Influence of Alumina Overlay on the Performance of Thin and Thick Film Microstrip Band Pass Filter

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Abstract

This paper reports the influence of alumina substrate overlay over the thin and thick film microstrip band pass filter. Due to overlay, the changes in characteristics of the microstrip filter such as pass band, mid-band frequency is observed. Also, the mid-band transmittance increases due to the overlay.

Key words
Microstrip, band pass filter, thin film, thick film, overlay

1.0 Introduction

Shielding of electronic devices becomes more and more important due to increase of electromagnetic pollution. Products whose radiation exceeds certain level will not be licensed to come on the market. A redesign of shielding, after being rejected by licensing authority would be time consuming and expensive. On the other hand, sensitive electronic devices, which are not sufficiently shielded, could suffer from the penetration of exterior electromagnetic waves causing malfunction-errors, which would be rectify and not reproduce. Microstrip circuits covered with superstrates are generally used to provide protection against environmental damage especially in air-and space born applications. Oxides are the most common material used for the superstrates or overlay applications. Bulk overlays have been used to reduce cross-talk between adjacent microstrip, to
provide mechanical strength against accidental damage [1], to reduce dispersion [2] and to achieve higher directivity of directional couplers [3-5]. By overlaying the microstrip circuits by means of dielectric material one can also reduce the electromagnetic pollution. Changes in the microstrip circuit characteristics and reduction in losses due to overlay have been reported earlier [6-11]. The influence on the characteristics of thin and thick film microstrip band pass filter due to alumina substrate overlay is reported in this paper.

2.0 Experimental

The design of seven-section microstrip band pass having a band width of 1000 MHz (10.0 – 11.0 GHz) was taken from Edward [12] and fabricated using copper thin film and silver thick film of different paste compositions (SBR series and ESL, USA). The layout of the band pass filter is shown in Figure 1. The SBR series pastes were indigenously formulated in the authors’ laboratory. The properties of these pastes are reported elsewhere [13]. The thin film component was photolithographically delineated on 99.6 % coated alumina (A492, Kyocera, Japan) and thick film component directly screen printed on 96 % alumina (A476, Kyocera, Japan). The thick film circuits were fired at 700 °C in a furnace followed by a conventional thick film firing cycle [13]. The thickness of thin film circuit was 6 µm and that of the thick film circuits was 12-14 µm. The alumina substrate (Kyocera, Japan) of thickness 625 µm (25 mil) was placed over the circuit such that it covers all the coupling sections leaving behind portions for the contacts. The alumina substrate used as overlay was A492 of 99.6 % with a dielectric constant of 9.9. The mechanical data of the alumina substrate is given in Table 1. The

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Volume resistivity (Ω-cm)</th>
<th>Dielectric constant (@ 25°C, 1 MHz)</th>
<th>Dielectric strength (mil)</th>
<th>Thermal conductivity (W/m-K)</th>
<th>Surface Finish (µm)</th>
<th>Average grain size (µm)</th>
<th>Normal Density (g/cm³)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>@ 25°C, 1 MHz</td>
<td></td>
<td></td>
<td>2.0</td>
<td>&lt;1.0</td>
<td>3.87</td>
<td>Alumina (A 492)99.6 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10⁴ @ 25°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Alumina (A 476)96 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10⁹ @ 700°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4x10⁷ @ 700°C</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Mechanical data of Alumina substrate [14]
microwave transmittance and reflectance was measured point-by-point using and X band wave-guide set up. The transmittance and reflectance was obtained from the ratio of output voltage and input voltage for the particular frequency. The measurements were taken for both the no overlay and with overlay condition.

3.0 Results

The transmittance and reflectance characteristics of the thin film band pass filter are shown in Figure 2 and for the thick film band pass filter are shown in Figures 3, 4, and 5. It is observed from all the figures that due to alumina overlay there is an increase in transmittance for both (i.e. thin film and thick film) the type of circuits. The reflectance in the pass band region is almost zero as
expected and there is no change due to overlay. The pass band has shifted to lower frequency side with an increase in the average pass band transmittance and bandwidth. The increase in transmittance due to overlay is more dramatic for the thick film component.

The data of bandwidth, midband frequency and midband transmittance is given in Table 2. From the table, it is seen that the circuit covered with alumina substrate shows higher bandwidth compared to no overlay condition for thin film circuit and thick film circuit with

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Figure 3 (a, b). Transmittance and Reflectance characteristics of Thick Film (SBR Microstrip band pass filter.

SBR4 paste whereas the circuit with SBR3 and ESL paste, there is decrease in bandwidth due to overlay.

The midband transmittance is higher compared to no overlay condition for all the circuits. The ESL paste circuit shows highest mid-band transmittance whereas SBR4 paste shows lowest mid-band transmittance due to overlay. But there is drastic decrease in mid-band frequency for all the types of circuits studied.
Figure 4(a, b). Transmittance and Reflectance characteristics of Thick Film (SBR4) Microstrip band pass filter.

4.0 Discussion

From the above results, it can be stated that due to alumina substrate overlay over the filter, changes in the filter characteristics is observed.

Our previous work [15] on the comparison between thin and thick film microstrip band pass filter have shown that the thick film circuits are comparable to thin film circuit and also thick film circuit of SBR3 paste is comparable to ESL (USA) paste circuit.
Figure 5(a, b). Transmittance and Reflectance characteristics of Thick Film (ESL) Microstrip band pass filter.

