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Materials for Microwave Devices

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Abstract: *The transmission lines for the guided propagation of electromagnetic waves in the microwave frequency range (1GHz – 100 GHz) are microwave integrated circuits (MIC). The wave-guide components/devices are bulky and expensive but can carry high power where as MICs show their versatility in low power, light weight, miniaturized microwave systems. The development of this wave-guide based components and MICs depends upon the availability of materials with specific characteristics. Hence the physiochemical properties of such materials have an impact on microwave technology. In this paper, a few sets of such microwave materials and their characteristics which make them suitable for microwave devices are described. The properties of materials like ferrites, garnets, ferroelectrics, relaxer ferroelectrics, temperature compensated dielectrics and copper-coated PTFE based composites which are used extensively in microwave devices are discussed.*

Keywords: *Microwaves, Ferrites, Garnets, Ferroelectrics, Dielectric resonators and Metalized PTFE. Microwave materials and Characteristics*

I. Introduction

The primary requirements of microwave materials are low dc conductivity, low dielectric and magnetic losses, and temperature independent dielectric or magnetic properties. Some of the materials that satisfy these requirements are ferrites, garnets,ferroelectrics and temperature compensated dielectrics which are ceramic materials and copper cladded composites based on PTFE wich are used as substrates for MICs.

Ferrites and Garnets

Spinet ferrites are a class of magnetic materials which are a general formula Mfe2O4 M a can be replaced with divalent metals with the chemical formula.The parameter x varies from 0 to 1, thus changing the physical parameters as per device requirements. M can also be replaced with monovalent and trivalent metals and lithium and lithium zinc ferrites belong to such a family garnets are another class materials with the cat ions being are earths and ion. An example of such a family of compounds is yttrium iron garnet. One can prepare garnets and ferrite powder materials using conventional ceramic methods and this is most widely used by industrial organizations.

A comparision of ferrite and garnet compound is given in table 1 .Various techniques are currently employed in characterizing these materials at the microwave frequency . How ever the most realiable method cavity perturbation technique;has been used for the microwave characterizing of these materials and the details are given by Muthy and Raman (1989) .The specification of a ferrite material for isolator attenuator applications are given in table 2 and some charecterstics of lithium ferrite for such devices are given in Table.3.

Table 1. Comparison of the characteristics of Ferrites and Garnets

Ferrites	Garnets
Variable resistivity	Very high resistivity
Saturation magnetization variable	Low
Curie temperature variable	High
Coercivity low	Low
Stable compounds	Stable compounds
Can be prepared at low temperatures also	Very high temperatures only
Structure cubic	Cubic
Partially filled structure	Completely filled structures
Line-width high	Low
Microwave losses medium	Low
Dielectric constant high	High
Low cost	High cost

Table 2. Typical specifications of a microwave material (ferrite) for use as isolator/attenuator

Saturation magnetization	200-2000 Gauss
Microwave loss tangent	1×10^{-4}
Coercivity	l O_s
Linewidth	1 – 10 O_e
BH squareness ratio	0.75
Dielectric constant	15

Table 3. Typical characteristics of lithium ferrite

Resistivity	8×10^5 Ohm-cm
Saturation magnetization	3745 Gauss
Resonance linewidth	30 O_e
Squareness ratio	0.95
Curie temperature	890 K
Microwave loss	1×10^4
Dielectric constant	10

Ferroelectrics:

Ferroelectrics are electrical analogues of ferromagnets displaying Curie-Weiss law in their dielectric constant variation with temperature (Lines and Glass 1977). For microwave applications they are used above the curie temperature (Tc) that is paraelectric region because these materials don't exibit their characteristic hysteresis, prezoelectric and polyelectric in the paraelectric state

But still exibit large constant which depends on voltage and temperature with a lower dielectric loss.Mazority of the applications utilizing ferroelectrics depends on their large non-linearity in dielcric constant at a particular temperature above Tc either under a dc bias or under varying fiels strength of the microwave power (Horton and Donaldson 1967).A ferroelectric whose Tc is given below the room temperature hav9ing low dielectric loss at room temperature , exhibiting large non-linearity in dielectric constant above tc but depends on temperature only sluggishly i.e deal for microwave applications . Materials like $BaTiO_3$, $SrTiO_3$(Pbx Sr1-x) tiO_3, with x=0.317,0.35 and 0.45,(Ba0.75Sr0.25) TiO3 are used widely in microwave applications .All of them crystallize in perovskite structure with T_c below 393K. They are used in ceramic form and have resistivities of the order of 10^{13} ohm met.

