United States Patent

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[54] **HIGH Q CIRCUITS ON CERAMIC SUBSTRATES**

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[52] **U.S. Cl.** ....**333/82 R,** 333/84 M, 117/212, 117/217

[51] **Int. Cl.** **H01p 7/00**

[58] **Field of Search**........117/212, 217, 215, 160, 38, 117/71 R, 70 A; 252/514; 333/84 M, 82 R; 204/52 R, 23, 24, 38 B, 38 C; 317/242, 258

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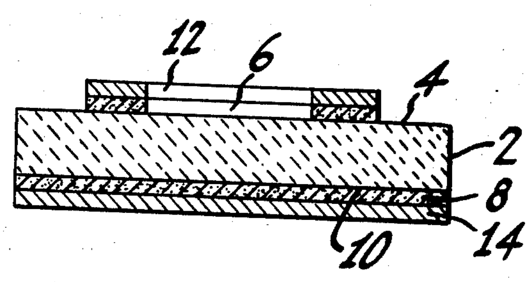
[57] **ABSTRACT**

High Q circuit for operation in the UHF band comprising a ceramic substrate having on one major surface a pattern of metal particle-glass frit conductors having a coating of copper thereon, and on the other major surface a metallic ground plane of similar structure.

4 Claims, 5 Drawing Figures



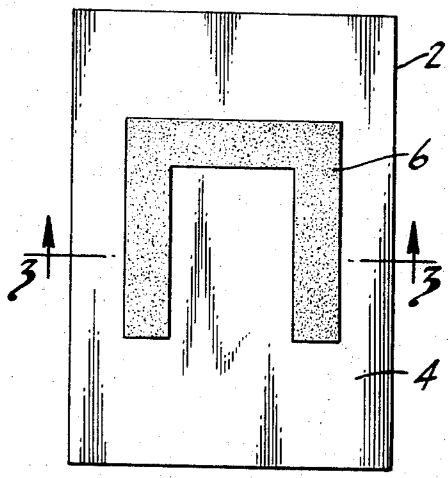


Fig. 1.

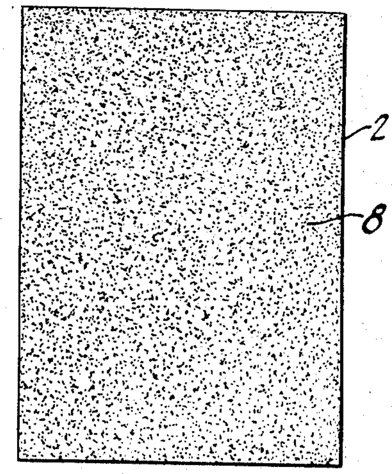


Fig. 2.

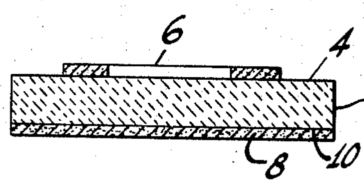


Fig. 3.

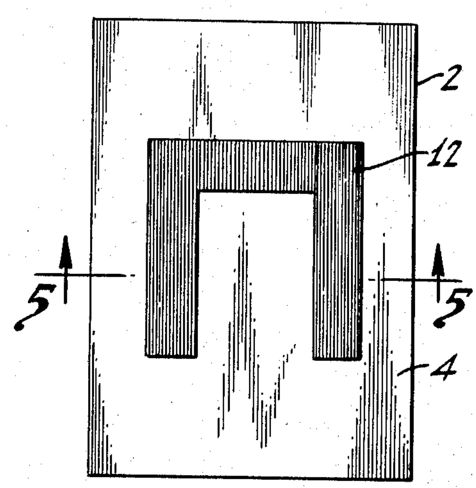


Fig. 4.

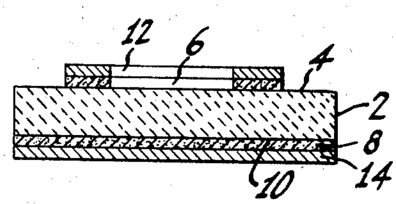


Fig. 5.

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HIGH Q CIRCUITS ON CERAMIC SUBSTRATES

BACKGROUND OF THE INVENTION

Circuits designed to oscillate at frequencies within the UHF band have previously utilized coaxial conductors and stripline units composed of layers of metal foil laminated to opposite sides of a strip of insulating material. The need for lower cost circuits adaptable to mass production techniques, however, has brought about a change to a circuit comprised of layers of metallic inks screen-printed on opposite sides of a fired ceramic plate.

The metallic inks which have been used heretofore have generally comprised a high percentage of silver particles suspended in a vehicle made up primarily of a glass frit, organic plasticizers and solvents. These inks are designed to have good thixotropic properties rendering them suitable for screen printing.

The circuits made from these inks have been found to have certain disadvantages. One of these is that, under high humidity conditions, many of the circuits fail due to silver migration. Silver migration can occur between two silver electrodes when a continuous film of water extends between them on the substrate and when they are under DC bias.

