Permittivity measurements on a variety of light weight refractory materials manufactured by ZIRCAR Ceramics, Inc.

Ceramics Expo 2019
History

• ZIRCAR Ceramics, Inc. 100 N. Main Street, Florida, New York 10921 USA
• 60 miles North West of New York City
• Incorporated June 2000 – 18 years old.
• Formerly Vacuum Formed Fiber Products Profit Center of ZIRCAR Products, Inc.
• ZPI – Originally Founded 1974 by Bernie Hamling - Founder
ZIRCAR Ceramics, Inc.

- David P. Hamling - V/P
- Phil D. Hamling - President

Zircar Ceramics
Third Generation Hamlings
Joined ZCI Sept. 2011

- Phil Hamling - Sales
- Cole Hamling - Production
Admin. & Engineering

- 100 N. Main Street

Zircar
CERAMICS
“BMR” Plant and Warehouse

• 203 Black Meadow Rd.
Assets – People
as of May 2018

• 46 Full Time Employees
– 5 degreed Engineers
What Does ZCI Do?

- Manufacture and Market Internationally
- A wide range of high temperature ceramic fiber based thermal & electrical insulation products.
- Many other related products.
High Temperature Stability and Reliable Refractoriness are possible only with Properly Engineered & Combined raw materials.

• This is our specialty!
• 40+ year history!
What We Are Doing

• This paper presents Microwave Permittivity exhibited by a range of ZIRCAR Ceramics’ low mass Al2O3 insulation materials.

• The data was collected in frequencies between 4GHz and 17GHz

• Testing was done at room temperature – 23°C
“Microwaves are a form of electromagnetic radiation with wavelengths ranging from about one meter to one millimeter; with frequencies between 300 MHz (1 m) and 300 GHz (1 mm). Different sources define different frequency ranges as microwaves; the above broad definition includes both UHF and EHF (millimeter wave) bands.”

- Wikipedia, “Microwave”
“Epsilon single-prime is the number we usually deal with, and causes no loss, and in most day-to-day engineering you don't see the prime notation. The imaginary epsilon double-prime is the culprit.”

- Microwaves 101, “Permittivity”
How

• A Transmission Tunnel with a transmitting antenna and a receiving antenna is set up as shown in the sketch.
• A flat panel test sample is inserted into the signal path of the Transmission Tunnel.
• A VNA (Vector Network Analyzer) is used to measure the Transmission (S21) through the test sample.
• Theoretical calculation of Transmission through a panel of identical thickness is computed.
• A search algorithm is employed to find the permittivity which results in the best fit of the computed transmission data to the measured transmission data.
Transmission Tunnel Test Set-Up

Absorber Lined Transmission Tunnel
- 8in x 8in Cross Section
- 8 ft. total length, (4 ft. long each half)

Flat Panel Test Sample

Tx Antenna

Rx Antenna

Tx

Rx
### Materials Tested

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Al2O3/SiO2</th>
<th>Density, pcf</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZAL-12</td>
<td>SiO2 bonded PCW</td>
<td>85/15</td>
<td>12</td>
</tr>
<tr>
<td>ZAL-12</td>
<td>SiO2 bonded PCW with AL-CEM coating</td>
<td>85/15*</td>
<td>12</td>
</tr>
<tr>
<td>ZAL-15</td>
<td>SiO2 bonded PCW</td>
<td>85/15</td>
<td>15</td>
</tr>
<tr>
<td>AL-25/1700</td>
<td>Al2O3-SiO2 bonded PCW &amp; Al2O3 Powder</td>
<td>80/20</td>
<td>25</td>
</tr>
<tr>
<td>SALI</td>
<td>Mullite bonded PCW</td>
<td>80/20</td>
<td>30</td>
</tr>
<tr>
<td>AL-30AAHB</td>
<td>Al2O3 bonded PCW</td>
<td>98.4/1.6</td>
<td>32</td>
</tr>
<tr>
<td>ZAL-45AA</td>
<td>Al2O3 bonded PCW</td>
<td>97/3</td>
<td>45</td>
</tr>
<tr>
<td>Bubble Alumina</td>
<td>Al2O3 bonded hollow Al2O3 spheres</td>
<td>99+</td>
<td>60</td>
</tr>
</tbody>
</table>

* Applies to base ZAL-12 only, AL-Cem is 99+% Al2O3
ZAL-12

A 12pcf density SiO$_2$ bonded polycrystalline Al$_2$O$_3$ fiber product.

