A Novel Miniature Super Conducting Material At Room Temperature

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ABSTRACT

This paper deals with the investigation on diamagnetic ferrite in an inhomogeneous magnetic field at room temperature using ferrite as substrate material, thereby giving rise to a reduced size practicable super conducting material. Samples of iron, chromium, manganese, titanium, yttrium and bismuth diamagnetic ferrite have been developed whose intrinsic magnetic field and susceptibilities are very much suited for such super conducting material, which is very simple in shape, light in weight with added advantage of levitation effect, independent nature to rise in temperature and storing of electrical power.

Keyword: - *Levitation Effect, Diamagnetic, Super Conductor, Inhomogeneous.*

1. Introduction

Superconductor with zero resistance and infinite conductivity at normal room temperature is the dream of human race for long. With a view to that, series of investigations during 1911 to 1933 have been carried out by various scientists and researchers. The first Dutch scientist H.K. Onnes discovered superconductivity in element mercury with zero resistivity along with continues flow of electrical current and zero loss at 4.2 K in liquid helium in the year1911. However, about 20 years after during 1933, the two German physicists W. Meissner and R. Oschenfeld discovered the behavior of superconductor of lead and tin respectively in a relatively weak magnetic field at the temperatures of 7 K for lead and 18 K for tin, wherein the field penetrates only a thin layer of the material which can be measurable in nanometers before quickly decaying to zero. This phenomenon, which is unique to superconductors, is commonly known as Meissner effect or Meissner-Oschenfeld effect [1]. The Meissner effect reflects the perfect diamagnetism. Meissner predicted that in a perfect diamagnetic material the applied magnetic lines of forces are repelled and the material then behave as Soft type 1 and Hard type 2 superconducting material in cold atmosphere. A lead bismuth alloy was the first known type 2 superconducting material ever produced. Later, F. and H. London in 1935 postulated, reported and published in the proceedings, Royal Society, London, about two electromagnetic field equations of superconductor which modifying Maxwell' s field equations for explaining Meissner effect, and later Supraleitung diamagnetism was again reported and published in Physics during 1935 by London. F. and H. London showed that the Meissner effect was a consequence of the minimization of the electromagnetic free energy carried by superconducting current [2]. Also in 1950, Maxwell and Reynolds et al. found that the critical temperature of a superconductor depends on the isotopic mass of the constituent element led to the discovery of the electron-phonon interaction as the microscopic mechanism responsible for superconductivity. The complete microscopic theory was proposed in 1957 by Barden, Cooper and Schrieffer. The BCS theory by Barden, Cooper and Schrieffer explained the superconducting current as a superfluid of Cooper pairs, pairs of electrons interacting through the exchange of phonons. Paired electrons behave quite differently than single electrons.

In 1962, the first commercial superconducting wire was developed by researchers at Westinghouse, led to the first practical superconducting magnets. In the same year Josephson effect was exploited for making superconducting devices such as SQUIDs. Superconducting wires and magnets towards Maglev trains and also for MHD generators. In addition to that superconducting wires with Nb_3Sn and NbTi were also developed by melt process at 77 K. Apart from these, during 1977 superconducting wires also prepared with $REBa_2Cu_3O_{7-}$ for Maglev train in Japan, at 77K. However, further research work in the year 1986 by two IBM scientists G. Bednorz and A. Muller led to the development of a ceramic Type 2 material with LaBaCuO, known as LBCO, which is superconducting at 35 K. Subsequently, a new class of superconductors was found by Bednorz and Muller involved copper based ceramics in 1986 at 40 K. During 1987, Paul Chu and his colleagues developed perovskite ceramic material as superconductor at a critical temperature of 90 K with liquid nitrogen. Thus the races for achieving more and higher critical temperature, many new superconducting materials were developed at about 125 K. In 1993, the highest temperature superconductor was a ceramic material consisting of thallium, mercury, copper, barium, calcium and oxygen with T_C as 138K. In 1995, R. Ott el has predicted superconductivity on the composite mixture of $HgBa_2Ca_2Cu_3O_{8+\delta}$ in a cold atmosphere at 134 K. Nevertheless, the scientists have actually achieved superconductivity at temperature as warm as 164 K, but under high pressure [3].

