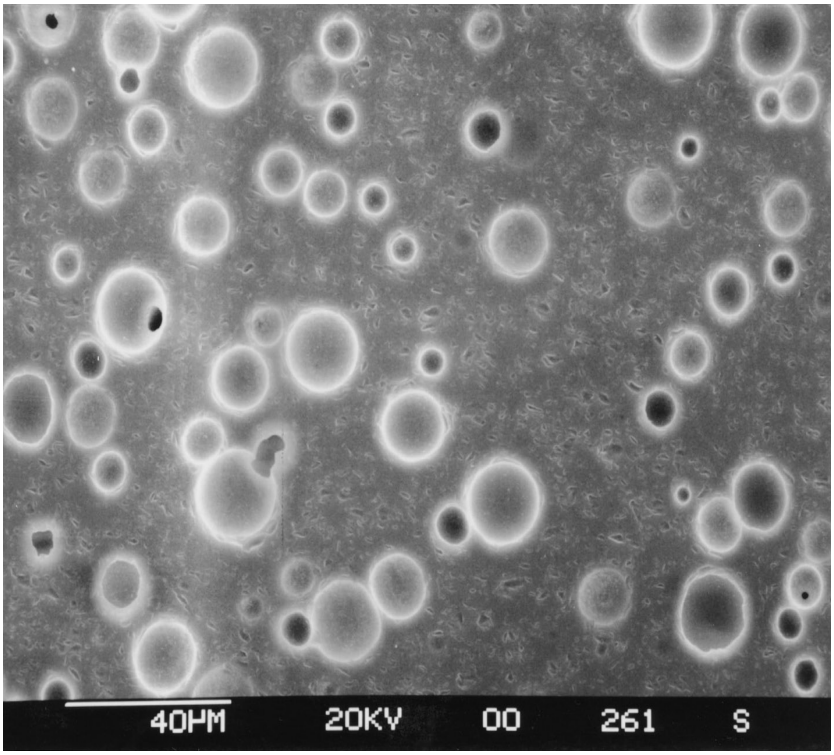


OP-1
100x

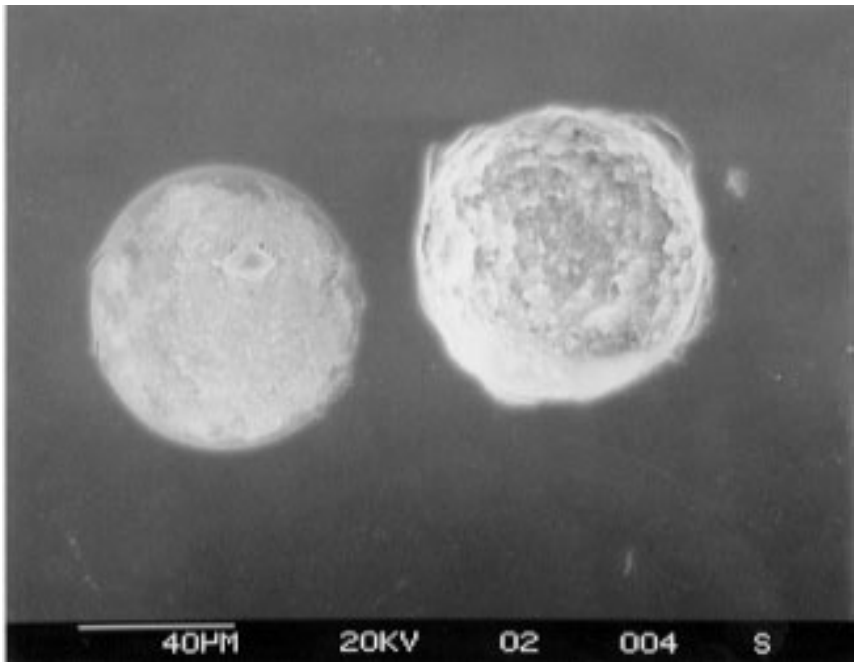


Bubble Structure

Pyro-LD80
500x



OP-1
500x



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