![Graph showing transmission (dB) vs frequency (GHz) with values: 0.0°, 0.0°, slab_inches = 0.968, rms_error = 0.0033.](image)
ZAL-12
A 12pcf density SiO₂ bonded polycrystalline Al₂O₃ fiber product, coated with Alumina Cement Type AL-CEM
ZAL-15

A 15pcf density SiO$_2$ bonded polycrystalline Al$_2$O$_3$ fiber product.
AL-25/1700
A 25pcf density SiO₂ bonded, polycrystalline Al₂O₃ fiber product.

Transmission (dB)

Frequency (GHz)

0.0°, 0.0°
Te-Te

slab_inches = 1.002
rms_error = 0.0073
SALI
A 30pcf density SiO₂ bonded, polycrystalline Al₂O₃ fiber product.
AL-30AAHB
A 30pcf density \( \text{Al}_2\text{O}_3 \) bonded, polycrystalline \( \text{Al}_2\text{O}_3 \) fiber product.

![Graph showing transmission vs. frequency](graph.png)
ZAL-45AA
A 45pcf density Al₂O₃ bonded, polycrystalline Al₂O₃ fiber product.
Bubble Alumina
A 60pcf density Al₂O₃ cemented, Al₂O₃ bubble product.

Transmission (dB) vs Frequency (GHz)

- Frequency (GHz): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20
- Transmission (dB): -0.0, -0.25, -0.50, -0.75, -1.00, -1.25, -1.50

- Slab inches = 1.042
- RMS error = 0.0244

0.0°, 0.0° Te-Te
## Permittivity Data Summary

<table>
<thead>
<tr>
<th>ZIRCAR Ceramics Alumina Type</th>
<th>Nominal Composition, W%, Al₂O₃/SiO₂</th>
<th>Nominal Density, pcf (g/cc)</th>
<th>T, inch (mm)</th>
<th>ε' (4 GHz)</th>
<th>ε' (17 GHz)</th>
<th>ε&quot; (ave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZAL-12</td>
<td>85/15</td>
<td>12 (0.19)</td>
<td>0.968 (24.587)</td>
<td>1.22</td>
<td>1.21</td>
<td>0.001</td>
</tr>
<tr>
<td>ZAL-12/AL-CEM*</td>
<td>85/15</td>
<td>12 (0.19)</td>
<td>0.995 (25.273)</td>
<td>1.29</td>
<td>1.28</td>
<td>0.004</td>
</tr>
<tr>
<td>ZAL-15</td>
<td>85/15</td>
<td>15 (0.24)</td>
<td>0.983 in (24.968)</td>
<td>1.29</td>
<td>1.28</td>
<td>0.002</td>
</tr>
<tr>
<td>AL-25/1700</td>
<td>80/20</td>
<td>25 (0.40)</td>
<td>1.002 in (25.451)</td>
<td>1.44</td>
<td>1.43</td>
<td>0.000</td>
</tr>
<tr>
<td>SALI</td>
<td>80/20</td>
<td>30 (0.48)</td>
<td>1.004 in (25.502)</td>
<td>1.56</td>
<td>1.53</td>
<td>0.015</td>
</tr>
<tr>
<td>AL-30AAHB</td>
<td>98.4/1.6</td>
<td>30 (0.96)</td>
<td>1.009 in (25.629)</td>
<td>1.64</td>
<td>1.62</td>
<td>0.002</td>
</tr>
<tr>
<td>ZAL-45AA</td>
<td>97/3</td>
<td>45 (0.72)</td>
<td>1.012 in (25.705)</td>
<td>1.95</td>
<td>1.90</td>
<td>0.015</td>
</tr>
<tr>
<td>Bubble Alumina</td>
<td>99+</td>
<td>60 (0.96)</td>
<td>1.042 in (26.467)</td>
<td>2.22</td>
<td>2.19</td>
<td>0.019</td>
</tr>
</tbody>
</table>

* AL-CEM is a 99+% alumina coating – more information [HERE](#)!
Future Work

Lower Frequency – 2.45 GHz

High Temperature – RT to 1400°C
Thank you for your interest in ZIRCAR Ceramics, Inc.

• Please see www.zircarceramics.com for further information on ZAL-15, AL-25/1700, SALI, Bubble Alumina, ZAL-45AA and AL-30AAH. Contact ZIRCAR Ceramics for additional information on ZAL-12.

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• Vector Electromagnetics, LLC. 2670-B Indian Ripple Rd, Beavercreek Twp., OH 45440 Tel +1 937 912 9902 Email errol.english@vector-em.com