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Review Article

Review on the importance of material synthesis of nicuzn-mgcuzn ferrite materials for various applications.

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Abstract:

Because of the rapid development of technology newly improved techniques are replacing the older ones. Miniaturization of electronic components have great demand since last few decades. Due to their high electrical resitivities and for other efficient properties, ferrites have attracted the potential researchers due to their versatile applications in various fields, especially in the field of electronic industrial applications, also production of ferrites will increase as their applications become more diverse. Ferrites are used in the fabrication of multilayer chip inductors (MLCIs) as surface mounting devices for micro miniaturization of various electronics devices. Recently, surface mounting devices have been rapidly developed for micro-indcutor applications,which have great demand in electronic applications. Dominant materials for MLCIs are soft ferrites materials. This brief review outlines the work being carried out on the various synthesis of NiCuzn-MgCuzn ferrites materials for their various applications.

Keywords: multilayer chip inductors; miniaturization of components; ferrite materials; electrical and magnetic properties; surface mounting devices etc.

1. Introduction:

Research area plays major role to develop the new activities in science and technology. The concept of miniaturization was developed originally by a word called surface mounting. Originally surface mounting was called as "planar mounting". "Surface-mount" refers to a methodology of manufacturing, which distinguishes the components, technique, and machines used in manufacturing and different terminology will be used, when it is referring to the different aspect of the methods. In 1960s, surface-mount technology was developed and became widely used in the 1980s, as a trend in the industry. it has largely replaced a traditional through-hole technique construction method of fitting of the components with the leads into the holes in the circuit board, with the surface mounted technology (SMT) using surface mounted devices (SMD). Surface-mount technology (SMT) is a method for producing electronic circuits in which the components are mounted (or) assembled (or) placed directly onto the surface of printed circuit boards (PCBs). The SMT technique opens advantages and new applications through miniaturizing of the components and increasing of reliability. Both technologies can be used on the same board for components not suited to surface mounting such as large transformers and heatsinked power semiconductors.

1.1 Importance of miniaturization:

Miniaturization is important because improved chip packaging led to creating newest markets by enabling new applications. Personal communications is a developing major consumer market created by mimiaturization. Higher speed, lower cost and greater density are the inherent advantages of miniaturization. It also reduces the cost of electronics by packing more functionality into a smaller or same sized device.

1.2. Miniaturization process of SMDs:

The SMD is not a “new technique”, it is only a miniaturisation of the components. But this component requires a different processing technology. It is an electronic device, so made is called a surface-mount device (SMD). SMDs which means a trend to continue many new components available such as active, passive, electronic components (or) electromechanical components without conventional connecting wires as shown in Fig.1. Most of the SMD components available during 1998 ends with pin-outs, SMD/classic and classic/SMD.

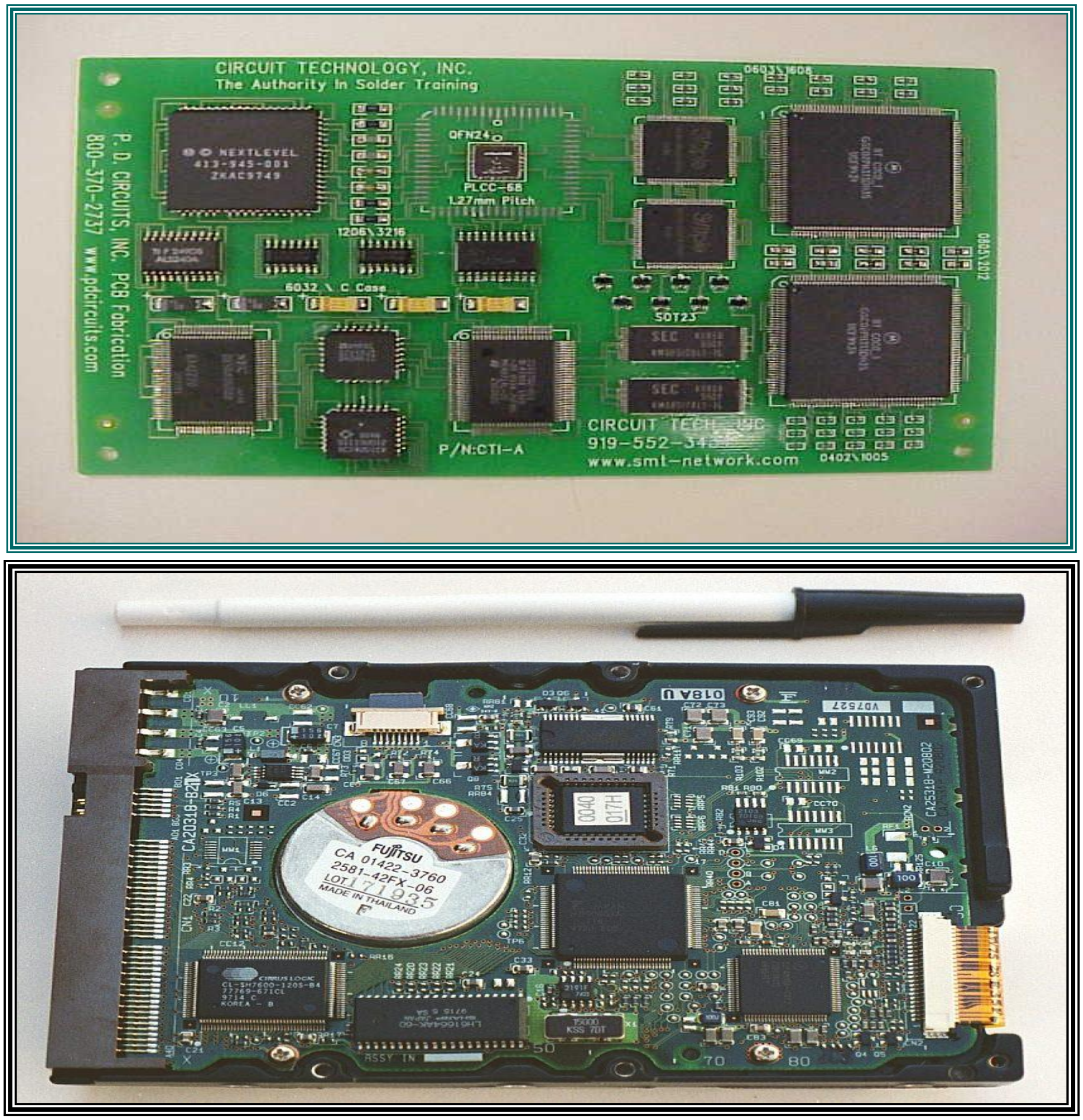

Fig. 1. Surface Mounting Devices (SMD).

The tendency to miniaturize electronic components began in the 1990s. Rapid progress also occurred in surface-mounting technology, and attempts have been made to accomplish high density, by incorporating ferrite inductors into a printed circuit board. A ferrite inductor is made up of ferri magnetic material or ferro magnetic material known as "magnetic core" consisting mainly powdered iron, which posses high permeability and and high electrical resistivities which are useful for transformers, recording heads, inductors and generators etc., This has, as a result, allowed development of various types of multilayer ferrite chip inductors [1]. Mostly ferrite magnebtic materials are used in radios for tunning a inductor. Coil has to wound around the ferrite core so that inductance can be adjusted through the coil when coil changes the flux. Generally, this has a length of 10 mm and a width of 0.5 mm, to be used in television receivers, video equipment, headphone stereos, hard disk device systems, personal computers, cordless telephones, automobiles parts etc. Multilayer ferrite chip inductors are manufactured using the thick film printing method, and the latest chip inductors are successfully constructed as a single monolithic structure that combines the inductor with other passive elements such as capacitors and resistors.