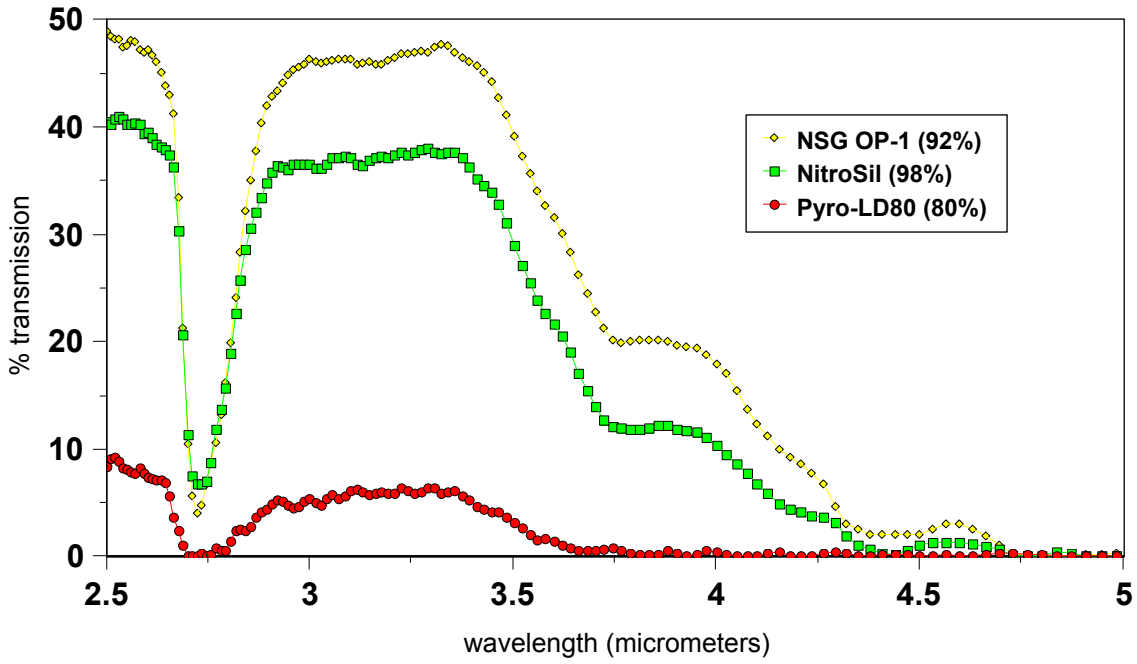
Section 4 -
Radiant Heat Transfer Properties

- **Total Infrared Transmission**
- **Total Ultraviolet and Visible Light Transmission**
- **Direct Infrared Transmission**