At room temperature scientists of Cambridge University have reported during July, 2008 in Science daily that they have identified a key material to unraveling the mystery of room temperature superconductivity, which could potentially transport electricity with zero loss. However, numbers of investigations have been carried out by various authors on superconducting materials and also their alloys, showing zero resistivity without the formation of magnetic induction in a very cold atmosphere either in liquid helium or liquid nitrogen. Though these superconducting materials are very much common in a very cold atmosphere preferably tuned as High T_C superconducting material. Even now the race is on going. Keeping the above in view, a series of further investigations have been carried out with an untiring effort by the authors to explore superconducting material or diamagnetic material at normal temperature within the range of 25ºC to 30ºC [4]. This paper deals with the investigations on diamagnetic material in an inhomogeneous magnetic field at normal room temperature using ferrite as substrates and core elements. With a view to that, numbers of elements from the transitional and nontransitional group of elements of the periodic table have been searched out by the authors in response to their behaviors, properties and characteristics as and when those are subjected and tested in an inhomogeneous magnetic field. The searched out elements are like as, iron, chromium, manganese, vanadium, titanium, cobalt, nickel, yttrium and bismuth. Afterwards, ceramic powdered oxide materials of those searched out elements with 99.9% purity have been considered for further processing. Those powdered oxide materials are firstly crushed and then converted to micron size in a peculiar manner and subsequently tested by a table microscope with various lenses having different magnifications to examine the size of the powdered particles on a laboratory scale. Subsequently, composite mixture compositions with respect to their chemical formulas have been developed. Accordingly the aim of this paper has been to develop two types of ferrites, which will be diamagnetic in nature at normal room temperature.

1.1 Fabrication technique of diamagnetic ferrite

In view of the above, two composite mixture composition of powdered oxide materials like (1) Fe-Cr-Mn-Ti-Y-Bi-O and (2) Fe-Cr-Ti-Mn-V-Y-Bi-O, having the chemical formulas as $Fe_{1.461}\,Cr_{0.4808}\,Mn_{0.48}Ti_{0.0545}Y_{0.261}Bi_{0.182}O_4$ and $Fe_{1.737}Cr_{0.58}Ti_{0.68}Mn_{0.64}V_{0.26}Y_{0.14}Bi_{0.054}O_4$ respectively have been considered for the development of diamagnetic ferrites. Afterwards, these micron size powered oxide materials are blended thoroughly with binders like " enamel" as such; each and every powdered particle will be coated with binders for each composite composition in accordance to their chemical formulas. Subsequently the blended powdered materials are compacted in different dices, dices which are made of chrome steel so as to withstand high mechanical pressure during compaction in a hydraulic press within the range of 0 to 100 PSI. The configurations of dices are different as per the design consideration of substrates and core elements. Substrates and core elements will be different in .nature like as, torroid (small and large size), circular disc with a central hole and rectangular slab etc. Later, the blended and compacted powdered oxide materials in the form of substrates and core elements for both the compositions are subjected for sintering followed by powdered metallurgical modified sintering technique in a Chamber type Muffle furnace at a high temperature of 1200ºC to 1500ºC. Here, the ferrite samples are sintered at a high temperature of 1400ºC for 14 hours and later cooled in an inert atmosphere of helium, later followed by grinding and lapping, if necessary. Thus the ferrites are fabricated with respect to their composite compositions and chemical formulas. The placement of the ferrite samples inside the chamber of the Muffle furnace is very peculiar, and if, it is not followed, then there will be shrinkage and deformations on the ferrite samples. Moreover, the preliminary sintering is made at a temperature of 600ºC before the final sintering for the removal of unwanted ingredients from the powdered mixture materials.

Afterwards crushed and converted to micron size again followed by final blending, compaction and modified sintering at a high temperature of 1400ºC on a laboratory scale.

1.2 Configurations of developed Ferrite Samples

The developed diamagnetic ferrite Samples configurations for both the composite mixture compositions are noted below like as: [(1) Small torroid (treated as hollow cylinder): [Outer diameter= 43.5 mm, Outer radius= 21.75 mm; Inner diameter= 17 mm, Inner radius= 8.5 mm, Thickness= 11mm, Volume= $13.84x10^{-6}$ cubic meter]. [(2) Circular disc with a central hole (treated as solid cylinder)] [Diameter= 64 mm, Thickness= 11 mm, Volume= $77.17x\ 10^{-6}$ cubic meter] and (3) Big Torroid (treated as hollow cylinder) [Outer diameter= 68 mm, Outer radius= 34 mm, Inner diameter= 39 mm, Inner radius= 19.5 mm, Thickness= 7 mm, Volume= $17.05x10^{-6}$ cubic meter].