An improved multilayer chip inductor comprises a plurality of sheets which are multilayered, which means is composed of an upper cover and a lower cover sheet and several sheets multilatyered between them; these sheets can be selected as magnetic or non-magnetic material according to design requirements. By making them multilayered and using low-temperature co-fired ceramic (LTCC) technology an unshielded area is left on the packaging surface to result in open magnetic force such that current carrying capability of the chip inductor can be improved. The main feature is that the internal layer of the sheet is made of magnetic material (or non-magnetic material) and non-magnetic material (or magnetic material) as shown in Fig.2.

Microminiaturization of electronic circuits especially in the fields of mobile communication and information technology demands the fabrication of electronic devices of very small size [2]. Recently, the surface mounting technology demands the electronic components in a miniature form and surface mounting devices (SMD) have been rapidly developing for various electronic applications such as micro-inductor applications. Chip inductors are one of the passive surface mounting devices (SMD). They are important components for the latest electronic products such as cellular phones, video cameras, notebook computers, wireless communications, laptop computers, hard and floppy drives etc., which need to have qualities of small dimensions, light weight and better functions [3-4]. To satisfy these demands few ferrites materials are best suited for these applications as Surface Mounting Device (SMD).

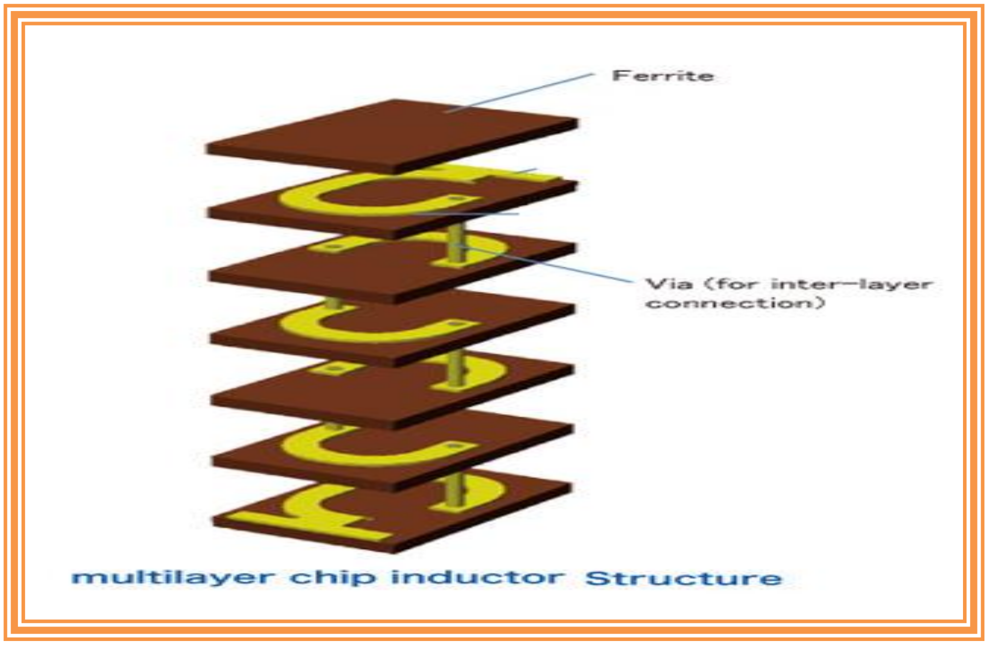

Fig. 2. Multilayer Chip inductor.

There are two types of SMDs, viz., multilayer chip inductors (MLCIs) [5-7] and wire wound chip inductors [7]. The traditional wire wound chip inductors can only be miniaturized to a certain limit and lack of magnetic shielding leads to the development of new materials for the multilayer chip inductors. In this direction, only a few ferrites and ferrite composites were developed as the core material used in the chip inductors [4-5] which was found that these ferrites developed by [4-5] are comparatively sensitive to stress and possess good electro magnetic properties.

1.3. Wire wound inductors:

Dram type inductors are wire wound and moulded to a resin to withstand against moisture and mechanical shocks. During hardening, the resin shrinks and applies compressive stress to the core material, which influences the core material substantially. The shrinkage of resin produces very high stress on the core and as a consequence, the inductance decreases [8-9]. This decrease in inductance results in much lower values of the moulded inductor and thus poses a problem in mass production. The initial permeability of ferrite is a very sensitive property to the external stress.

The present chip inductor features make the miniaturization process very easy. The flux is entirely free from leakage because the coil is shielded with the ferrite material. Hence it is expected that the demand for the chip inductors will increase in future.

Silver is generally used as the material for the internal electrode of the multilayer chip inductors due to its low resistivity, resulting in the components with high-quality factor (Q) [10]. In addition to this, Ag paste is commercially available at lower cost than Ag-Pd paste. Since the melting point of silver is 961ºC, the sintering temperature of ferrite which is used for the manufacture of chip inductor should be below 950 ºC. This is because of the need to prevent Ag diffusion into the ferrite that would increase the resistivity of the internal conductor. Further, the segregation of Cu^{2+} from the ferrite induced by the diffused Ag can be avoided and thus no deterioration in magnetic properties of the material. In order to overcome these problems, MgCuZn ferrites were found to be suitable [11-13]. Normally, MgCuZn ferrites were sintered at temperatures higher than 1100 ºC [11-12, 14]. In order to use these ferrites in multilayer chip components, the sintering temperature must not be more than the melting point of silver.

With the rapid development and advancement of mobile communication and information technology, the electronic components with small size, high efficiency, and low cost are urgently needed [15]. Multilayer chip inductors (MLCIs) as a key component of electronic devices confront new challenges. Better magnetic properties, especially high initial permeability are required for reducing the number layers of multilayer chip inductors. At present NiCuZn ferrites have been used extensively for the production of the MLCI [16] but they are highly stress sensitive.

1.4. Suitable ferrite materials

In search of suitable ferrite materials for microinductor applications, a review has been made, in the present work, hence the author has under taken this review and outlines the work being carried out, these studies revealed the development of new materials for the multilayer chip inductors by concluding that these ferrites possess good electromagnetic properties, can be exploited as core material for microinductor applications and DC-DC transformer core applications.

2. Resume of important investigations on the soft ferrite:

2.1. Materials for microinductor applications:

The summary of research work carried out by various researchers for microindcutors applications is represented in Table. 1. Penchal Reddy et.al. [17] carried out the work on structural, electrical and magnetic characterization of NiCuZn spinel ferrites with chemical formulae $Ni_{0.35}Cu_{0.05}Zn_{0.60}Fe_{1.98}O_{4-\delta}$ prepared by microwave sintering (MS) method, and the results were compared with the properties of materials prepared by conventional double sintering method (CS). The essential difference in the microwave and conventional sintering process is in the heating mechanism. Varalaxmi and Sivakumar reported [18] a comparative study on structural, magnetic, electric properties and stress sensitivity of the $Ni_{0.175}Mg_{0.125}Cu_{0.15}Zn_{0.55}Fe_2O_4$ with equimolar nano composite ferrite $0.5((Ni_{0.35}Cu_{0.05}Zn_{0.6}Fe_2O_4)+(Mg_{0.25}Cu_{0.25}Zn_{0.5}Fe_2O_4))$ prepared by conventional double sintering technique, with a view to develop a ferrite composition for its use as core material for microinductor applications.

Penchal Reddy et.al. [19] investigated microwave sintering of nickel ferrites nanoparticles processed via sol-gel method. Low-temperature synthesis of iron deficient Ni-Cu-Zn ferrites for multilayer chip inductors using the microwave sintering technique studies was carried out by Penchal Reddy et.al. [20]. Influence of copper substitution on magnetic and electrical properties of MgCuZn ferrite with chemical formulae $Mg_{0.50-x}Cu_xZn_{0.50}Fe_2O_4$ prepared by microwave sintering method were investigated by Penchal Reddy et.al. [21]. Microwave sintering of high-permeability MgCuZn ferrite at low sintering temperatures suitable for microinductor applications with the composition $Mg_{0.40}Cu_{0.10}Zn_{0.50}Fe_{1.95}O_{4-\delta}$ was prepared by microwave sintering and conventional sintering techniques by Penchal Reddy et.al., [22].