TOTAL (DIFFUSE) TRANSMISSION IN THE NEAR AND MID-INFRARED SPECTRUM



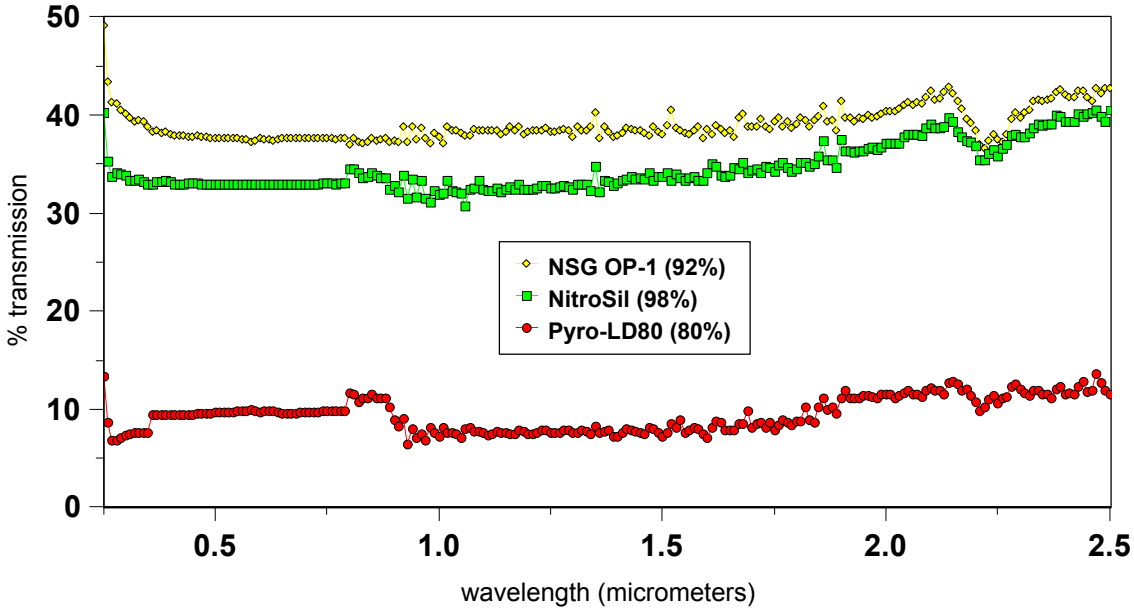
Notes

1) All three samples were 3mm thick.
2) "NSG" stands for Nippon Silica Glass Co., Ltd.
3) OP-1 is an opaque fused quartz grade produced by NSG.
4) NitroSil and Pyro-LD80 are opaque fused quartz grades produced by Pyromatics Corp.
5) The percentages in parentheses show the density of the material per the theoretical value of fused quartz (2.2 g / cc).
6) The measurements were carried out by Optical Data Associates on a Nicole Nexus 670 FTIR spectrophotometer with an integrating sphere.

Conclusions

Total transmission measures the amount of radiant heat transfer and the lower the value, the better the material performs as an insulator. This graph clearly shows that Pyro-LD80 has superior insulating properties, with an 85% improvement over NSG OP-1.

TOTAL (DIFFUSE) TRANSMISSION IN THE ULTRAVIOLET-VISIBLE-NEAR INFRARED SPECTRUM



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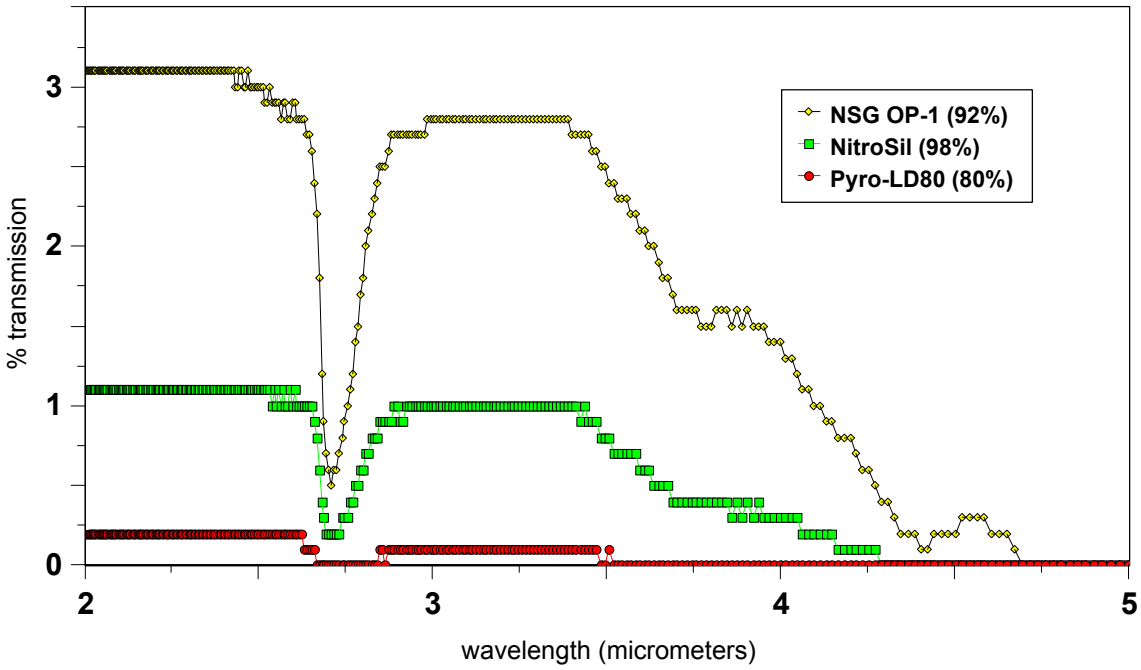
5) The percentages in parentheses show the density of the material per the theoretical value of fused quartz (2.2 g / cc).
6) The measurements were carried out by Optical Data Associates on a Cary 5E spectrophotometer with an integrating sphere.

