

# Role of Nano Crystalline Spinal Ferrite Material in Switch Mode Power Supply as Magnetic Energy Storage device to improve the efficiency

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**Abstract:** Herein, the magnetic properties such as Saturation magnetization [Ms(emu/gm)], Magnetic moment [Mr(emu/gm)], Coercivity [Hc(Oe)], are reported for the series [Cu<sub>x</sub> Co(constant) Ni<sub>0.8-x</sub> Fe<sub>2</sub>O<sub>4</sub>] where constant=0.2 with x=0.2, 0.4 and 0.6 of nano crystalline spinel ferrites, synthesized by Sol-Gel auto-combustion technique. High purity metal nitrates are used for synthesis and citric acid as a catalyst. The sintering temperature is 300 degree centigrade. The variation in the Saturation magnetization [Ms(emu/gm)], Magnetic moment [Mr(emu/gm)], Coercivity [Hc(Oe)] are studied at room temperature due to the effect of substitution of Cu<sup>2+</sup> density 'x' in [(Ni<sub>0.8-x</sub>Cu<sub>x</sub> Co(constant))Fe<sub>2</sub>O<sub>4</sub>]. The nano crystalline spinal Structural of ferrite material is confirm Fourier Transform Infrared Spectroscopy (FT-IR). The magnetic properties are studied by using Vibrating Sample Magnetometer (VSM). The variations in the magnetic properties of the prepared ferrite material are discussed. The fabricated nano crystalline material is use as ferrite core in an inductor coil.

**KEYWORDS** - Sol-gel auto-combustion, FT-IR, VSM, Voltage, Current

## I. INTRODUCTION

The excellent electrical, Di-electric and magnetic properties of some of the nano crystalline ferrite materials make them suitable for high frequency applications in the field of telecommunication and satellite communication. Ferrites can also be used as an electromagnetic wave absorber, multilayer chip indicators (MLCIs), transformer core and in surface mounting devices (SMD), ferrites have been widely used in microwave devices such as circulators, insulators and phase shifters because of their high resistivity, low dielectric loss and excellent magnetic properties [1,2]. The general formula of ferrite is MFe<sub>2</sub>O<sub>4</sub> and electrical and magnetic properties of ferrites are dependent on the distribution of metal cation at tetrahedral A-site and at octahedral B-site [3]. Where M=Ni<sup>2+</sup>, M=Cu<sup>2+</sup>, M=Co<sup>2+</sup>, M=Mg<sup>2+</sup>, M=Zn<sup>2+</sup> etc. Different techniques have been developed for the preparation of the nano sized ferrites, namely sol-gel, micro emulsion, double sintering, hydrothermal, co-precipitation, ball milling and microwave heating to improve the performance of the nano ferrites [4-7]. Sol-gel auto-combustion is the simplest methodology to synthesize the nano sized ferrites with good homo-geneity at low annealing temperature. The aim of the present work is to investigate the effect on magnetic properties due to substitution of Cu<sup>2+</sup> ions density 'x' in [(Ni<sub>0.8-x</sub>Cu<sub>x</sub> Co(constant))Fe<sub>2</sub>O<sub>4</sub>].

## II. EXPERIMENTAL

### 2.1 Synthesis

The high purity AR grade ferric nitrate [Fe(NO<sub>3</sub>)<sub>3</sub>.9H<sub>2</sub>O], Copper nitrate [Cu(NO<sub>3</sub>)<sub>2</sub>.6H<sub>2</sub>O], Nickel nitrate [Ni(NO<sub>3</sub>)<sub>2</sub>.6H<sub>2</sub>O], Cobalt nitrate [Co(NO<sub>3</sub>)<sub>2</sub>.6H<sub>2</sub>O], citric acid (C<sub>6</sub>H<sub>8</sub>O<sub>7</sub>), ammonium hydroxide solution (NH<sub>4</sub>OH) were used to prepare the series [Cu<sub>x</sub> Co(constant) Ni<sub>0.8-x</sub> Fe<sub>2</sub>O<sub>4</sub>] where constant=0.2 with x=0.2, 0.4 and 0.6 of ferrite nano particles by sol-gel auto combustion synthesis technique. In this chemical process Citric acid was used as a Fuel. All metal nitrates and citric acid were weighed accurately to have proper stoichiometric proportion required in the final product and all metal nitrates are dissolved in 100 ml deionized water to form mixed solution. The mixed solutions of all the chemicals were stirred by using magnetic stirrer until the homogeneous solution is obtained. During the stirring process ammonium hydroxide solution was added drop by drop to obtain pH at constant value of 7.