Nanocrystalline magnesium-copper-zinc ($Mg_{0.30}Cu_{0.20}Zn_{0.50}Fe_2O_4$) ferrites were prepared by microwave sintering technique and effects of sintering temperature on structural and electromagnetic properties were investigated by [23]. Penchal Reddy et al. [24] carried out the studies on the possibility of NiCuZn ferrites composition for stress sensor applications with generic formulae ($Ni_{0.42+x}Cu_{0.10}Zn_{0.60}Fe_{1.76-2x}O_{3.76-2x}$), and initial permeability measurements on these samples were carried out in the temperature range of 30 to 300°C. Madhuri et.al.[25] investigated a series of non-stoichiometric MgCuZn ferrites ($Mg_{0.5-x}Cu_xZn_{0.5}Fe_{1.9}O_{4-\delta}$) and compared the initial permeability of MgCuZn ferrites sintered by both conventional and microwave methods. Praveena et.al [26] carried out studies on structural, magnetic and electrical properties of Cr^{3+}-doped Sr Hexaferrites, which were prepared by a microwave-hydrothermal method with generic formulae $SrCr_xFe_{12-x}O_{19}$ and sintered at 950°C for 90 min.

Penchal Reddy et.al. [27] successfully synthesized cobalt substituted manganese nanocrystalline spinel ferrites having general formula $Co_xMn_{1-x}Fe_2O_4$ ($0 \leq x \leq 1{:}0$) using the hydrothermal method. Effects of sintering temperature on the structural and magnetic properties of $Mn_{0.50}Zn_{0.50}Cr_{0.4}Fe_{1.6}O_4$ which were synthesized by combustion method and sintered at various temperatures (1250, 1300 and 1350°C) has been discussed by Alam et.al. [28].

Table.1: Preparation methods, study carried out by various researchers and conclusion/observations/Applications of soft ferrites

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/ Applications
1.	Penchal Reddy et.al.	[17]	Microwave sintered (MS) method and compared with the conventional double sintering method (CS).	Structural electrical and magnetic characterization of NiCuZn spinel ferrites	The MS material has excellent microstructure and good electromagnetic properties for application in MLCI. With this MS Sintering temperature and soaking the time and temperature can be reduced from 5h to 1250°C to 30 min, 950°C, also the processing efficiency can also be improved significantly. The MS process is an important processing technique to explore these materials in MLCI technology. Also, they are suitable in microwave applications and electromagnetic devices
2.	Varalaxmi et.al.	[18]	Conventional double sintering technique	Comparative Studies of NiMgCuZn composite ferrites with Equimolar (NiCuZn+MgCuZn) Nanocomposite ferrite useful for microinductors applications	Initial permeability of $Ni_{0.175}Mg_{0.125}Cu_{0.15}Zn_{0.55}Fe_2O_4$ sample is drastically reduced when compared to equimolar composite ferrite. Low temperature sintered $Ni_{0.175}Mg_{0.125}Cu_{0.15}Zn_{0.55}Fe_2O_4$ samples also possess good electromagnetic behaviour, as well as fine - grained microstructures, making them suitable materials for MLCIs having high performance and low cost.
3.	Penchal Reddy et.al.	[19]	Sol-gel method	Microwave sintering of nickel ferrites nanoparticles	Method is expected to be useful for large scale synthesis of $NiFe_2O_4$ nanoparticles for the application as magnetic recording.
4.	Penchal Reddy et.al.	[20]	Microwave sintering technique	Microwave sintering of iron deficient Ni-Cu-Zn ferrites for multilayer chip inductors	Present ferrites are well suited as candidates for multilayer chip inductors due to its low temperature sintering for synthesis of good magnetic properties and low loss at high frequencies.
5.	Penchal Reddy et.al.	[21]	Microwave sintering technique	Influence of copper substitution on magnetic and electrical properties of MgCuZn ferrite	Composition$Mg_{0.30}Cu_{0.20}Zn_{0.50}Fe_2O_4$ showed that the best electromagnetic properties among all the compositions and would be a suitable material for MLCI applications

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S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/ Applications
6.	Penchal Reddy et.al.	[22]	Microwave sintering technique & conventional sintering (CS) techniques.	Microwave sintering of high-permeability MgCuZn ferrite at low sintering temperatures suitable for microinductor Applications	Initial permeability of MgCuZn ferrites prepared by the MS method was higher than that of MgCuZn ferrites prepared by the CS method. Microwave-synthesized MgCuZn ferrite can be used as the core magnetic material for MLCIs.
7.	Penchal Reddy et.al.	[23]	Microwave sintering technique	Effects of sintering temperature on structural and electromagnetic properties of MgCuZn ferrite prepared by microwave sintering	Electrical and magnetic properties of microwave sintered $Mg_{0.30}Cu_{0.20}Zn_{0.50}Fe_2O_4$ ferrite extremely suitable for LTCC multilayer substrates and microwave applications. Therefore, the MS process is a potentially important technique to fabricate chip components for LTCC technology.
8.	Penchal Reddy et.al.	[24]	Conventional ceramic double sintering technique.	Possibility of NiCuZn Ferrites Composition for Stress Sensor Applications	Compositions $Ni_{0.42}Cu_{0.10}Zn_{0.60}Fe_{1.76}O_{3.76}$ and $Ni_{0.44}Cu_{0.10}Zn_{0.60}Fe_{1.72}O_{3.72}$ showed best magnetic properties among the five compositions which are choosen for different values of 'x' these would be prominent materials for inductive stress sensor applications.
9.	Madhuri et.al.	[25]	Both conventional and microwave methods	Comparison of initial permeability of MgCuZn ferrites sintered by both conventional and microwave methods	Initial permeability magnitudes of conventionally sintered samples are higher than those of the microwave sintered samples. The MgCuZn ferrite samples obtained conventionally exhibit magnetic permeabilities comparable to those of NiCuZn ferrites and hence can be used for MLCI material and high definition television deflection yoke materials.
10.	Praveena et.al	[26]	Microwave-hydrothermal method	Structural,Magnetic& Electrical Properties of MicrowaveSintered Cr^{3+}-Doped Sr Hexaferrites	Observation suggests that the presented samples are suitable for application in microwave devices

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
15.	Varalaxmi and Sivakumar	[32]	Conventional double sintering method	Initial permeability & Stress sensitivity	Equimolar mixture of the ferrite composites showed high initial permeability (μ_i) of the order of 9619. It may be pointed out that this composition is fairly stress independent also. Not only equimolar composition, even the $Mg_{0.25}Cu_{0.25}Zn_{0.5}Fe_2O_4$ also showed stress insensitivity which are useful for microindcutor applications
16.	Batoo and Ansari	[33]	Auto-combustion method	Low temperature-fired Ni-Cu-Zn ferrite nanoparticles through auto-combustion method for multilayer chip inductor applications	----------
17.	Zahi et.al	[34]	sol–gel technique	Synthesis, magnetic properties and microstructure of Ni–Zn ferrite by sol–gel technique	Sol–gel route yielded finer particles; Temperatures and time of preparation were reduced as compared to the conventional process which led to some advantages such as saving energy,
18.	Dimiri et.al	[35]	Citrate precursor method	Structural, dielectric and magnetic properties of NiCuZn ferrite grown by citrate precursor method	Measured values of present method are higher than that reported for ferrites prepared by the conventional ceramic method. NiCuZn ferrites with enhanced properties at low processing temperatures, suitable for multiplayer chip inductors operable in the RF frequency region.
19.	Kaczkowsi	[36]		Stress sensitivity in Ni-Mn, Ni-Mn-Co and Ni-Mn-Co-Cu ferrites	Observed greatest stress sensitivity for ferrites with the smallest magneto crystalline anisotrophy containing maximum of cobalt ions

