SLOTTED POLYIMIDE-AEROGEL-FILLED-WAVEGUIDE ARRAYS

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OUTLINE

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• Millimeter-wave waveguides
• Slotted arrays
• Conclusions
• Questions
INTRODUCTION

• Polyimide aerogels offer great promise as an enabling technology for lightweight aerospace antenna systems.
• They are highly porous solids possessing low density and low dielectric permittivity combined with good mechanical properties.
• Aggressively explored for thermal insulation
• Little effort has been made to use them for microwave and millimeter-wave antenna applications
POLYIMIDE AEROGELS

• Formulation made using DMBZ, BPDA and TAB cross-link
  • Lowest density (0.14 g/cm³)
  • Lowest dielectric measured (1.16)
  • Lowest loss tangent
  • Great mechanical properties

• Fabricated suitable sizes to make antennas
AEROGEL MEASUREMENTS

- Measured 12 different aerogel formulations with Agilent PNA E8364C/85071E (X-band and Ka-band), and with Agilent 4291B (1 MHz – 1.2 GHz).
AEROGEL MEASUREMENTS

- First time the electrical properties of these aerogels are measured at Ka-band
- Best electrical performance for formulation 17.03
- $\varepsilon_r = 1.16$, $\tan\delta_X = 0.0015$, $\tan\delta_{Ka} = 0.0008$
MILLIMETER-WAVE WAVEGUIDES

- Reference: WR28, 1.016 mm thick Al 6061 walls.
- Aerogel ($\varepsilon_r=1.16$, $\tan\delta=0.001$) filled: same $f_{c_{mn}}$ as WR28, 2 $\mu$m thick Au walls.
- Duroid 5880 SIW: same $f_{c_{10}}$ as WR28, 17 $\mu$m thick Cu walls.
- Aerogel SIW: same $f_{c_{10}}$ as WR28, 2 $\mu$m thick Au walls.

<table>
<thead>
<tr>
<th>Waveguide type</th>
<th>mass (g) for 20 mm long section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerogel filled WG</td>
<td>0.081</td>
</tr>
<tr>
<td>Commercial WG</td>
<td>1.394</td>
</tr>
<tr>
<td>Aerogel SIW</td>
<td>0.025</td>
</tr>
<tr>
<td>Duroid 5880 SIW</td>
<td>0.140</td>
</tr>
</tbody>
</table>
SLOTTED WAVEGUIDE ARRAY

- Scaled from X-band to Ka-band a slotted waveguide array reported by Orefice and Elliott.
- Used one of the columns of the planar array on a WR28 waveguide.
- Aerogel filled waveguide designed to have the same $\lambda_g$ as WR28.
- All arrays provide about the same gain (9.4 dBi).
## Slotted Waveguide Array

<table>
<thead>
<tr>
<th>Dimension</th>
<th>WR28</th>
<th>Aerogel Slot</th>
<th>Aerogel Folded Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l_1, l_4$ (mm)</td>
<td>3.870</td>
<td>3.599</td>
<td>3.560</td>
</tr>
<tr>
<td>$l_2, l_3$ (mm)</td>
<td>3.863</td>
<td>3.592</td>
<td>3.554</td>
</tr>
<tr>
<td>$\theta_1, \theta_4$ (deg)</td>
<td>19.67</td>
<td>19.67</td>
<td>19.67</td>
</tr>
<tr>
<td>$\theta_2, \theta_4$ (deg)</td>
<td>-23.74</td>
<td>-23.74</td>
<td>-23.74</td>
</tr>
<tr>
<td>$w_s$ (mm)</td>
<td>0.375</td>
<td>0.349</td>
<td>0.169</td>
</tr>
<tr>
<td>$S_n$ (mm)</td>
<td>N/A</td>
<td>N/A</td>
<td>0.143</td>
</tr>
</tbody>
</table>
• Used fundamental Floquet modes in HFSS to determine S parameters for variations in folded slot dimensions
• Used these results in antenna design
SLOTTED WAVEGUIDE ARRAYS: $S_{F1}$, VARYING $\theta$
SLOTTED WAVEGUIDE ARRAYS: $S_{21}$, VARYING $\theta$
SLOTTED WAVEGUIDE ARRAYS: $S_{F1}$, VARYING $L_S$
SLOTTED WAVEGUIDE ARRAYS: S11, VARYING $L_S$
SLOTTED WAVEGUIDE ARRAYS: $S_{F1}$, VARYING $S$
SLOTTED WAVEGUIDE ARRAYS: S21, VARYING S
SLOTTED WAVEGUIDE ARRAYS: $S_{11}$ AND GAIN FOR WR28 SLOT, AEROGEL SLOT AND AEROGEL FOLDED-SLOT ARRAYS
CONCLUSIONS

• Polyimide aerogels could be used to substitute PTFE and ceramic loaded substrates (e.g., Duroid) in applications where mass is of great importance.
• The operating bandwidth and gain of antennas can be increased when compared to standard antenna substrates.
• Their low dielectric constant make coaxial probe and aperture-coupled feeding more attractive alternatives for microstrip antennas.
• For waveguide applications, there are significant advantages in mass that more than compensate for the slightly higher loss of the aerogel filled waveguide, when compared to a commercial waveguide.
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QUESTIONS