Under the applications of a dc bias voltage both the dielectric constant and loss of a ferroelectric will decreases .The non-linear dielectric properties enable them to be used in a microwave filters,limiters, phase shifters , switches , mixers and modulators and as the active element for microwave parametric amplifier/osvcillators, harmonic generators and electromagnetic shock wave generators.

The advent of the ferroelectric thin films will help this fields, as it will decrease the amount of dc voltage required to bring in enough change in the dielectric constant (Das 1967).Ferroelectrics generally have relaxation in or around the microwave region. They can be used only at frequencies far away from the relaxation region. Ferroelectrics are characterized using coaxial cavities at smaller microwave frequencies and by transmission technique at higher frequencies . However, a deart of the data exists about the large signal microwave dielectric properties of the ferroelectrics. Table4 contains the data of a few ferroelectrics, which are used in microwave applications .Unless otherwise specified the materials given in this table employed in ceramic from (das 1964).

Table 4. Characteristics of some ferroelectrics used in microwave devices

Material	ε^1	Tanδ	Measured at Frequency GHZ	% Temp^{0}C	Curie Temp^{0}C
Single crystal Ba TiO_3	2000	-0.15	24.0	20	130
Ceramic Ba TiO_3	60	-0.3	3.0	25	130
Hot pressed $Cd_2Nb_2O_2$	435	0.069	4.0	26	-88
$(Ba_{o.73}\ Sr_{0.27})\ TiO_3$	3350	-0.16	12.4	21	20
Single crystal $SrTiO_3$	-1000	0.0013	7.65	-150	-163
$(Pb_{0.45}Sr_{0.55})\ TiO_3$	4800	0.008	0.218	120	116

Relaxor ferroelectrics:

Another class of materials, which shows novel properties of that of its ferroelectric counter part, is relaxor ferroelectrics. These materials are often identified by its frequency Dependent diffuse phase transition. Unlike ferroelectric materials, the relaxor ferroelectrics do not posses well defined domains below Tc and also does not exibit optical anisotropy. Several investigations have been in progress to understand the diffused nature of the phase tranisition in this material .Many relaxation materials have been proposed to data to explain the phenomenon .$Pb(Mg_{1/3}Nb_{2/3})\ O_3$ was the first material reported to be the relaxor ferroelectrics and very well studied on technical as well as scientifically for its large dielectric constant near the room temperature (Smolenskii,1958).

In this material the disordered nature of Mg and Nb ions considered to be instrumental in producing local field fluctuation,which ultimately diffused the phase transition. Relaxor ferroelectrics are widely used as multilayer capacitors, piezoelectric actuators and transducers .The composition $0.9Pb(Mg_{1/3}Nb_{2/3})\ O_3$ -0.1 PbTiO3 is widely used as pyroelectric detector for its large pyroelectric coefficient near Tc (Uchinok,1986).

Materials for dielectric resonators:

Dielectric resonators are used in MiCs for frequency control. They are just a ceramic pallet in the form of a parallelopiped or cylindrical disc (fieldziszko 1986) .When a contionus band of microwave is passed through through a dielectric resonator .it will resonate at a few discreet frequencies determ9ined by the geomentry and dimensions of the pellet. Since the electromagnetic field can satisfy the boundary conditions in more than one mode. One will get a series of modes each having different field pattern The most widely used moe is TE011 mode. The material used for making dielectric resonators should satisfy the following conditions (Subba Rao et al..,1990).

a) The dielectric constant should be high (generally 10 to 100).
b) The dielectric loss should be low ($\tan\delta = 0.0003$)
c) The temperature coefficient of resonant frequency must be very small (τ_f must be less than = + or - 50 ppm)

A large e will aid the miniaturization while a low dielectric loss will result in a high Q value.But the value of τ_f depends on both the temperature coefficient of dielectric constant (τ_e) and coefficient of thermal expansion (a) since $\tau_f = -(\tau_e /2+\alpha\ )$

Materials with compensating τ_E and a given low value of τ_f. τ_e depends only on the lattice dynamics of the material while a can be controlled through heat treatments.The materials should not have any relaxation near the frequency range of interest. The materials which are widely used as DR have perovskite related structures. But the role of secondary phases In DR materials is considerable. They help sintering as well as in enhancing the desirable properties.