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
20	Szewczyk and Bie´nkowski	[37]	--------	Stress dependence of sensitivity of fluxgate sensor	Co-rich alloys seem to be useful as the cores for stress-resistant fluxgate sensors.
21	Bie´nkowski and Szewczyk	[38]	------	The possibility of utilizing the high permeability magnetic materials in construction of magnetoelastic stress and force sensors	Output frequency signal from the sensor operating in this configuration is suitable for further digital processing.
22.	Yan and Hu	[39]	Microwave sintering and conventional sintering technique	Microwave sintering of high-permeability $(Ni_{0.20}Zn_{0.60}Cu_{0.20})Fe_{1.98}O_4$ ferrite at low sintering temperatures	Microwave sintering technique has much shorter sintering time compared with conventional sintering technique. Microwave sintering is a very promising technique for the preparation of high-permeability NiZn ferrites.
23.	Nakamura et.al	[40]	Ceramic Method	Complex impedance spectra of chip inductor using Li-Zn-Cu-Mn ferrite	Li–Zn–Cu–Mn ferrite was a potential candidate for MCI application,
24.	Zhang et.al	[41]	------	Electromagnetic simulation and experiments were carried out for discussing the miniaturization of the sensor node.	Energy scavenging was possible with a high-performance micro inductor and the simulation indicated that microfabrication process is necessary for achieving Large number of turns in a limited volume in order to develop a micro inductor for realizing either current sensing or power generation.
25.	Roy and Bera	[42]	Auto combustion method	Effect of Mg substitution on electromagnetic properties of $(Ni_{0.25}Cu_{0.20}Zn_{0.55})Fe_2O_4$ Ferrite prepared y auto combustion method	$(Ni_{0.07}Mg_{0.18}Cu_{0.2}Zn_{0.55})Fe_2O_4$ composition would be a better material than Ni-Cu-Zn based composition for reducing the number of layers in MLCI and realizing more miniaturization.

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
26.	Madhuri et.al	[43]	Microwave sintering Technique	Transport properties of microwave sintered pure and glass added MgCuZn ferrites	Due to their lower conductivities and sintering temperatures. The 1 wt% PBS glass added samples are suitable for multilayer chip inductor (MLCI) and high definition TV deflection yoke material applications.
27.	Penchal Reddy et.al	[44]	conventional mixed oxide method	Effect of sintering temperature on structural and magnetic properties of NiCuZn and MgCuZn ferrites	Microwave sintered MgCuZn ferrite sample sintered at 900 ^{0}C for 30 min has higher initial permeability with better sintered density and a similar microstructure as that of NiCuZn ferrite, which can be a competent ferrite material for low-temperatureco-fired ceramic technique (LTCC) of multilayer chip inductor fabrication
28.	Penchal Reddy et.al	[45]	Microwave sintering Method	Structural electrical and Magnetic characterization of Ni-Cu-Zn spinel ferrites.	Microwave sintering improves structural as well as electromagnetic parameters measured and thus makes the ferrite more suitable in microwave applications and electromagnetic devices.
29.	Penchal Reddy et.al	[46]	Novel microwave sintering method	Structural, magnetic and electrical properties of NiCuZn ferrites prepared by microwave sintering method suitable for MLCI applications	Composition$Ni_{0.30}Cu_{0.05}Zn_{0.65}Fe_2O_4$ showed the best electromagnetic properties among all specimens studied in the present work and would be a better material for MLCI applications.
30.	Penchal Reddy et.al	[47]	Conventional ceramic double sintering technique.	Possibility of NiCuZn ferrites composition for Stress sensor applications	$Ni_{0.42}Cu_{0.10}Zn_{0.60}Fe_{1.76}O_{3.76}$ and $Ni_{0.44}Cu_{0.10}Zn_{0.60}Fe_{1.72}O_{3.72}$ samples are found to be suitable for inductive stress sensor applications.
31.	Penchal Reddy et.al	[48]	Microwave sintering technique	Microwave sintering of iron deficient NieCueZn ferrites for multilayer chip inductors	Due to its low temperature sinterability,with good electrical- magnetic properties and low loss at high frequency, the present ferrites are well suitable for the application in multilayer chip inductors.

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
32.	Penchal Reddy et.al	[49]	Microwave sintering technique	Microwave sintering of high-permeability MgCuZn ferrite at low sintering temperatures suitable for micro inductor applications	Initial permeability of MgCuZn ferrites prepared by the MS method was higher than that of MgCuZn ferrites prepared by the CS method. The low-temperature-sintered MgCuZn ferrites prepared possess good electromagnetic properties, as well as good microstructure, thus making them suitable materials for multilayer chip inductors (MLCIs) having high performance and low cost
33.	Bera and Roy	[50]	Conventional ceramic powder processing technique	Effect of grain size on electromagnetic properties of $Ni_{0.7}Zn_{0.3}Fe_2O_4$ ferrite	The ferrite with 1250ºC/60 min firing was best for high-frequency low-loss application. The resistivity of the ferrite is highly dependent on grain size upto5 mm.
34.	Roy et.al.	[51]	Nitrate-citrate auto-combustion method.	Study on electro-magnetic properties of La substituted Ni-Cu-Zn ferrite synthesized by auto-combustion method	The composition $(Ni_{0.25}Cu_{0.20}Zn_{0.55})La_{0.025}Fe_{1.975}O_4$ would be a better material for reducing the number of layers in MLCI and realizing more miniaturization.
35.	Roy and Bera	[52]	Nitrate-citrate auto-combustion route.	Enhancement of the magnetic properties of Ni-Cu-Zn ferrites with the substitution of small fraction lanthanum for iron.	The La solubility in the Ni–Cu–Zn ferrite lattice was found very low (0.1 atom/unit cell).
36.	Roy and Bera	[53]	Solgel auto-combustion method"	Characterization of nanocrystalline Ni-Cu-Zn ferrite powders synthesized by solgel auto-combustion method	The composition $Ni_{0.8}Cu_{0.2}Zn_{0.6}Fe_2O_4$ shows highest permeability, magnetization and lower loss factor among all the compositions studied here. The composition is highly suitable for application up to 4MHz frequency. Considering all the advantages, especially sinterability below 960ºC, the composition may be suggested as a better material for MLCI applications.

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
37.	Roy and Bera	[53]	nitrate–citrate auto-combustion method"	Electromagnetic properties of samarium substituted Ni-Cu-Zn ferrite prepared by auto combustion method	The composition $Ni_{0.25}Cu_{0.2}Zn_{0.55}Sm0.05\text{-}Fe_{1.95}O_4$ showed the best electromagnetic properties among all specimens and would be a better material for MLCI applications.
38.	Patil and Ladgoankar	[54]	Chemical method	To develop an embedded technology based smart sensor module for humidity measurement a sensor material	Deploying these materials the inter digited thick film sensors are fabricated and used to develop an embedded system for measurement of humidity.
39.	Awati et.al.	[55]	Auto-combustion method	Structural and magnetic properties of Cu^{2+} substituted $Ni_{0.8-x}Cu_xZn_{0.4}$ ferrites	These nanoferrites may have application in core materials and in electronic device technology.
40.	Varalaxmi and Sivakumar	[56]	Conventional ceramic double sintering process	High permeability and stress insensitivity of MgCuZn–NiCuZn ferrite composites for microinductor applications	Equimolar mixture of the ferrite composites showed high initial permeability (μ_i) of the order of 9,619. It may be pointed out that this composition is fairly stress independent also. The equimolar mixture of NiCuZn and MgCuZn ferrites may be used as core material for the fabrication of multilayer chip inductors (MLCI).
41.	Brasandon et.al.	[57]	low temperature deposition of thick,ceramic magnetic films is	Printed Microinductors on Flexible Substrates for Power Applications	Along with polymer thick film resistors and high dielectric capacitors, a wider range of RLC circuits can be fabricated on conventional flexible materials using this approach.