The mechanism by which the silver migrates is that when a DC field is applied, silver ions tend to leave the anode. Hydroxyl ions from the water move toward the anode. Silver ions and hydroxyl ions react to form silver oxide which is precipitated as a dark ring along the edge of the anode. And, silver hydroxide, which is also present, is quite soluble in water and allows silver ions to migrate to the cathode where the silver is discharged and precipitates in a dendritic form.

Another disadvantage of previously-used UHF circuits composed of silver inks is that their Q is not as high as desired. One reason for the low Q value is that films of metallic inks have a myriad of minute surface irregularities. A measure of the Q of a circuit is the width of the frequency band at which it can be caused to resonate at a given value of db in response to a signal of given strength. For many uses it is desirable that a circuit exhibit a very narrow-band frequency response so that it can be sharply tuned.

OBJECTS OF THE INVENTION

One object of the present invention is to provide a circuit for UHF band use which has a relatively high Q.

Another object of the invention is to provide a high Q circuit composed in part of silver metallizing ink in which the silver is prevented from migrating.

The improvements which have been accomplished in the improved circuits of the present invention have been brought about by depositing a thin layer of copper on the exposed surface of the fired silver ink circuit patterns.

THE DRAWING

FIG. 1 is a top plan view of a partially completed test circuit on one side of a ceramic substrate, in accordance with the present invention;

FIG. 2 is a bottom plan view of the other side of the substrate of FIG. 1;

FIG. 3 is a section view taken along the line 3—3 of FIG. 1;

FIG. 4 is a top plan view of the circuit of FIG. 1 in completed form, and

FIG. 5 is a section view taken along the line 5—5 of FIG. 4.

A method of making a test circuit in accordance with the invention will now be described. In this example, the circuit dielectric portion is a ceramic substrate 2 composed of two thin sheets of a composition consisting of 85 percent alumina and 15 percent calcium magnesium silicate laminated together. After firing, the substrate has a thickness of 0.050 inch.

On one side 4 of the substrate a conductive ink pattern 6 in the shape of a "U" is screen-printed. The dimensions of the screened-on pattern are chosen such that, after firing, the width of the U is 2.3 cm. and the outside length of each leg is 3 cm. The width of the lens is 0.4 cm.

The ink composition is not critical but may comprise silver powder 75 percent lead borosilicate glass powder 3 percent, glycerol ester of hydrogenated rosin 12 percent, nitrocellulose 2 percent and butyl carbitol acetate 8 percent. In general, the ink should have a viscosity of 75,000 to 125,000 cps. as measured on a Brookfield Model HBF Viscometer using No. 4 spindle at 10 r.p.m.

The ink is screen-printed on the substrate using a 325 mesh stainless steel screen. The wire threads of the screen have a diameter of 0.0011 inch. The thickness of the print after firing should be 0.0004–0.0006 inch. Sufficient settling time should be allowed, after printing, for the ink dots to flow together and form a uniform layer. This time is usually 3–5 minutes. Lower mesh screens can be used but the results have been found to be less desirable if, for example, the number is as low as 80, since there are more non-uniformities in print thickness under this condition.

A ground plane 8 of the ink is also deposited over the entire surface 10 on the back of the plate.

The ink is dried at about 100°–150° C. and fired at 900° C. (a variation from 890°–920° C. being permissible). The entire time in the furnace from room temperature to maximum and back to room temperature is about 40 minutes. After firing, the conductive patterns are about 95 percent silver.

The circuit now has the appearance illustrated in FIGS. 1–3. At a resonant frequency of 850 Mc/s a large number of circuits tested had an average Q of 135. In circuits intended for apparatus such as TV tuners it is desirable that the Q be higher. Also, as stated previously, it is highly desirable that the tendency for silver migration, which is present in circuits made as described above, be reduced or completely eliminated.

In making circuits of the present invention, the next step is to electroplate a layer of copper 12 on the fired silver ink pattern 6 on the top sides of the substrate 2 and another layer of copper 14 on the fired silver layer 8 on the bottom of the substrate 2. The plating bath may comprise:

Copper sulfate ($CuSO_4 \cdot 5H_2O$)	1.76 lbs./gal. of solution
Sulfuric Acid (98% H_2SO_4)	206.2 cc./gal. of solution
Water (ion free)	remainder of solution

Suitable plating conditions are: a current density of 2 amps/10 sq. in. of screen-printed conductor to be plated, if the bath is not agitated, and a plating time of about 10–30 minutes. If the bath is agitated, a current density of 3.5 amps/10 sq. in. can be used and the time can be correspondingly decreased. A preferred plating time in a non-agitated bath is 10 minutes.

The thickness of the copper plating is preferably 0.0002 to 0.0005 inch.

After the copper plated circuit is removed from the plating bath, it is thoroughly rinsed in de-ionized water, and then dried either by centrifuging for 2 minutes or being pressed against absorbent tissue, and being subjected to forced air in an oven at 90°–120° C. for ½ hour.