2. Experimental Setup

Afterwards, the torroid and the circular disc with a central hole developed ferrite samples have been considered for further study and measurements. Moreover, when those developed diamagnetic ferrites are characterized at normal room temperature in an inhomogeneous magnetic field, revealing number of peculiar properties like resistivity and susceptibilities with an added advantage of levitation effect and independent nature to rise in temperature. Here, all the measurements have been carried out on a laboratory scale by the authors with the use of an Experimental Setup as shown in Fig.1 and Fig.2. The Fig. 2 represents the whole experimental setup, where all the measurements have been carried out on a laboratory scale by the authors. In the experimental setup the ferrite samples are suspended by a string from one of the arm of a mechanical weighing balance made of brass as shown in the Fig.2 in between the two inhomogeneous pole faces as three fourth portion of the sample is within the pole faces and one fourth portion is on the air. The pan on the other arm of the balance is meant for the placement of weights.

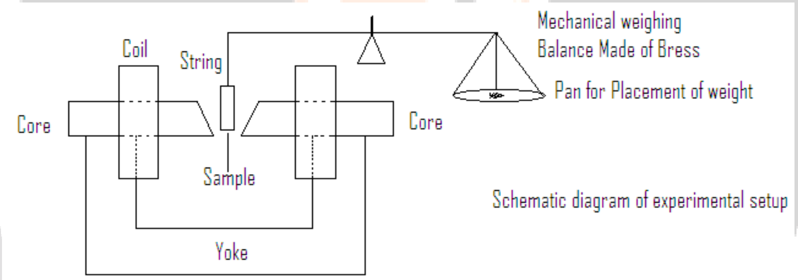

Fig. 1 Schematic diagram of experimental setup

Fig. 2 The whole laboratory experimental setup, where all the experiment and measurements of diamagnetic ferrite was carried out inside the laboratory at normal room temperature of 25ºC to 30ºC

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2.1 Experimental analysis

Moreover, the samples show variation in properties due to their having different sintering temperatures. With the increase of applied step by step inhomogeneous magnetic field all the measurements of the parameters have been taken into considerations. The properties like intrinsic magnetic field strength, resistivities, dielectric constant, levitation effect, magnetic displacement due to opposition force and independent nature to rise in temperature for each type of ferrite compositions have been studied and measured with the help of torroid shaped ferrite pieces. In the next phase circular slabs with central hole are also fabricated, both its surfaces are coated with conducting material and the coated slabs represent the capacitor configurations of the diamagnetic ferrites [3] having their usefulness as magnetic super conducting material at normal room temperature in an applied inhomogeneous magnetic field. The torroid and the circular disc with a central hole developed ferrite samples have been considered along with the values of different parameters like magnetic induction (intrinsic magnetic field), resistivities, dielectric constant, levitation effect, magnetic displacement due to opposition force and independent nature to rise in temperature.

The measured properties for both the composite mixture compositions which are chronologically tabulated in Tables I and Table II respectively. In this regard the values of different parameters as shown in Table I and Table II have been considered and their graphical presentations are shown in the Fig.3, Fig.4, Fig.5, Fig.6, Fig. 7, and also in Fig.8, Fig.9, Fig.10 and Fig.11 respectively. Thus the measured values appeared to be different as and when are compared with each other. However, the measured values as shown in Table I and the graphical presentations as shown in Fig.3, Fig.4, Fig.5, Fig.6, Fig.7 very well establish the suitability of using powdered oxides materials having the composite mixture composition like as (1) Fe-Ti-Mn-Cr-Y-Bi-O for fabricating diamagnetic ferrite, which is found to be very much satisfactory and establishing that, this diamagnetic ferrite behaves as Soft Type I and Hard Type II magnetic superconducting material at normal room temperature. This Graphical presentation as shown in Fig.4 depicts the behavior of the diamagnetic ferrite as Soft Type I and Hard Type II magnetic superconducting material at normal room temperature with variation of critical magnetic fields along with levitation effects, saturation effects and demagnetizing effects with the repetitions and exhibiting an oscillations during excitations.