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
47.	Hu and Yan	[63]	conventional ceramic process	The preparation of high-permeability NiCuZn ferrite	Using the low temperature sintering method produced the novel NiZn ferrite having higher permeability together with much lower sintering temperature.
48.	Penchal reddy et.al.	[64]	Microwave sintering method	The low-temperature sintered NiZn and NiCuZn ferrites with the composition of $Ni_{0.40}Zn_{0.60}Fe_2O_4$ and $Ni_{0.35}Cu_{0.05}Zn_{0.60}Fe_2O_4$	Cu substitution in NiZn-ferrite enhances initial permeability and saturation magnetization
49.	Sutka and Mezinskis	[65]	Sol–gel auto-combustion method	Enhancing magnetic permeability, resonance frequency and mechanical properties	widening applications area of the products.
50.	Jacek Salach	[66]	----	unified methodology for testing tensile and compressive stress	It may be useful for construction of magnetoelastic compressive and tensile stress sensors.
51	Saita et.al.	[67]	Both microwave sintering and conventional sintering	Microwave sintering study of NiCuZn ferrite ceramics and devices	Property of the MLCI sintered under microwave processing was found to be comparacble to that for conventional processing, also observed that electrode (Ag) melted and diffused into ferrite material under microwave sintering.
52	Brito et.al	[68]	conventional ceramic method	Evaluation of a Ni-Zn ferrite for use in temperature sensors	Maximum temperature sensitivity of the ferrite may be adjusted by temperature range by appropriate selection of the fabrication parameters.

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
42.	Varalaxmi and Sivakumar	[58]	Conventional double sintering technique	Structural,Electromagnetic and Stress Sensitivity Studies of Ball Milled NiCuZn & MgCuZn FerritesSuitable for MicroindcutorApplications	The MgCuZn ferrite sample is exhibiting good electromagnetic properties comparable to those of NiCuZn ferrites Hence can be used as a core material for microinductor applications and high definition television deflection yoke materials.
43.	Varalaxmi and Sivakumar	[59]	Conventional double sintering process	Stress sensitivity of inductance in NiMgCuZn ferrites and development of a stress insensitive ferrite composition for microinductors.	It was observed that the addition of SiO_2 reduces the stress sensitivity in these ferrites. It was noticed that the addition of 0.05 wt% SiO_2 in sample $Ni_{0.3}Mg_{0.3}Cu_{0.1}Zn_{0.3}Fe_2O_4$ produces stress insensitivity.
44.	Ramamaohar reddy et.al	[60]	Conventional ceramic method	Stress insensitive NiCuZn ferrite compositions for microinductor applications	It is found that the addition of 0.5 wt% SiO_2 to $Ni_{0.35}Cu_{0.05}Zn_{0.65}Fe_2O_4$) and addition of 0.5-0.75 wt% of SiO_2 to $Ni_{0.36}Cu_{0.10}Zn_{0.60}Fe_{1.88}O_{3.88}$ produces stress insensitivity which are useful as microindcutor applications
45.	Varalaxmi and Sivakumar	[61]	Conventional double sintering technique	Structural, magnetic, DC–AC electrical conductivities and thermo electric studies ofMgCuZn Ferrites for microinductor applications	Thus low temperature sintered MgCuZn ferrite samples possess good electromagnetic properties, as well as fine-grained microstructures, making them suitable materials for MLCIs having high performance and low cost.
46.	Varalaxmi and Sivakumar	[62]	Conventional double sintering technique	Studies on structural and electrical properties of Ball-milled NiCuZn-MgCuZn nanocomposites ferrites were investigated by Varalaxmi and Sivakumar [62].	The DC electrical conductivity (σ_{DC}) reveals that the composite ferrite samples have conductivities varying from 10^{-7} to 10^{-10} ohm^{-1} cm^{-1}. This indicates that they are fairly resistive, which meets the requirement of MLCIs.

S.No	Author's Name	Ref.No	Preparation Method	Studies Carried out	Observations/ Conclusions/Applications
53	Kaczkowski	[69]	------	The stress sensitivity in Ni-Mn, Ni-Mn-Co and Ni-Mn-Co-Cu fer-rites	The high stress sensitivity was observed for the ferrites with the smallest magne-tocrystalline anisotropy
54	Nakano et al.	[7]	------	Development of low temperature fired NiCuZn ferrites and studied the high performance multilayer chip inductors	Controlling stress by the internal Ag-conductor and CuO1-x/Ag on ferrites grain boundary is most important key point for high performance multilayer chip ferrites as well as the chemical composition of ferrites
55	Nakanoet al.	[70]	------	Magnetic properties of MgCuZn ferrites under stress were investigated and compared with Ni-Cu-Zn ferrite under a compressive stress.	Observed that the change in permeability with stress of low temperature sintered MgCuZn ferrite was lower than that of low temperature sintered NiCuZn ferrite and the multilayer chip inductor using low temperature sintered MgCuZn ferrite would show a higher inductance than the chip using low temperature sintering NiCuZn ferrite.
56	Ikeda and Kumagi	[8]	------	Developments of stress-insensitive ferrite	Sensitivity of the magnetic property to the external stress in NiCuZn ferrite was examined from the relationship between stress and permeability
57	Murayamna et.al	[71]	------	High strength NiCuZn ferrites used for surface mounting devices	----

Sintering behavior, microstructure and electromagnetic properties of NiCuZn ferrites doped with B_2O_3 sintered in the temperature range of 850–950^{0}C were investigated by Shen et.al. [29]. The thermolysis of copper ferrimalonate $Cu_3[Fe(CH_2C_2O_4)_3]_2{\cdot}9H_2O$ has been investigated up to 1073 K in flowing air atmosphere employing various physicochemical techniques by Singh et.al [30] and concluded that the temperature of ferrite formation (623 K) is considerably lower than that of conventional ceramic method (>1273 K). Cobalt ferrite materials with different concentrations of manganese additions have been prepared by the conventional ceramic technique by [31]. Varalaxmi and Sivakumar [32] carried out the studies on the development of a stress insensitive MgCuZn-NiCuZn composite ferrite useful for microinductors applications and concluded that composite ferrites are useful for microinductor applications. Batoo and Ansari [33] have investigated ferrite nanoparticles of composition $Ni_{0.7-x}Zn_xCu_{0.3}Fe_2O_4$ ($0.0 \leq x \leq 0.2$, x = 0.05) which were synthesized through auto-combustion method. These studies were conducted for structural properties investigation. Zahi et.al. [34] carried out the studies on the Ni-Zn ferrite powder with generic formula $Ni_{0.3}Zn_{0.7}Fe_2O_4$ which was synthesized by the sol-gel route using metal acetates at low temperatures.

Dimiri et.al [35] studied powders of $Ni_{0.6-x}Cu_xZn_{0.4}Fe_2O_4$, within the range $0 \leq x \leq 0.4$, prepared by the citrate precursor method to investigate its structural, dielectric and magnetic properties. Kaczkowski [36] carried out the studies on stress sensitivity in Ni-Mn, Ni-Mn-Co and Ni-Mn-Co-Cu ferrites and observed greatest stress sensitivity for ferrites with the smallest magnetocrystalline anisotrophy containing a maximum of cobalt ions. Szewczyk and Bie´nkowski [37] presented their results of the investigation of the stress sensitivity of the fluxgate sensor with amorphous alloy $(CoFe)_{89}(MnMoSiB)_{11}$ (Vitrovac 6150F) ring core.