The mixed solution was simultaneously heated at 100 °C for 3 to 4 h to form sol. The sol turns into a viscous brown gel. The temperature of the gel was further increased up to 150 °C, after some time combustion of the gel takes place and fine powder of [Cu<sub>x</sub> Co(constant) Ni<sub>0.8-x</sub> Fe<sub>2</sub>O<sub>4</sub>] ferrite nano particle was obtained. The powder was dried and annealed at 400 °C for 4 hours in furnace having super kanthal (MoSi<sub>2</sub>) heating elements and alumina insulation boards as chamber walls [8-9]. Three ferrite materials

for  $x=0.2$ ,  $x=0.4$  and  $x=0.6$  are represented by the symbol C, F, and D are  $[(\text{Ni}_{0.6}\text{Cu}_{0.2}\text{Co}_{0.2})\text{Fe}_2\text{O}_4]$ ,  $[(\text{Ni}_{0.4}\text{Cu}_{0.4}\text{Co}_{0.2})\text{Fe}_2\text{O}_4]$  and  $[(\text{Ni}_{0.2}\text{Cu}_{0.6}\text{Co}_{0.2})\text{Fe}_2\text{O}_4]$  respectively.

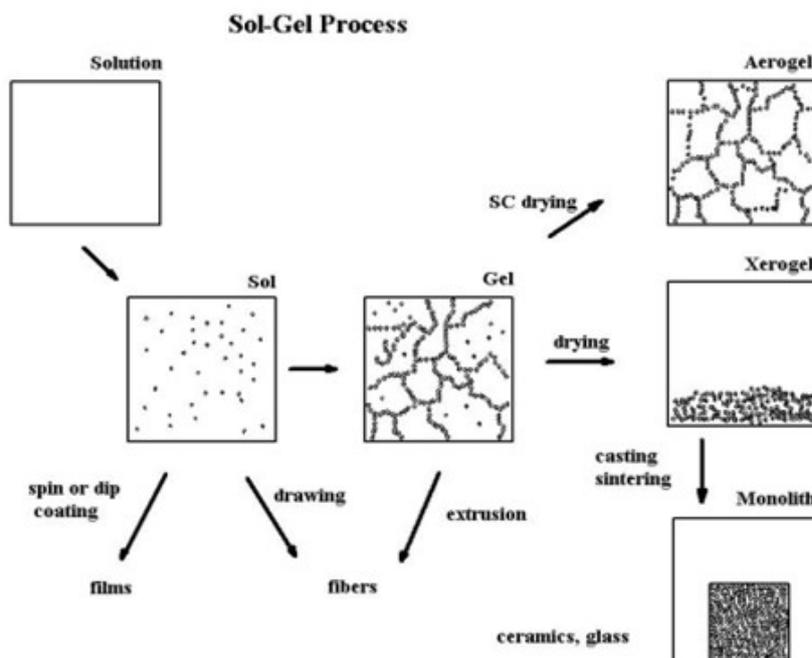


Fig.1 Sol Gel method Blocks

## 2.2 Characterization

The magnetic measurements at room temperature were carried out using vibrating sample magnetometer. The variation in the Saturation magnetization  $[M_s(\text{emu/gm})]$ , Magnetic moment  $[M_r(\text{emu/gm})]$  and Coercivity  $[H_c(\text{Oe})]$  are studied at room temperature due to the effect of substitution of  $\text{Cu}^{2+}$  density 'x' in  $[\text{Cu}_x\text{Co}(\text{constant})\text{Ni}_{0.8-x}\text{Fe}_2\text{O}_4]$ .

Fig. 2 to Fig.5 shows the hysteresis curve for the  $[\text{Cu}_x\text{Co}(\text{constant})\text{Ni}_{0.8-x}\text{Fe}_2\text{O}_4]$  spinel ferrites recorded at room temperature. The saturation magnetization  $[M_s(\text{emu/gm})]$ , Magnetic moment  $[M_r(\text{emu/gm})]$  and the coercivity  $[H_c(\text{Oe})]$  values were obtained from Vibrating Sample Magnetometer (VSM). These parameters depend on the microstructure and distribution of cations on the A-sites and B-sites of the spinal structure.  $M_s$ ,  $M_r$  and  $H_c$  are dependent on ferrite composition.

The values of  $M_s$ ,  $M_r$  and  $H_c$  for the  $[(\text{Ni}_{0.8-x}\text{Cu}_x\text{Co}(\text{constant}))\text{Fe}_2\text{O}_4]$  ferrite samples (annealed at  $400^\circ\text{C}$  4hours) are presented in Table 1. It is observed that values of  $M_s$  increase up to  $x=0.4$  and then decrease with further increase in x.

## III. RESULTS AND DISCUSSIONS

### 3.1 Hysteresis:

The total magnetization of the spinal ferrites comes from the difference in the magnetization of B-sites and A-sites and it is also known that the octahedral (B) site has larger magnetic moment than the tetrahedral (A) site. When the  $\text{Cu}^{2+}$  ions replace the  $\text{Fe}^{3+}$  ions at A-site, the  $\text{Fe}^{3+}$  ions migrate to B-site and this increases the saturation magnetization, it is happening because the  $\text{Fe}^{3+}$  ions have larger magnetic moment than the  $\text{Cu}^{2+}$  ions. With further increase in the concentration of  $\text{Cu}^{2+}$  ions, the magnetic moment on the B-sites increases and it increases the B–B exchange interaction. This increased B–B exchange interaction induces anti-parallel spin coupling, which decreases the magnetization [10-13]. From table No. 1 it is observed that saturation magnetization  $[M_s(\text{emu/gm})]$  increases and then decreases. Fig.2 shows the Hysteresis graph.