Table -1: (Results of the 1st composite mixture composition Fe-Ti-Mn-Cr-Y-Bi-O)

Current in Amps.	Intrinsic mag. Field (B) Within the ferrite material in Gauss	Applied inhon geneous mag. field H in Tesla	Resistivity ρ in Ohm-cm	Opposition Force $\times 10^{-8}$ in dyne	Susceptibility χ	Nature of the Diamagnetic ferrite
1 Ampere	B ≠ 0 but Nearer to 6	0 to 0.23864	Nearer to 0 But ≠ 0 but it is 400 Ohm-cm	Opposition Force 0, no levitation effect	Susceptibility X= – 0.01	Superconducting in nature but levitation starts
2 Ampere	13	0. 47728	360	- 3255	– 0.02	Levitation

3 Ampere	12	0. 71592	248	- 6535.6	– 0.03	Levitation
4 Ampere	10	0. 95456	216	-6810	– 0.04	Low levitation
5 Ampere	16	1. 1932	118	-8882.6	– 0.05	More Levitation
6 Ampere	23	1. 43184	102	-9765 .15	– 0.06	Levitation effect Ceases
7 Ampere	9	1. 67048	67	- 12949.7	– 0.07	Demagnetiza Effect begins
8 Ampere	23	1. 90912	32	-18436.4	– 0.08	More demagne tization

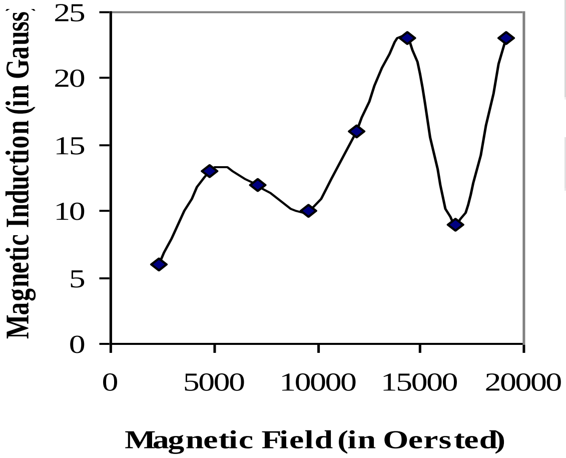

Fig.3 Magnetic Induction in Gauss Vs. Inhomogeneous magnetic field in Oersted [From HC1 to HC as Soft type I] [From HC to HC2 as Hard Type II] showing superconducting property of the material

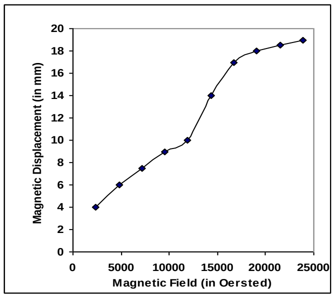

Fig.4 Magnetic displacement in mmVs Inhomogeneous magnetic field in Oersted

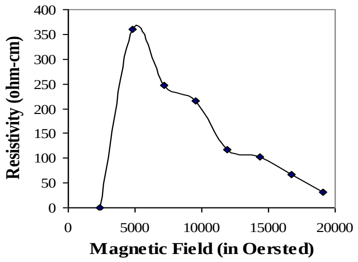

Fig.5 Resistivity in Ohm-cm Vs. Inhomogeneous magnetic field in Oersted

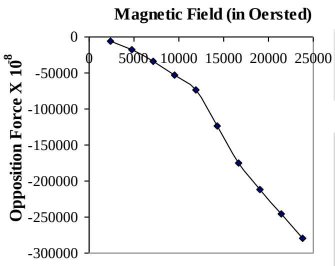

Fig.6 Magnetic displacement Vs. Inhomogeneous magnetic field in Oersted

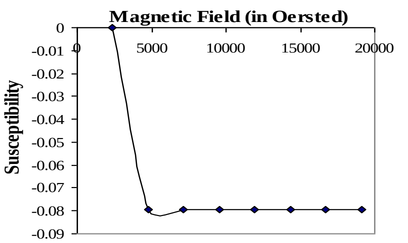

Fig.7 Susceptibility Vs. Inhomogeneous magnetic field in Oersted

Table -2: Composite mixture composition of (2) $Fe_{1.737}Cr_{0.58}Ti_{0.68}Mn_{0.64}V_{0.26}Y_{0.14}Bi_{0.054}O_4$

