APPLICATION NOTE

No. 693: Ferrimagnetic Substrates for Microwave Integrated Circuits

Introduction

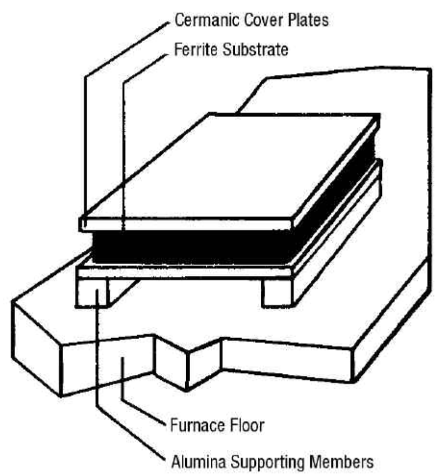
A number of microwave investigators[1,2,3] have succeeded in demonstrating the feasibility of constructing useful microwave components on ferrimagnetic substrates utilizing printed circuit techniques. In this Tech Brief, methods are described for the ceramic fabrication of microwave ferrite substrates of four square inch area. The economic production of MICs on ferrimagnetic substrates requires that as-fired geometric tolerances be held within values that are compatible with circuit design requirements. These parts exhibit intrinsic technical properties and as-fired mechanical tolerances suitable for construction of microstrip ferrimagnetic devices. The elimination of machining to obtain usable mechanical tolerances provides for a cost reduction of ferrite parts. Also, methods of improving the surface finish when required are discussed.

Fabrication Methods

When fabricating ceramic parts, the attainable mechanical tolerances depend in considerable measure on the forming method selected which also effects the magnetic and dielectric properties of the final part. At Trans-Tech, it has been found that the best forming powders are obtained by the spray drying method. These powders exhibit good die fill uniformity and require a minimum amount of binder which is important in reducing non-uniform shrinkage and warpage during sintering.

The fraction of spray dried powder employed is 90 to 150 microinch. The substrate compact is then pressed at 6000 psi, resulting in a green density high enough to insure optimum substrate properties. Ejection of the formed substrate under pressure is important in obtaining maximum flatness of the substrate surface. This is accomplished by relieving the upper punch pressure and ejecting with the lower punch, forcing the substrate and upper punch up simultaneously. Parts ejected in this manner show no edge deformation. The green formed substrate is strong enough to be easily handled and prepared for the final sintering operation.

A key step required to hold the mechanical flatness of the substrates to ±0.001 inch involves loading the substrate during sintering with a ceramic cover plate of approximately equal cross sectional area. This plate weighs approximately the same as the substrate it covers. One arrangement used is shown in Figure 1; here the substrate is sandwiched between two plates. Various types of ceramic cover plates can be employed, such as yttria stabilized zirconia for gannets and alumina or mullite for spine1 type ferrites. An isotherm is set up across the substrate thickness due to the presence of the cover plate. This results in more uniform sintering and better mechanical integrity.



Preparation for Sintering Ferrite Substrate

Figure 1

Results

Substrates have been fabricated that exhibit a surface finish (roughness) of 10 to 15 microinches. Surface flatness to within 0.0015" can be obtained on the same substrates. Parallelism between the two flats can be held to ± 0.001 inch.

A summary of the mechanical tolerances obtained on the as-fired substrates is given in Table 1.

When required, rapid lapping and polishing methods are employed to reduce the surface finish to less than 5 microinches. Lapping and polishing is achieved using a planetary lapping machine which simultaneously removes equal amounts of material from each side of the work. The choice of lapping compound is dependent on surface finish and stock removal desired. All polishing is done with chromic oxide polishing compounds on pellon paper. To decrease polishing time it is necessary that the substrates be lapped flat first using 25 micron lapping compound. Surface finishes of 1 microinch on garnet and 3 microinches on ferrite have been achieved. Annealing is needed for all magnetostrictive materials after lapping or polishing to remove strains which effect the, hysteresis loop. (See Tech Brief #691.)

The technical properties and electrical characteristics of the as-fired substrates when compared to those of substrates cut from bulk material are found to be identical when the surface finishes are the same. Typical methods of forming microstrip components on ferrite substrates have been described in the literature[1,2,3]

Table 1. As-Fired Ferrite Substrate Mechanical Tolerances

	Tolerance Attained	
	1 sq. in. area	**4 sq. in. area**
Length, width (in.)	0.005	0.010
Thickness (in.)	0.001	0.001
Total indicated run out (waviness) (in.)	0.003	0.003
Surface finish (microinch)	10–15	10–15

Cost Reduction

A measure of the cost reduction accomplished via the fabrication methods described here is in order. To accomplish this, a typical cost estimate has been made for ten thousand (10,000) substrates of four (4) square inch area, assuming substrates machined from bulk stock vs. substrates formed and sintered to size and for three (3) surface roughness criteria. The results are as follows:

Material		From Bulk Stock	As Formed & Sintered
Garnet	A.	15.45 each	$6.75 each
	B.	$16.80 each	$7.05 each
	C.	$17.40 each	$7.20 each
Ferrite	A.	$6.35 each	$2.20 each
	B.	B. $7.55 each	$2.50 each
	C.	$7.60 each	$2.65 each
Surface Roughness:	A ≤ 20 microinches		
	B ≤ 10 microinches		
	C ≤ 5 microinches		

Applications

MICs find application in areas similar to traditional ferrimagnetic components except that they are smaller and lend themselves to higher reproducibility because of the printed circuit methods employed in fabrication.

To date MICs exhibit higher insertion loss and lower power handling capability than conventional ferrimagnetic devices. Some typical uses include: phase shifters, isolators, phased arrays, latching circulators, multiple port and other similar devices.

Acknowledgments

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References

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3. Roome, G T.; Hair, H. A. and AuMiller, C.; *"Ferrite devices for Microwave Integrated Systems,"* 1968 ISSCC Digest Technical Papers, p. 52 (1968).