INTEGRATED ELECTRONICS AT UHF

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The development of microwave microcircuits utilizing uncased semiconductor chips and thin films promises a revolution in the design and construction of microwave circuits. The more intimate contact between the semiconductor device and circuit, without constraints of the package, will allow the attainment of device performance never before achieved. The construction of rf circuitry in a standardized micromodule form will allow rf circuitry to be compatible with standard microelectronic packaging techniques and similar in cost to low frequency circuits.

That a challenge to the microwave designer exists is evident by the system designers' assertion that the rf front end constitutes 35% of many receivers with the lower frequency circuits yet to reduced an order of magnitude by integrated electronic techniques. It is the hope of the authors that the techniques discussed herein are useful in meeting this challenge for frequencies up to 10gc.

Microwave microcircuits will be designed using strip line techniques and then reduced to micromodual size by use of high dielectric constant substrates and thin film components. One important concern with thin film circuits is tunability because the structure does not lend itself to mechanical tuning except for the use of trimmer capacitors. However, most requirements can be satisfied by use of plug-in modules, digital fixed tuned adjustments or continuous solid state tuning. This latter tuning is achieved either by voltage variable varactors at the lower microwave frequencies or Yig crystals at the higher microwave frequencies.

The interconnection problem for microwave microcircuits is particularly difficult because transmission line continuity must be maintained to avoid disturbing the performance of the individual modules. A proposed solution to this problem is to use strip line interconnections which provides both shielding and continuity. The respective modules will be stacked with strip line interconnections placed at right angles to the stack along its edge.

Two factors limiting the use of thin films at microwave frequencies are dissipation and power handling. The small size of the circuits contribute to the increased dissipation and hence limitation of power handling. The power handling is also limited because of reduced voltage breakdown because of close conductor spacing.

Microwave microcircuits can be fabricated by photo etching strip line circuits on copper clad substrates. Thin film nichrome and tin oxide resistors can be vapor deposited along with silicon monoxide and dioxide capacitors. Diodes and transistors can be bonded directly to the circuit in passivated chip form.

For design purposes the low frequency values of thin film components, shown in figure 1, can be used at higher frequencies. In addition to these components conductor patterns can be fabricated with thin film techniques. Tolerance-wise this thin film fabrication is advantageous, being capable of holding a $\pm$ .0002" tolerance compared to a $\pm$ .002" for printed circuits.

One of the most important attributes of thin film fabrication is the ability to integrate microwave and lower frequency circuits. This results in a lower overall production cost since almost all circuit fabrication can be automated.

A VHF tunnel diode mixer was fabricated in thin film form and evaluated to illustrate the advantages of microwave microcircuitry. Such a circuit was chosen because it has rf, af, and bias circuitry, all of which must be closly integrated in a functional sense to achieve stability and reasonable sensitivity.

Initially a printed circuit prototype mixer was fabricated. This mixer consists of a shorted strip transmission line loaded at the high impedance end by a gallium antimonide tunnel diode and the rf input. The rf ground of the tunnel diode is connected to the if output. Shunting the if output of the tunnel diode is a 60mc tank circuit consisting of a 47pf capacitor and 0.15 microhenry choke, which also forms part of the bias circuit. The remainder of the bias circuit consists of a 790pf if bypass and a 56 ohm damping resistor.

The remainder of the mixer consists of a matching circuit between the tunnel diode and the input of the following tube if amplifier used for text purposes.

From this printed circuit prototype a thin film counterpart; shown in figure 2, was fabricated incorporating essentially the same circuitry. Four general processes were used for the fabrication; these are: (a) substrate processing, (b) vacuum deposition through contact metal masks, (c) photo-resist processing, and (d) aqueous solution processing. Substrate processing includes cutting the substrate, which is glass, upon which the circuit was fabricated and shaping holes in it to accept the connectors, the variable trimmer capacitor, the diode, and to make connections to the ground plane below the substrate. Vacuum deposition processes were done in conventional vacuum evaporators with sufficient pumping capacity to allow the depositions to take place in a 10^{-5} to 10^{-6} mm of Hg atmosphere. Photo-resist processing, using Kodak Metal Etch Resist, was done under yellow light lighting so as not to expose the resist prior to the desired exposure. Aqueous solution processing includes all processes which required the substrate to be immersed in a water solution of some kind.