Current in Amps.	Intrinsic magnetic.field within the ferr in Gauss	Applied Inhomogeneous magnetic.field H in Oersted	Resistivity ρ in Meg. ohm-cm	Opposition Force x10 $^{-8}$ in dyne	Susceptibility χ	Nature of the diamagnetic ferrite
1 Ampere	$B \neq 0$	2386. 4	Very nearer to zero but $\neq 0$	-528.44	Susceptibility $\chi \neq 0$	Super conducting in nature but levitation starts

2 Ampere	5	4772.8	0. 36	–2642 .2	- 0.07941	Levitation begins
3 Ampere	8	7159. 2	0. 33	– 6341.33	-0.07942	Levitation continues
4 Ampere	6	9545. 6	0. 28	– 12682.66	-0.07943	Levitation continues
5 Ampere	16	11932	0. 23	– 15949.7	-0.07944	More Levitation
6 Ampere	22	14318. 4	0.16	– 19816.66	-0.07945	Levitation effect Ceases
7 Ampere	24	16704. 8	0. 15	– 23365.33	-0.07946	Demagnetiza Effect begins
8 Ampere	32	19091.2	0.24	– 33291.99	-0.07947	More demagnetization
9 Ampere	56	21477.6	0. 2	– 42275.55	– 0.07948	More demagnetization
10 Ampere	21	23864	0.31	– 49938	– 0. 07949	More demagnetization

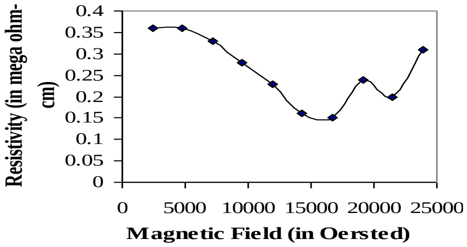

Fig. 8 Resistivity in Meg. Ohm-cm Vs Inhomogeneous magnetic field in Oersted

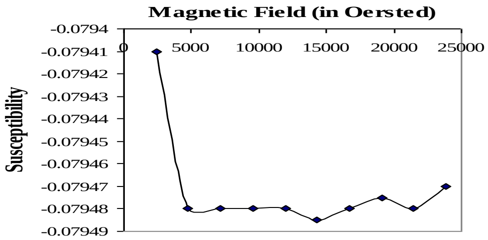

Fig. 9 Susceptibility Vs Inhomogeneous magnetic field in Oersted

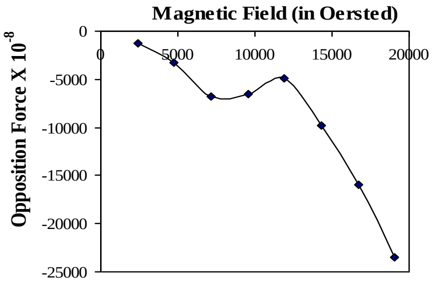

Fig.10 Opposition force in dyne Vs. Inhomogeneous magnetic field in Oersted

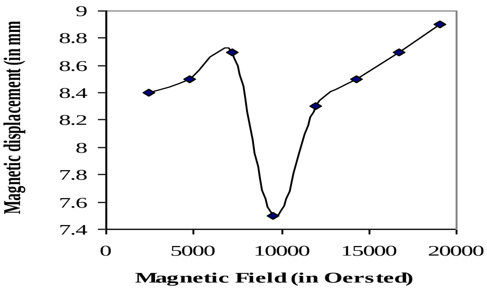

Fig.11 Magnetic displacement in mmVs. Inhomogeneous magnetic field in Oersted

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However, the values of the parameters as shown in Table II and their graphical presentations as shown in the Fig.8, Fig.9, Fig.10 and Fig.11 as and when are studied, which are not found to be compatible as Soft Type I and Hard Type II magnetic superconducting material at normal room temperature within the range of 25ºC to 30ºC. Moreover, as and when compared with the measured values as shown in Table I and their graphical presentations as shown in the Fig.4, Fig.5, Fig.6, and Fig. 7 exhibiting the difference between the values of the Table I and Table II respectively.