A large number of circuits tested at a resonant frequency of 850 Mc/s were found to now have an average Q of 160. One of the reasons for the improvement in Q values is that the copper tends to fill in the surface irregularities of the metal ink film, resulting in a much more uniform layer.

A number of identical test circuits having the same shape shown in the drawing and having the same dimensions and made by the same method described in the example were tested for their Q before and after the copper plating step. The results are set forth in the table below.

In making the test, the frequency of maximum resonance (maximum db output) was determined. This data is noted in the column "*f* center" in the table below. Then, at the same signal strength input, the signal was tuned off the center frequency both higher and lower, and the frequencies noted where the oscillation output was 3 db. down from that of the center frequency. The high and low frequencies for each center frequency are given in the columns marked "*f* high" and "*f* low" in the table.

The Q for the circuit is then found by dividing the center frequency by the difference between the measured high frequency and the measured low frequency.

The data given in the first 5 columns of the Table is that obtained for each sample after copper plating. For comparison purposes, the Q measured for each circuit sample before copper plating is given in the 6th column. The Q data in the 6th column were obtained exactly as described for the copper plated circuits, but, to save space, the actual frequency measurements have not been included in this Table.

The 7th column of the Table shows the percentage increase in Q obtained by copper plating each sample. The percentage increase varies because of variations in such parameters as coating thickness, coating uniformity, substrate imperfections, and the like.

TABLE

	After Copper Plating					Before Copper Pltg.	% ΔQ	Plating Conditions	
No.	f_{center}	f_{high}	f_{low}	$f_{H}-f_{L}$	Q	Q		4 v. 1.4 amp	Time (min)
std.	864.49	867.57	862.17	5.90	160				
1	843.13	846.05	841.10	4.95	170	121	39%	"	30
2	844.92	847.53	842.73	4.80	176	118	47%	"	30
3	843.36	846.33	841.28	5.05	167	131	27%	"	30
4	842.76	845.48	840.35	5.13	164	120	35%	"	30
5	841.33	844.11	839.09	5.02	167	118	40%	"	30
6	842.87	845.70	840.77	4.93	170	145	16%	"	20
7	842.58	845.31	840.20	5.11	164	120	37%	"	20
8	841.15	844.18	838.89	5.29	159	121	31%	"	20
9	842.42	845.22	840.11	5.11	164	130	25%	"	20
10	843.32	846.19	840.97	5.22	161	144	12%	"	20
11	846.01	848.93	843.80	5.13	164	129	27%	"	20
12	843.39	846.28	841.12	5.16	163	149	09%	"	10
13	845.28	848.26	843.02	5.24	161	149	07%	"	10
14	842.10	845.01	839.59	5.42	155	149	03%	"	10
15	837.00	840.10	834.52	5.58	150	139	4%	"	10
16	838.82	841.98	836.42	5.56	150	117	28%	"	10
17	840.31	843.33	837.93	5.40	155	135	15%	"	10
18	840.43	843.61	838.12	5.49	153	113	34%	"	10
19	839.48	842.61	857.34	5.27	159	123	29%	"	10
20	836.60	840.51	843.90	6.67	125	113	10%	"	10
21	837.31	840.53	835.00	5.53	151	124	21%	"	10

In order to compare silver migration in circuits which had been copper plated as described above, with migration in circuits that had not been plated, two sets of plates were made up with a standard printed electrode migration test pattern. Both sets of plates were printed with the same silver ink and put through identical processing steps except that one set of plates was copper plated and the other was not.

Both sets of plates were subjected to test conditions as follows:

Time of testing	1663 hours
Temp. of testing	40° C.
Relative humidity	95–98%
Voltage bias between plates	150

Samples in the group that had not been copper plated failed at about 89.5 hours and were removed from the test oven. The set that had been plated with copper had no failures at the end of the test.

After copper plating, the circuits may be given further processing which does not substantially affect their Q. For example, certain areas may have solder applied so that connections may be made; and protective resin coatings may also be applied everywhere except where connections are to be made.

What is claimed is:

1. A high Q circuit for operation at ultra high frequencies comprising:
   - a ceramic substrate having two major surfaces,
   - a fired pattern of conductors of the silver particle-glass frit mixture type on one of said surfaces,
   - a ground plane composed of a fired silver particle-glass frit mixture type composition on the other of said surfaces,
   - said fired pattern of conductors and said ground plane normally each having surfaces characterized by a myriad of minute surface irregularities,
   - a layer of copper plated on and integrally united to the exposed surface of said fired pattern of conductors and to the surface of said ground plane such that said surface irregularities tend to be filled in by said copper,
   - the combination of said metal pattern, said ground plane and said substrate being dimensioned such that it will resonate at a particular frequency within the UHF band.

2. A circuit according to claim 1 in which said copper layer is about 0.0002 to 0.0005 inch thick.

3. A circuit according to claim 2 in which said silver particle-glass frit composition contains about 95 percent silver.

4. A circuit according to claim 3 in which said ceramic substrate has a thickness of 0.050 inch.

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