The possibility of utilizing the high permeability magnetic materials in the construction of magnetoelastic stress and force sensors studies were carried out by Szewczyk and Bie´nkowski [38]. Yan and Hu [39] carried out studies on $(Ni_{0.20}Zn_{0.60}Cu_{0.20})Fe_{1.98}O_4$ ferrite sintered using microwave sintering and conventional sintering technique and observed that microwave sintering technique has much shorter sintering time compared with conventional sintering technique. Nakamura et.al [40] investigated a multi-layer chip inductor (MLCI) which is prepared with the green-sheet technique, using polycrystalline Li-Zn-Cu-Mn ferrite. The complex impedance spectra were evaluated with the help of numerical calculations, and the experimentally obtained complex impedance spectra of the MCI component were quite well reproduced by the calculation in the case of Li-Zn-Cu-Mn ferrite but not in the case of Ni-Zn-Cu ferrite. The magneto-striction coefficient, and the magnetostriction effect was negligible in the MCI component using Li-Zn-Cu-Mn ferrite. Simulation and design of micro inductor for in wireless sensor network eletrcomagnetic energy scavenging at low-frequency studies were carried out by Zhang et.al [41]. Roy and Bera [42] carried out studies on effect of Mg substitution on electromagnetic properties of $(Ni_{0.25}Cu_{0.20}Zn_{0.55})Fe_2O_4$ ferrite synthesized through nitrate-citrate auto-combustion method.

Madhuri et.al., [43] studied stoichiometric and 1 wt% lead borosilicate (PBS) glass added MgCuZn ferrite with the general formula $Mg_{0.5}Cu_xZn_{0.5-x}Fe_2O_4$ synthesized by microwave sintering technique. Penchal Reddy et.al. [44] has carried out the studies on low temperature microwave sintered NiCuZn and MgCuZn ferrites with chemical composition $Ni_{0.35}Cu_{0.05}Zn_{0.60}Fe_2O_4$ and $Mg_{0.35}Cu_{0.05}Zn_{0.60}Fe_2O_4$, which were synthesized by conventional mixed oxide method.

Studies were carried out on $Ni_{0.35}Cu_{0.05}Zn_{0.60}Fe_{1.98}O_{4-\delta}$ ferrite prepared by microwave sintering (MS) method and compared with the conventional sintering method (CS) by Penchal Reddy et.al [45]. In order to study structural, magnetic and electrical properties suitable for MLCI applications polycrystalline NiCuZn soft ferrites with stoichiometric iron were prepared by a novel microwave sintering method [46]. Penchal Reddy et.al [47] investigated a NiCuZn ferrite with composition $(Ni_{0.42+xx}Cu_{0.10}Zn_{0.60}Fe_{1.76-2xx}O_{3.76-2xx})$ prepared by the conventional ceramic double sintering technique in order to study their possible applications as stress sensor.

Microwave sintering of iron deficient NiCuZn ferrites for multilayer chip inductors studies was 0carried out by [48]. Penchal Reddy et.al. [49] investigated $Mg_{0.40}Cu_{0.10}Zn_{0.50}Fe_{1.95}O_{4-\delta}$ ferrite samples prepared by the microwave sintering (MS) and conventional sintering (CS) techniques and concluded that MS method was higher than that of MgCuZn ferrites prepared by the CS method. The electromagnetic properties of polycrystalline $Ni_{0.7}Zn_{0.3}Fe_2O_4$ with varying grain size in the range 1–12 mm were investigated by Bera and Roy [50]. The grain size was varied by sintering the ferrite at different temperatures/time upto $1300^0C/240$ min. $(Ni_{0.25}Cu_{0.20}Zn_{0.55})La_xFe_{2-x}O_4$ ferrite compositions were synthesized through the nitrate-citrate auto-combustion method by Roy et.al [51], and the electromagnetic properties were found best in the ferrite composition of x = 0.025 which would be better for more miniaturized multilayer chip inductor. Roy and Bera [52] also carried out further studies on enhancement of the magnetic properties of Ni-Cu-Zn ferrites with the substitution of small fraction of lanthanum for iron.

With generic formulae $Ni_{0.25}Cu_{0.2}Zn_{0.55}Sm_xFe_{2\_x}O_4$ ferrite compositions characterization of nanocrystalline NiCuZn ferrite powders synthesized through the nitrate-citrate auto-combustion method was studied by [53]. Patil and Ladgoankar [54] carried out studies with the view to developing an embedded technology based smart sensor module for humidity measurement; a sensor material with generic formula $Ni_xZn_{1-x}Fe_2O_4$ was synthesized by chemical method and concluded that deploying these materials the inter-digited thick film sensors are fabricated and used to develop an embedded system for measurement of humidity. Structural and magnetic properties of Cu^{2+} substituted $Ni_{0.8-x}Cu_xZn_{0.4}$ ferrites for x = 0.0 to 0.6 with the step increment of 0.2 prepared by an auto-combustion method have been investigated by Awati et.al. [55].

Varalaxmi and Sivakumar [56] carried out on ferrite composites with ferrimagnetic phases (X) $Ni_{0.35}Cu_{0.05}Zn_{0.6}Fe_2O_4$ + (1-X) $Mg_{0.25}Cu_{0.25}Zn_{0.5}Fe_2O_4$ in which 'x' varies from 0.0 to 1.0 were prepared by the conventional ceramic double sintering process, and the study concludes that the equimolar mixture of NiCuZn and MgCuZn ferrites may be used as core material for the fabrication of multilayer chip inductors (MLCI). A low-profile microinductor was fabricated on a copper-clad polyimide substrate where the current carrying coils were patterned from the existing metallization layer and the magnetic core was printed using a magnetic ceramic-polymer composite material by Brandon [57]. NiCuZn and MgCuZn ferrites with generic formulae $Ni_{0.35}Cu_{0.05}Zn_{0.6}$ Fe_2O_4 and $Mg_{0.35}Cu_{0.05}$ $Zn_{0.6}Fe_2O_4$ have been successfully synthesized by conventional double sintering technique, in order to examine their use for microinductor applications by Varalaxmi and Sivakumar [58]. They concluded that the variation of $(\Delta L/L)\%$ with external compressive stress in MgCuZn ferrite is almost less than 0.2, hence the MgCuZn ferrite material can be used as stress insensitive core material for microinductor applications by adding suitable additives to it. Varalaxmi et.al. [59] investigated three series of NiMgCuZn ferrites which were prepared by the conventional sintering process in order to study the stress sensitivity of inductance in NiMgCuZn ferrites and development of a stress insensitive ferrite composition for microinductors. Studies on two series of stoichiometric and iron deficient NiCuZn ferrites prepared by the conventional ceramic method were carried out by Ramamaohar reddy et.al.[60].

A series of polycrystalline MgCuZn ferrites with generic formula $Mg_xCu_{0.5}Zn_{0.5-x}Fe_2O_4$ synthesized by conventional double sintering technique was carried out by Varalaxmi and Sivakumar [61] and the investigated ferrites were found to exhibit excellent properties that are suitable for the core materials in multilayer chip inductors. Studies on structural and electrical properties of ball-milled NiCuZn-MgCuZn nanocomposites ferrites were investigated by Varalaxmi and Sivakumar [62]. Hu and Yan [63] studied the preparation of high-permeability NiCuZn ferrite and reported that high permeability of 1700 and relative loss coefficient $\tan\delta/\mu i$ of 9.0×10^{-6} at 100 kHz was achieved in the $(Ni_{0.17}Zn_{0.63}Cu_{0.20})Fe_{1.915}O_4$ ferrite when sintered at 930ºC for 5h, which is superior to that of the conventional $(Ni_{0.32}Zn_{0.63}Cu_{0.05})Fe_{1.915}O_4$ ferrite (having initial permeability of 1500) which was prepared by conventional ceramic process and sintered at 1200 °C for 2 hr.