Conclusions

Total transmission measures the amount of radiant heat transfer and the lower the value, the better the material performs as an insulator. This graph clearly shows that Pyro-LD80 has superior insulating properties, with a 75% improvement over NSG OP-1.

DIRECT INFRARED TRANSMISSION



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4) NitroSil and Pyro-LD80 are opaque fused quartz grades produced by Pyromatics Corp.
5) The percentages in parentheses show the density of the material per the theoretical value of fused quartz (2.2 g / cc).
6) The measurements were carried out by Optical Data Associates on a Perkin Elmer 983G spectrophotometer.

Conclusions

Direct transmission measures the amount of radiant heat transfer along a straight line and the lower the value the better the material performs as an insulator. This graph clearly shows that Pyro-LD80 has superior insulating properties, effectively blocking all direct infrared energy.

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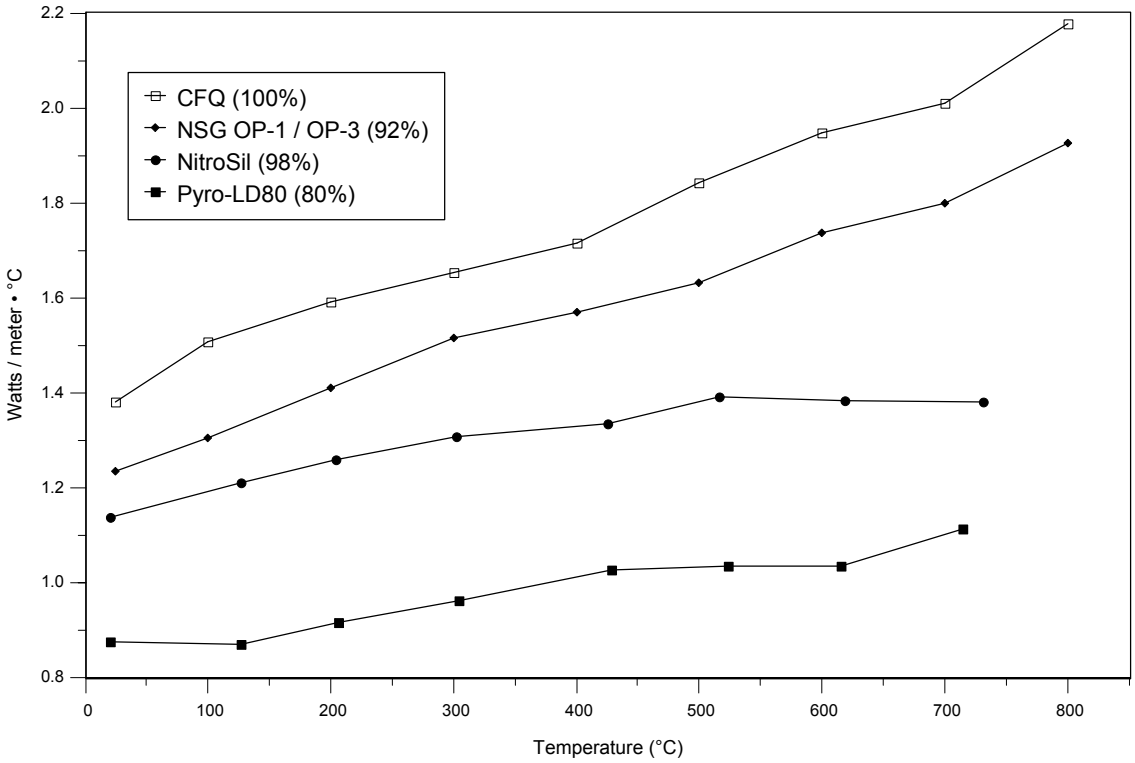
Section 5 -
Conductive Heat Transfer Properties

- **Thermal Conductivity Graph**
- **Thermal Conductivity Chart**
- **Specific Heat Graph**
- **Specific Heat Chart**

THERMAL CONDUCTIVITY



Notes

1) "CFQ" stands for semiconductor grade clear fused quartz.
2) "NSG" stands for Nippon Silica Glass Co., Ltd.
3) OP-1 and OP-3 are opaque fused quartz grades produced by NSG.
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5) The percentages in parentheses show the density of the material per the theoretical value of fused quartz (2.2 g / cc).