Dielectric resonators are used in various types of filter and oscillators and as miniature radiating elements in microwave integrated circuits. Couple to DR is easy and can replace bulky cavity resonators in many applications. These temperature compensated dielectrics and characterized in the micro wave frequency range using a method popularly known as Courtneys method 9country 1970).

Charecterstics of some representative temperature compensated dielectrics are given in Table5.

(Nomura1983; Wakino city 1984).

Copper coated PTFE(Poly Tetra fluro enthylene).

Metalized fluorocarbon polymers (PTFE) with woven or nonwoven glass fiber and high dielectric

constant ceramic fibres offer combinations of properties suitable for applications like microwave antenna (Traut ,1980) and microwave integrated circuits (Olyphant and ball 1970). For these microwave applications the microwave substrate chosen should meet certain exacting demands like uniform dielectric constant, controlled thickness and low loss (Woenbkem 1979).The copper coated PTFE sunstrate is most commonly used for this purpose.The substrate was conditioned sodium hydrozide, acetone and water mixture . The preconditioned substrates were subsequently pretreated with stannous chloride sensitizer and palladium chloride activator. The copper coating was achieved by electroless method using a copper bath, Electroplating of copper should be resorted to fur further increase in the thickness if required.One can use electroless method to deposit copper for good adhesion, uniformity smoothness. This approach is least expensive and reliable. The charecterstics of copper–coated PTFE for microwave devices are that the dielectric constant is around 2.2 and diddipation factor of 0.0001

Dielectric relaxation in organic liquids and its mixtures:

In liquids the molecules has the rotational freedom and its dispersion occurs at microwave frequencies So studying the dielectric properties at micro wave frequencies will releave the dielectric relaxation of polar molecules and its variation with respect to the interaction with neighboring polar as well as non-polar molecules.

The effect of hydrogen bonding on the dielectric relaxation can also be studied at microwave frequencies (V.R.K.Murthy, 1979).

II. Conclusions

Considering the strategic role enjoyed by the microwave technology in aerospace and communications, the method for materials with more specific charecterstics will be increasing, especially for miniaturized microwave systems ferroelectric thin films can get a renewed interest.

Temperature compensated dielectrics can be used as MIC substrates also. Properties oh high temperature superconductors are being exploited are being exploited for various microwave applications. Materials with low loss and high e are required for developing MICs in the lower microwave frequencies. Overcrowding of a microwave frequencies and the special charecterstics of millimeter wave force more and more systems to operate in millimeter range, which requires materials with the low dielectric constant and low loss at that high frequencies.

Relaxor ferroelectrics:
Another class of materials which shows novelproperties to that of its ferroelectric counterpart, is relaxor ferroelectric. These materials are often identified by its frequency.

References

[1] Bab P.D., G.M.Argentine, W.E.Courtney , G.F.Dionee and D.Temme, IEEE Transactions on Magnetics ,(1971)7,p,351
[2] W.E.Courtney, iEEE Transactions of microwave Theory and techniques (1971).18,No.8, p 476-485.
[3] Das R, solid state electronic (1967), 10, 857
[4] Das S.N, IEEE Trans Microwave Theory and technique 12, 440
[5] Fiedziuszka J.S Microwave journal (1986), 189
[6] Horton J.B, M.R Donadson, IEE Trans microwave Theory and Technique 15, 517
[7] Lines and Glass, principles and applications of Ferroelectrics and related materials,1977, Claredon Press, Oxford.
[8] Murthy V.R.K. and Raman R, solid state communication, 49, 61
[9] Olyphant M,JHBall ,IEEE Trans Elect, Insul.,(1970), 102. 155
[10] Smolenskii G.A.A.I. Agranovskaya , Sov physics:- tech physics ,65,647-52
[11] Wakino K,K.Minai, H.Tamura ,J.Am. ceram .Soc.,(1984),67, 278.
[12] Murthy V. R. K., P. K. Kadba, P. K .Bhagat ,J.Am. Ceram. Soc., 17,1485-93
[13] Woermbke J.D., Microwaves , 18,66