Penchal Reddy et.al. [64] investigated the low-temperature sintered NiZn and NiCuZn ferrites with generic formula $Ni_{0.40}Zn_{0.60}Fe_2O_4$ and $Ni_{0.35}Cu_{0.05}Zn_{0.60}Fe_2O_4$ which were synthesized by the microwave sintering method. Recent developments and trends of sol–gel auto-combustion method for spinel ferrite nanomaterial synthesis are briefly discussed and critically analyzed by Sutka and Mezinskis [65] and concluded that by using sol–gel auto-combustion method, 1D spinel ferrite structures can be synthesized enhancing magnetic permeability, resonance frequency, and mechanical properties, as well as widening application area of the products.

Jacek Salach [66] studied unified methodology for testing tensile and compressive stress dependences of ring-shaped magnetoelastic properties of $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloys for cores testing. Saita et.al. [67] carried out studies on the sintering behavior, including densification and grain growth of NiCuZn ferrites ceramics carried out by microwave field of 2.45 GHz. When compared to conventional sintering, the shrinkage curves of a NiCuZn ferrites system processed by microwave sintering were observed to have shifted towards approximately 100ºC lower temperartures. Brito et.al. [68] carried out a work which investigates the variation of the real part of the complex magnetic permeability of a Ni-Zn ferrite for application to temperature sensors. Ferrite samples were fabricated by means of the conventional ceramic method. The stress sensitivity in Ni-Mn, Ni-Mn-Co and Ni-Mn-Co-Cu ferrites was studied by Kaczkowski [69] and concluded that the high-stress sensitivity was observed for the ferrites with the smallest magnetocrystalline anisotropy.

Nakano et al. [7] studied the development of low- temperature fired NiCuZn ferrites and studied the high-performance multilayer chip inductors and concluded that the controlling stress by the internal Ag-conductor and CuO1-*x*/Ag on ferrites grain boundary is most important key point for high-performance multilayer chip ferrites as well as the chemical composition of ferrite. Nakano et al., [70] have studied the magnetic properties of MgCuZn ferrites under stress, and compared the results with those of Ni-Cu-Zn ferrite under a compressive stress. They observed that the change in permeability with the stress of low-temperature sintered MgCuZn ferrite was lower than that of low temperature sintered NiCuZn ferrite. They have also shown that the multilayer chip inductor using low temperature sintered MgCuZn ferrite would show a higher inductance than the chip using low temperature sintering NiCuZn ferrite.

3. CONCLUSIONS:

Multilayer chip inductors (MLCIs) have been rapidly developed for electromagnetic
applications. NiCuZn ferrites are the most preferred ferrite materials to produce MLCIs, and MgCuZn ferrites have similar electromagnetic properties to those of NiCuZn ferrites. Typical synthesis methodologies involve routes including precipitation, sol-gel, hydrothermal, conventional double sintering techinque, dry vapor deposition, surfactant mediation, microemulsion, electro-deposition, etc.

The above-mentioned synthetic methods have several advantages and disadvantages for
preparing ferromagnetic particles. While these methods often furnish particles with narrow size distributions they tend to require re-optimization for each desired particle size, shape, or surface functional groups.

References:

1. T. Nomura and M. Takaya (1987) Hybrids., **3** pp.15.
2. X. Qi, J. Zhou, Z. Yue, Z. Gui and L. Li (2002) Key. Eng. Mater., **224-226** pp.593.
3. A. Ono, T. Muruno, and N. Kaihara (1991) Jpn. Elect. Eng., **28**, p. 5.