2.2 Discussions

The diamagnetic ferrites which have been developed on a laboratory scale as shown in Fig.1 and Fig.2 are satisfying all the properties of diamagnetic ferrite which behave as Soft type I and Hard type II magnetic super conducting material at normal room temperature with repetitions of the same as shown in Fig.4 and also in Fig.13 respectively when tested in an inhomogeneous magnetic field. Further investigation and research work is necessary for bringing the two critical magnetic fields H_{C1}, H_C and H_{C2} very close to each other, so as to show zero magnetic induction with the increase of inhomogeneous magnetic fields beyond 3 Tesla. There is no such material, which can give zero magnetic induction along with zero resistivity at normal room temperature. However, up till now whatever the developmental work on Soft Type I and Hard Type II super conducting materials has been developed under cold atmosphere specially known as High T_C superconductor. Moreover, when the D.C voltage and current is charged on these capacitor type configurations diamagnetic ferrites, are found to retain the electrical power within the ferrites for more than a month long and afterwards decays gradually. Further investigations are necessary to explore such diamagnetic ferrite that can give the property of complete super conducting material at normal room temperature with zero resistivity and zero magnetic induction with infinite conductivity.

3. Underlying proposed hypothesis of diamagnetism

The diamagnetism in a ferrite material develops due to the orbital motion of the free valance paired electrons in the outer most unfilled shell or sub-shell and thereby the angular momentum of the quantum numbers of those free valance orbiting electrons and their acquiring kinetic energies either accelerates or decelerates in an inhomogeneous magnetic field while the spin motion of electrons having equal and opposite energies cancelling each other, which ultimately produces a feeble orbital magnetic moment that effectively causes a repulsive action with the function of the magnetic shielding in the outermost periphery and does not allow the magnetic lines of forces to penetrate the material resulting the loss or gain in weight in the form of opposition force with levitation effect in the upward x-direction, with magnetic displacement as dH/dx showing negative susceptibility within the material in different applied magnetic field strength and moreover the diamagnetic ferrites are found to be independent to rise in temperature. The opposition force developed within the ferrite substrates due to the applied external inhomogeneous magnetic field H could be noted as, $-F = V \chi \mu_0 H\, dH/dx$, where V is the volume of the ferrite sample, μ_0 is the permeability of free space, χ is the susceptibility which has been developed on the ferrite sample, H is the applied inhomogeneous magnetic field strength. The levitation effect occurs when the applied magnetic field H is equal to the intrinsic magnetic field strength –M within the ferrite material, can be noted as $H= -M$. Resistivity is measured by a Four Probe Resistivity Tester. The susceptibility is measured in a conventional way likewise the density and dielectric constant.

4. CONCLUSIONS

Thus to utilize the composite mixture composition (2) Fe-Cr-Ti-Mn-V-Y-Bi-O for the fabrication of a diamagnetic ferrite, which will be compatible to the composite mixture composition of (1) Fe-Ti-Mn-Cr-Y-Bi-O, doping is found to be necessary. Here, doping has been made with the consideration of some suitable transitional and nontransitional powdered oxide elements in small percentage proportions of 0.02 to 0.08 % which are variable, towards the need based, wherever it would be necessary especially in the main ferrite compositions. Thereby due to doping, the main composite mixture composition has been changed to a modified composite mixture composition Fe-Cr-Ti-Mn-V-Y Bi-O, which has also brought a change in its chemical formula as $Fe_{1.737}Cr_{0.5}\ Ti_{0.590.9}Mn_{0.48}V_{0.2173}\ Y_{0.29}\ Bi_{0.168}O_4$ and later considered for the development of more ferrites on a laboratory scale. Numbers of diamagnetic ferrites have been developed followed by ceramic type powdered metallurgical blending, compaction and sintering technique at a high temperature of 1400ºC on a laboratory scale and later cooled in an inert atmosphere of helium. Subsequently the developed ferrites are further studied and characterized in an increasing step by step inhomogeneous magnetic field at normal room temperature in the experimental setup.

6. REFERENCES

[1]. W. Meissner and R. Ochsenfeld, Nature wissencnschaften, Vol.No.21, P787, 1933.
[2]. Proceedings, Royal Society (London), A149, 72, 1935 and Physics 2, 341, 1935.
[3]. I. Wolff & N. Knoppik, "Rectangular and Circular microstrip disc capacitors and resonators", IEEETransaction, MTT, Vol MTT- 22, No. 10, October 1974.
[4]. T.S. Christian and E.J. Millgan Super Conduction components techonology, Vol. 22, Maech, 1962.