The band pass filter consists of series of half wavelength resonators with the parallel side coupling along a distance of quarter wavelength. The characteristic impedance ($Z_0$) affects the relative phase velocity of even and odd modes of the parallel- coupled microstrip lines.

There is a complex field distribution involving the coupling regions spread by the field and radiative components, since the energy transfer has to take place seven times as the wave travels from the input to the output end. Thick film circuit shows higher losses compared to thin film circuits due to inferior edge definition, spreading of metallization and
Table 2. Data of Bandwidth, mid-band frequency and mid-band transmittance of overlayed microstrip filter.

<table>
<thead>
<tr>
<th>Metallization</th>
<th>Condition</th>
<th>Band width (MHz)</th>
<th>Mid-band Frequency (GHz)</th>
<th>Mid-band Transmittance (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>No overlay</td>
<td>800</td>
<td>10.6</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>With overlay</td>
<td>1100</td>
<td>9.45</td>
<td>0.62</td>
</tr>
<tr>
<td>SBR3</td>
<td>No overlay</td>
<td>600</td>
<td>10.1</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>With overlay</td>
<td>500</td>
<td>9.05</td>
<td>0.47</td>
</tr>
<tr>
<td>SBR4</td>
<td>No overlay</td>
<td>300</td>
<td>9.95</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>With overlay</td>
<td>900</td>
<td>9.15</td>
<td>0.43</td>
</tr>
<tr>
<td>ESL</td>
<td>No overlay</td>
<td>600</td>
<td>10.1</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>With overlay</td>
<td>400</td>
<td>9.0</td>
<td>0.64</td>
</tr>
</tbody>
</table>

also due to binder content [16]. Since microstrip discontinuities have associated reactive elements, the losses might be increased. The leaky modes from each resonator length will also contribute in a complex way to the properties of the seven-section band pass filter.

The reflectance data is not exactly complementary to the transmittance data for the thick film circuits, though the reflectance in band pass region of all the samples are less indicating impedance matching. The thick film metallization does not create additional impedance mismatches though there are very small changes in the reflectance due to type of metallization [10].

Due to overlay, there are stronger effects on the odd mode because of the concentration of electric energy within the gap area. One can match the velocities of the odd and even modes by appropriate control of dielectric overlay. When the velocities are matched, there is an improvement in the characteristics of the coupled circuits. Since the increase in bandwidth and transmittance of the pass band, Q of the filter increases which leads to decrease in the insertion loss of the filter.

Due to cover of high dielectric constant material, $\varepsilon_{\text{eff}}$ should increase because of the air above the microstrip circuit (open case) is replaced by a high dielectric constant material. Since the physical length of the resonator remains the same, when $\varepsilon_{\text{eff}}$ increases due to overlay, the frequency has to decrease for the same length of the resonator [9]. Free et al [17] have reported the suitability of the basic thick film process for fabricating the microstrip circuits and effect of glaze on the relative permittivity by performing the simulation of a 30 GHz filter. Due to reflection at film air interface the changes in $\varepsilon_{\text{eff}}$ are more. The conditions of permittivity below and above the
microstrip filter are expected to be the same since alumina substrate is used as overlay.

The thick film circuit gets more affected than the thin film circuits because of the edge discontinuities in the edges and separation between the coupling gaps. The edge definition of the Copper thin film circuit was 14 µm whereas for SBR3, SBR4 and ESL it was 47 µm, 43 µm and 44 µm respectively.

5.0 Conclusion

On the basis of above investigations conducted, it is concluded that the SBR3 paste (indigenously developed) is comparable to the ESL (imported) paste. Also the thick film circuits are comparable to thin film circuits. The transmittance increases due to overlay. It is felt that, using the bulk overlay one can enable to achieve highly accurate properties such as transmittance, reflectance, bandwidth etc. without changing the design parameters and also it is possible to gain the original properties of the circuit if needed by simply removing the overlay since it is placed above the circuit. The alumina overlay can be reliably used to modify the circuit properties such as coupling and cross talk as and when required since these are directly related to changes in the field distribution in the vicinity of the conductor.

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References


Biographies

Sunit Rane received his M.Sc. from North Maharashtra University, Jalgaon, India in 1993 and Ph.D. from Shivaji University, Kolhapur, India in 2000. Since 1998, he has been working at Centre for materials for Electronics Technology, Pune, India. His main research interests are in the field of thick film technology for high frequency and microelectronics applications, thick film pastes for LTCC etc. He is now engaged in the development of thick film materials for solar cell and other microelectronic applications. Recently, his work has also been oriented towards LTCC materials and applications for mobile communications. Dr. Rane is a member of IMAPS (USA) and Material Research Society of India.

Vijaya Puri received her Ph.D. from Pune University in 1982. Since 1984, she is a Scientist at Department of Physics, Shivaji University, Kolhapur, India. Her research is oriented towards thin and thick film microwave integrated circuits with a special emphasis on overlayed microstrip passive components. Recently her work has been oriented towards thick, thin film mixed ferrites for microstrip antenna and guided optical components. Dr. Puri is a member of IEEE, MTT, CHMT, Magnetic & AP-S societies and a life member of IMAPS, India, IETE, IPA, IVS, OSI and MRSI (India).