The performances of thin film and printed circuit mixers are comparable. Operating from 200 to 400mc without tuning and with a local oscillator injected via a coupler in the rf line before the mixer, a noise figure of about 9db was achieved. The printed circuit mixer generally has about 0.5 to 1db lower noise figure except near 300mc where the thin film mixer is better. Both mixers require only 20 to 40 microwatts of local oscillator power which is attractive where crystal controlled operation is required.

In summary microwave microcircuits offer the possibility of extremely compact assemblies without serious degradation of performance except where high Q cavities are required. To utilize microwave microcircuits fully a modulization of circuits is recommended with carefully designed interconnections, use of high dielectric constant, low loss, substrates and tuning with varactors, Yig crystals, or digital methods. Feasability of some of these techniques has been demonstrated with the tunnel diode mixer example.

TYPICAL CHARACTERISTICS OF THIN-FILM COMPONENTS

PARAMETER	NICHROME RESISTORS	TIN-OXIDE RESISTORS	SIO CAPS	TANTALUM CAPS	THIN FILM SPIRAL INDUCTORS
OHMS/□ RANGE	40 TO 400	500 TO 5000	——	——	——
CAPACITY/□" (APP.)	——	——	.01 μfd (AT 15V)	8 μfd (AT 25V)	——
WORKING VOLTAGE OF C'S	——	——	15 TO 30 V	12-1/2 TO 50 V*	——
TEMP. COEFF. (PPM/°C)	+100** TO -100	-1500±300 AT 5000 OHMS/□	+300 ±50	+300 ±100	VERY LOW
DEPOSITED ACCURACY***(BEST ACC. WITH GOOD YIELD)	±5%	±10%	±10%	±10%	±3%
MAX PRACTICABLE VALUES ON A .5" x 5" AREA	1.0 MEG.	10 MEG.	.0025 μfd (AT 20 V)	.2 μfd (AT 25V)	6 μh (AIR CORE)
LONG TERM DRIFT	.8%	5%	5%	——	VERY LOW
LONG TERM DRIFT (WITH PREAGING)	.25%	——	1%	——	——
AUDIO FREQUENCY D. F. (CAPS)	——	——	1.5%	1.0%	——
INDUCTANCE Q	——	——	——	——	25 FOR 2 μH COIL AT 10 MC

*ANODIZED AT 4 TIMES WORKING VOLTAGE

** TC CAN BE CONTROLLED CLOSER WITH INCREASED COST

*** TRIMMING OF BOTH R'S AND C'S IS PRACTICABLE TO OBTAIN TIGHTER TOLERANCES

Fig. 1. Typical characteristics of thin film components.

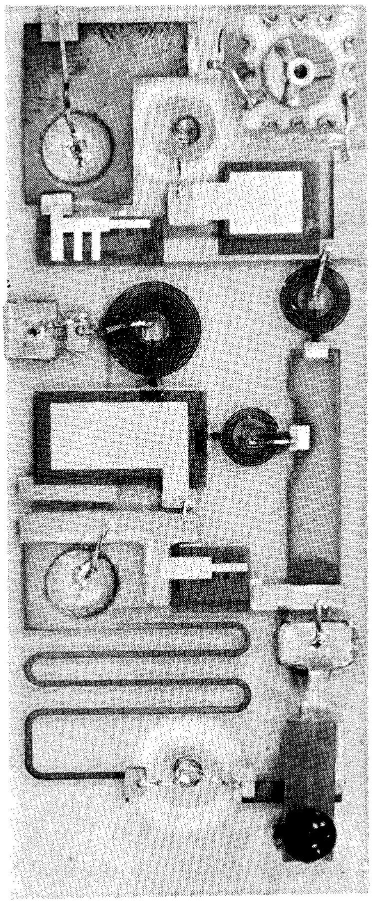

Fig. 2. Photograph of the thin film tunnel diode mixer.

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