Conclusions

Thermal conductivity measures the rate of heat flow and the lower the value, the better the material performs as an insulator. This graph clearly shows that Pyro-LD80 has superior insulating properties.

Thermal Conductivity

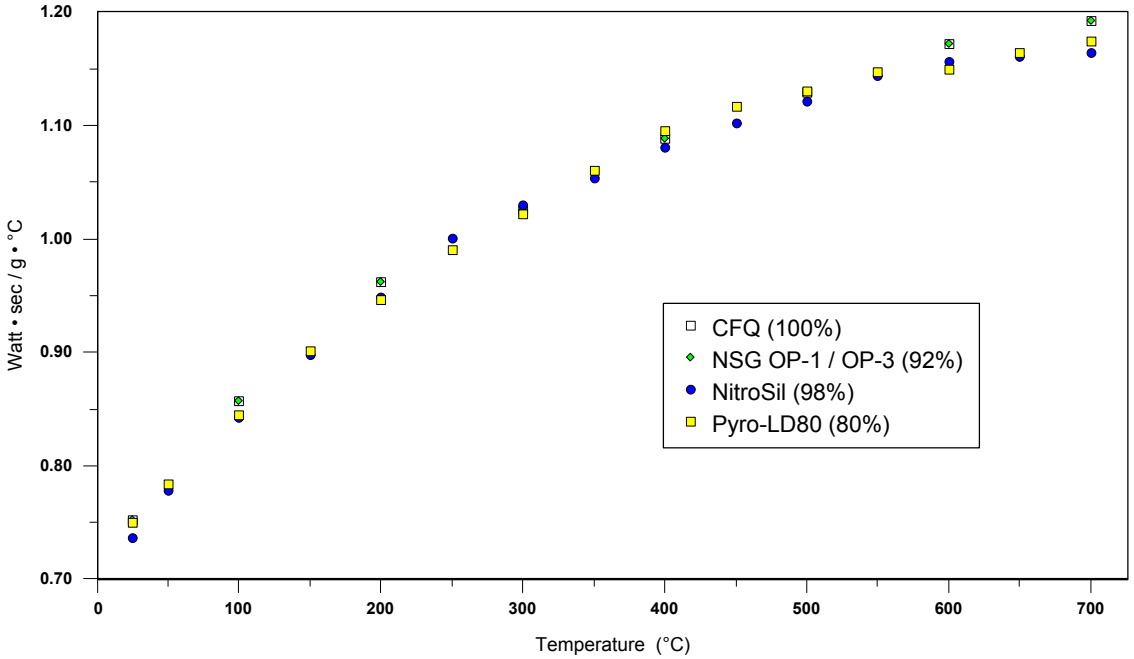
(watt / meter * ^{o}C)

°C	Pyro-LD80	NitroSil	NSG OP-1 / OP-3	Clear Fused Quartz
20	0.88	1.14		
25			1.24	1.38
100			1.31	1.51
127	0.87	1.21		
200			1.41	1.59
204		1.26		
206	0.92			
300			1.52	1.65
302		1.31		
304	0.96			
400			1.57	1.72
425		1.33		
429	1.03			
500			1.63	1.84
516		1.39		
524	1.04			
600			1.74	1.95
616	1.04			
619		1.38		
700			1.80	2.01
715	1.11			
731		1.38		
800			1.93	2.18

Notes

1) "NSG" stands for Nippon Silica Glass Co., Ltd.
2) OP-1 and OP-3 are opaque fused quartz grades produced by NSG.
3) NitroSil and Pyro-LD80 are opaque fused quartz grades produced by Pyromatics Corp.
4) The densities of the materials, per the theoretical value of fused quartz (2.2 g / cc), are as follows:
    - 80% for Pyro-LD80
    - 98% for NitroSil
    - 92% for NSG OP-1 / OP-3
    - 100% for clear fused quartz

SPECIFIC HEAT



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5) The percentages in parentheses show the density of the material per the theoretical value of fused quartz (2.2 g / cc).