4. T. Momura and A. Nakano (1992) Proc. ICF-6 Jpn. Soc. Powder Metall., p.1198.
5. H. Su, H. Zhang, X. Tang, L. Jia, Q.Wen, Mater (2006) Sci. Eng. B: Solid-State Mater. Adv.Technol. **129** pp.172.
6. J. Shin, Y. Jeong, J. Hahn, B. Song, J. Magn (1998) Soc. Jpn. **22** (Suppl. S1) pp.292.
7. A. Nakano, T. Suzuki, H. Momoi, J (2002) Jpn. Soc. Powder Powder Metall., **49** pp.77.
8. Y. Ikeda, M. Kumagai, J (1998) Jpn.Sci. Powd. Powd. Metall. **45**, pp.53
9. H. Fujji, S. Harada, T. Kawamata, J Magn. Soc. Jpn. **22** (Suppl S1), pp.311.
10. A. Nakano, H. Momoi and T.Nomura (1992) "*Proc of 6th International Conference on Ferrites"* Kyoto: Japan Soc.of Powd and Powd. Metallpp.1225.
11. 11 J. G. Koh and C. I. Yu (1984) New Phys., (Korean Phys, Soc.) **24** pp.359.
12. D. N. Bhosale, N. D. Choudhari, S. R. Swant and P.P. Bakare., J (1997). Magn. Magn. Mater.173 pp.51.
13. J. Park, J. Kim and S. Cho (1997) J. Phys., (France) **C1-193** pp.7.
14. J. G. Koh and K. U. Kim (1986) New Phys., (Korean. Phys. Soc.,) **26** pp.540.
15. X. Qi, J. Zhou, Z..Yue, et.al (2002) Key. Eng. Mater., **224-226** pp.593.
16. H. Zhang, Z. Ma,J. Zhou, Z. Yue, L. Li and Z. Gui (2000) J. Magn. Magn. Mater., **213**-304.
17. M. Penchal Reddy, M. Venkataramana,N. Ramamanohara Reddy, K. V. Sivakumar and R. Ramakrishna Reddy. (2011), Modern Physics Letters B, **25** pp.211–222.
18. N.Varalaxmi and K.V.Sivakumar. (2014), Int. Jour of Engg.Sci & Res. Tech., **3** pp.820- 826
19. M. Penchal Reddy ,W. Madhuri, K. Sadhana, I.G. Kim, K. N. Hui, K. S. Hui, K.V.Siva Kumar and R. Ramakrishna Reddy. (2014), J Sol-Gel Sci Technol
20. M. Penchal Reddy,W. Madhuri , G. Balakrishnaiah, N. Ramamanohar Reddy, K.V. SivaKumar,V.R.K. Murthy and R. Ramakrishna Reddy. (2011),J.Current Applied Physics., 11 pp.191-198.
21. M. Penchal Reddy, W. Madhuri , N. Ramamanohar Reddy, K.V. Siva Kumar,V.R.K. Murthy and R. Ramakrishna Reddy. (2010), J.Mater. Sci and Engg.C 30 pp.1094–1099.
22. M Penchal Reddy, W Madhuri, N Ramamanohar Reddy,K V Siva Kumar, V R K Murthy and R Ramakrishna Reddy. (2010), J. Phys. Scr. **81** 055801 (6pp).
23. M. Penchal Reddy, M. Venkata Ramana, W. Madhuri, K. Sadhana,K.V. Siva Kumar et al (2015), J. Advances in Applied Ceramics ., 00 pp.1-8.
24. M. Penchal Reddy,W. Madhuri,M. M.Venkata Ramana,I. G. Kim, D. S. Yoo,N. Ramamanohar Reddy,K. V. Siva Kumar,D. V. Subbaiah and R. Ramakrishna Reddy., Journal of Ceramics Volume Article ID 901375, 6 pages.
25. W Madhuri, M Penchal Reddy, N Rammanohar Reddy, K V Siva Kumar and V R K Murthy. (2009), J. Phys. D: Appl. Phys. **42** 165007 (7pp).
26. K. Praveeena, M. Bououdina, M. Penchal Reddy,S. Srinath, R. Sandhya, and K.Sadhana. (2015),J. Elect. Mater., **44** pp.524-531.
27. M.Penchal Reddy, X. Zhou, A.Yann, S. Du,Q.Huang and A. Mohamed. (2015), J. Superlattices and Microstructures., **81** pp.233-242
28. F. Alam, H. N. Das and A. K. M. Akther Hossain. (2012), 7th International Conference on Electrical and Computer Engineering 20-22 December, Dhaka, pp.443-446.
29. W.Shen, H. Zhu,Y. Jin, H.Zhou, Z.Xu J. (2014) Ceramics International 40 pp.9205–9209.
30. J.Singh, H.Kaur, M.Kaur and B. S. Randhawa. (2010), J. Appl. Phys., **107** pp. 09A520.
31. O.Caltun, G.S.N.Rao,K.H.Rao,B.Parvatheeswara Rao,I. Dumitrua, C.O.Kim, C.Kim. (2007) , J. Magn. Magn.Mater., **316** pp.e618–e620.
32. N. Varalaxmi and K. Sivakumar. (2010) , "Sintering Applications" Intech publishers., pp.229-258.
33. K.Mujasam Batoo and Mohd.S.Ansari. (2012), J. Nano.Research Lett., **7**:112 pp.1-14.
34. S.Zahi, M.Hashim and A.R. Daud. (2007), J.Magn. Magn. Mater., **308** pp.177–182.
35. M.C.Dimri, A.Verma, S.C. Kashyap, D.C. Dube, O.P.Thakur and Chandra Prakash. (2006), J. Mat. Sci and Engg B., **133** pp.42-48.
36. Z.Kaczkowski., J.Magn.Magn.Mater. (1984), **41** pp.338-340.
37. R.Szewczyka and A. Bie´nkowski . (2004), , J. Sensors and Actuators A. **110** pp.232–235.
38. A. Bie´nkowski and R.Szewczyka . **(1994)**, J.IEEE Trans on Magn., **34** pp.1366-1368.
39. M. Ya and J. Hu., J.Magn.Magn.Mater., **305** (2006) pp.171-176
40. T.Nakamura,M. Naoe and Y.Yamada. (2006), J.Magn.Magn. Mater., **305** pp.120-126.
41. Y. Zhang, J. Lu, H. Hiroshima, T. Itoh, and R. Maeda. (2009), PowerMEMS 2009, Washington DC, USA, December 1-4, pp.253-256.
42. P.K.Roy and Bera., J.Magn.Magn.Mater. (2006), **928** (1) pp.38-42.
43. W. Madhuri, M. Penchal Reddy, Il Gon Kim, N. Rama Manohar Reddy, K.V. Siva Kumar and V.R.K. Murthy. (2013), J.Mater. Sci and Engg B **178** pp.843-850.
44. M. Penchal Reddy, W. Madhuri , M.Venkat Ramana, N. Ramamanohar Reddy, K.V. Siva Kumar,V.R.K. Murthy and R. Ramakrishna Reddy. (2010), J.Magn.Magn.Mater., **322** pp.2819-2823.
45. M. Penchal Reddy, W. Madhuri, M. Venkat Ramana, K. Sivakumar, P. Sreedhara Reddy,
N. Ramamanohar Reddy, K. V. Sivakumar, V. R. K. Murthy and R. Ramakrishna Reddy. (2011), Modern.Phys. Lett B., **25** pp.211-222.
46. M.Penchal Reddy, G.Balakrishnaiah, W. Madhuri, M.Venkat Ramana, N. Ramamanohar Reddy, K.V. Siva Kumar and R.Ramakrishna Reddy. **(**2010), J. Phys and Chem of Solids., **7** pp.1373-1380.
47. M. Penchal Reddy,W. Madhuri, M.Venkata Ramana, I.G.Kim,D.S.Yoo,N. Ramamanohar Reddy, K.V. Siva Kumar, D. V. Subbaiah and R. Ramakrishna Reddy. (2013), J. Ceramics., Volume, Article ID 901375, 6 pages
48. M. Penchal Reddy, W. Madhuri, N. Ramamanohar Reddy, K.V. Siva Kumar, V.R.K. Murthy and R. Ramakrishna Reddy. (2010), J. Current Appl.Phys., xxx pp.1-8.
49. M Penchal Reddy, W Madhuri, N Ramamanohar Reddy, K V Siva Kumar, V R K Murthy and R Ramakrishna Reddy. (2010), J. Phys. Scr., 81 055801 (6pp)
50. J.Bera and P.K.Roy. (2005), J. Physica B., 363 pp.128-132.
51. P.K. Roy, B. B.Nayak and J. Bera., J.Magn.Magn.Mater. (2008), **320** pp.1128–1132.
52. P. K. Roy and J. Bera. (2007), J.Mater. Res. Bull., **42** pp.77–83.
53. P. K. Roy and J. Bera. (2009), J.Magn.Magn.Mater., **321** pp.247-251.
54. S. N. Patil and B. P. Ladgaonkar. (2013), Inter.J. of Adv. Res in Elect,Electron & Instrument.Engg., **2** **,** 8 pp.3813-3821.
55. V.V.Awati, D. H. Bobade, S. D. Kulkarni and S.M.Rathod . (2012), Inter. J.of Engg Res. & and Appls. **2,** 6 pp.482-489.

56. N. Varalaxmi and K. V. Siva kumar. (2003), J Mater Sci: Mater Electron **22** (2011) pp.555-560.E.J. Brandon, E. E. Wesseling and V.Chang., IEEE Trans.Comp.and Pack. Trech.,**26** 517-523.
57. N.Varalaxmi and K.V.Sivakumar. (2012), Int. J. Phy. Sci. Vol. III (1st Issue) pp. 7-17.
58. N.Varalaxmi, N. Ramamanohar Reddy, M.Venkata Ramana, E.Rajagopal,V. Ramakrishna Murthy and K.V.Sivakumar. (2008), J Mater Sci: Mater Electron, **19** pp.399-405.
59. N. Ramamanohar Reddy, M. Venkata Ramana,G. Rajitha, K.V. Sivakumar and V.R.K. Murthy. (2009), Current Appl. Phys., **9** pp.317–323.
60. N.Varalaxmi and K.V.Sivakumar. (2013), J. Mater. Sci and Engg C., **33** pp.145-152.
61. N.Varalaxmi and K.V.Sivakumar. (2014), J. Metall and Mater Trans A, **45A,** pp.1579-1585.
62. Hu Jun and Yan Mi. (2005), J Zhejiang Univ SCI., **6B** (6) pp.580-583.
63. M. Penchal Reddy, G. Kim, D. S.Yoo, W. Madhuri, N.Ramamanohar Reddy, K.V.
Siva Kumar, R. Ramakrishna Reddy. (2012), J.Mater. Sci and Appl., **3** pp.628-632.
64. A. Sutka and G.Mezinskis., J. Front. Mater. Sci., **6** (2) (2012) pp.128-141.
65. J.Salach., R. Szewczyk, A. Bieńkowski and P.Frydrych. (2010) , J. Electrl and Engg, 61**.** 7/s, pp.93-95.
66. H.Saita, Y.Fang, A.Nakano, D.Agrawal, M T.Lanagan. T.R.Shrout and C.A.Randall. (2002) Jpn. J. Appl.Phys. **41,** pp.86-92.
67. V.L.O. Brito, L.F.A.De Almeida, A.K (2010) Hirata and A.C.C. MIgliano., Prog in Eletro magnetic Res Lett. **13**, pp.103-112.
68. A. Nakano. I. Nakahata and T. Murase., J. (2001) of Japan Soc of Powder and Powder Metall., 48**,** No. 2, pp. 131-135.
69. S. Murayamna, M. Kumagi and Y. Ikeda (1992) Proceedings of 6th International Conference on Ferrites, Kyoto, pp. 366.