Conclusions

Specific heat can be used to calculate how much energy is necessary to heat a material to a given temperature. This graph clearly shows that the specific heats for all of the grades are equivalent. However, because there are significant density differences between the grades there will be differences in the amount of energy required to heat the materials.

Example: Consider two identical parts, one made out of OP-1 and the other out of Pyro-LD80, that are to be heated from room temperature to 1000°C. If both parts have a volume of 1000 cc, the OP-1 part will weight 2024 g while the Pyro-LD80 part will weigh 1750 g, a difference of 13%. Therefore, the amount of energy required for the Pyro-LD80 part will be 13% less than that required for the OP-1 part.

Specific Heat

(watt * sec / g * ^{o}C)

°C	Pyro-LD80	NitroSil	NSG OP-1 / OP-3	Clear Fused Quartz
25	0.750	0.737	0.753	0.753
50	0.784	0.778		
100	0.845	0.843	0.858	0.858
150	0.901	0.898		
200	0.947	0.949	0.962	0.962
250	0.991	1.001		
300	1.022	1.030	1.026	1.026
350	1.061	1.054		
400	1.096	1.081	1.089	1.089
450	1.117	1.102		
500	1.131	1.122	1.130	1.130
550	1.147	1.144		
600	1.150	1.156	1.172	1.172
650	1.120	1.161		
700	1.110	1.164	1.193	1.193

Notes

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4) The densities of the materials, per the theoretical value of fused quartz (2.2 g / cc), are as follows:
    - 80% for Pyro-LD80
    - 98% for NitroSil
    - 92% for NSG OP-1 / OP-3
    - 100% for clear fused quartz

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Section 6 - Mechanical Properties

- **Modulus of Rupture**

Modulus of Rupture (MOR)

Table 1
Pyro-LD80 Test Results

Sample #	Load (lb.)	MOR (MPa)	Rank
1	15.7	59.375	4
2	14.56	54.978	9
3	15.9	60.271	2
4	13.49	50.977	10
5	15.05	56.984	7
6	15.64	59.207	5
7	16.63	63.075	1
8	15.53	58.967	6
9	14.75	55.979	8
10	15.7	59.553	3
Average MOR		**58.25**	

Notes

1) Measured by 4 point bend using ASTM Type B specimens
2) All data measured by Dept. of Materials Science and Engineering, UCLA

Material	MOR
Pyro-LD80	58
NitroSil	90
NSG OP-1, OP-3	64 to 69

Notes

1) "NSG" stands for Nippon Silica Glass Co., Ltd.
2) OP-1 and OP-3 are opaque fused quartz grades produced by NSG.
3) The NSG data was taken from a technical brochure on OP-1 and OP-3
4) The NitroSil data was measured by the Research Div of Raytheon Co.

Conclusion

Pyro-LD80 exhibits strength comparable to OP-1 / OP-3.

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Section 7 - Electrical Properties

- **Dielectric Constant and Loss Tangent**

Dielectric Properties

Grade	Frequency	Temperature (degrees C)	Dielectric Constant	Loss Tangent
NSG OP-1 / OP-3	**1 KHz**	**n/a**	**3.9 - 4.0**	**0.00015**
	1 MHz	**n/a**	**3.5 - 3.8**	**0.0001**
	1 GHz	**n/a**	**3.3 - 3.6**	**0.0001**
	10 GHz	**n/a**	**n/a**	**0.00035**
NitroSil	**2.45 GHz**	**20 - 243**	**3.62 - 3.65**	**0.0001**
	9.5 - 11.5 GHz	**20**	**3.72**	**~0.008**
Pyro-LD80	**9.5 - 11.5 GHz**	**20**	**2.98**	**~0.006**

Notes

1) "NSG" stands for Nippon Silica Glass Co., Ltd.
2) OP-1 and OP-3 are opaque fused quartz grades produced by NSG.
3) The NSG data was taken from a technical brochure on OP-1 and OP-3
4) The 2.45 GHz NitroSil data was measured by the Research Div of Raytheon Co.
5) The Pyro-LD80 data and the 9.9 – 11.5 GHz NitroSil data were measured by Lindsey Associates.

Conclusion

Pyro-LD80 exhibits a significantly lower dielectric constant versus OP-1 / OP-3, making it ideal for applications that require maximum transmission of electromagnetic energy.