### 3.2 FT-IR:

The FTIR spectroscopy confirms the single phase nature of the prepared sample. The peak  $536.114\text{ cm}^{-1}$ ,  $524.643\text{ cm}^{-1}$  and  $532.257\text{ cm}^{-1}$  gives the confirmation of  $\text{Fe}_2\text{O}_4$ . [14-15].

## IV. FIGURES AND TABLES

Table 1  
 Variation in Magnetic moment [Mr(emu/gm)], Magnetic Saturation [Ms (emu/gm)] and Coercivity [Hc(Oe)] for [(Ni<sub>0.8-x</sub>Cu<sub>x</sub>Co<sub>(constant)</sub>)Fe<sub>2</sub>O<sub>4</sub>]

SAMPLE	Hc(Oe)	Mr(emu/gm)	Ms (emu/gm)
(C) Ni <sub>0.6</sub> Cu <sub>0.2</sub> Co <sub>0.2</sub> Fe <sub>2</sub> O <sub>4</sub>	560.8642	022.9151	43.7550
(F) Ni <sub>0.4</sub> Cu <sub>0.4</sub> Co <sub>0.2</sub> Fe <sub>2</sub> O <sub>4</sub>	71817.90	026.2112	44.0776
(D) Ni <sub>0.2</sub> Cu <sub>0.6</sub> Co <sub>0.2</sub> Fe <sub>2</sub> O <sub>4</sub>	1004.9383	019.2974	26.5841

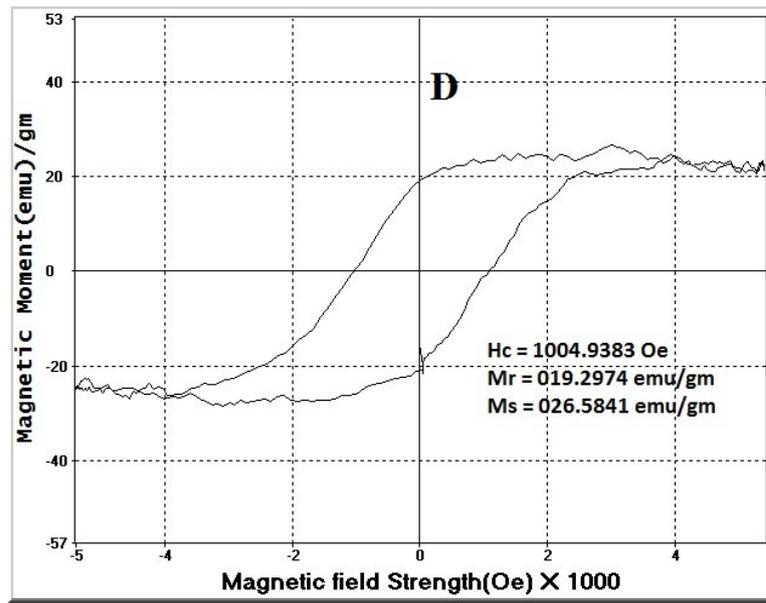


Fig. 2 Hysteresis loop of Ni<sub>0.2</sub>Cu<sub>0.6</sub>Co<sub>0.2</sub>Fe<sub>2</sub>O<sub>4</sub>

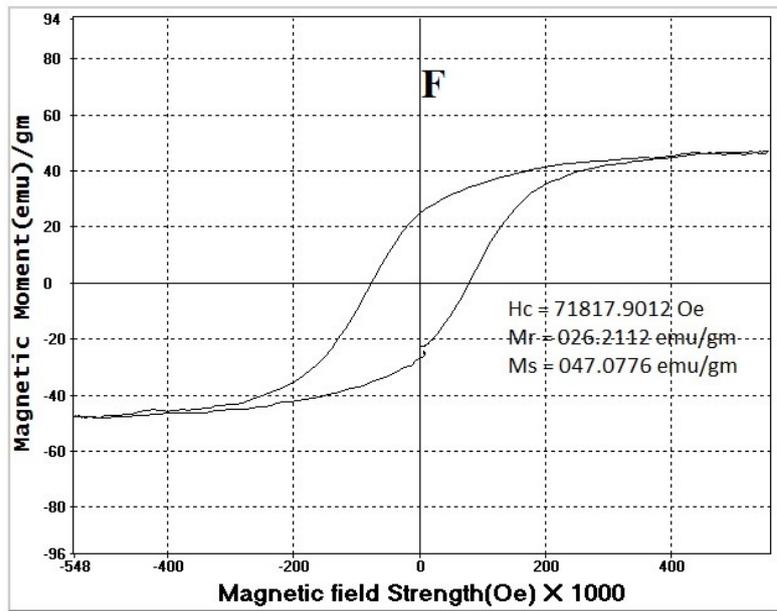


Fig. 3 Hysteresis loop of Ni<sub>0.4</sub>Cu<sub>0.4</sub>Co<sub>0.2</sub>Fe<sub>2</sub>O<sub>4</sub>

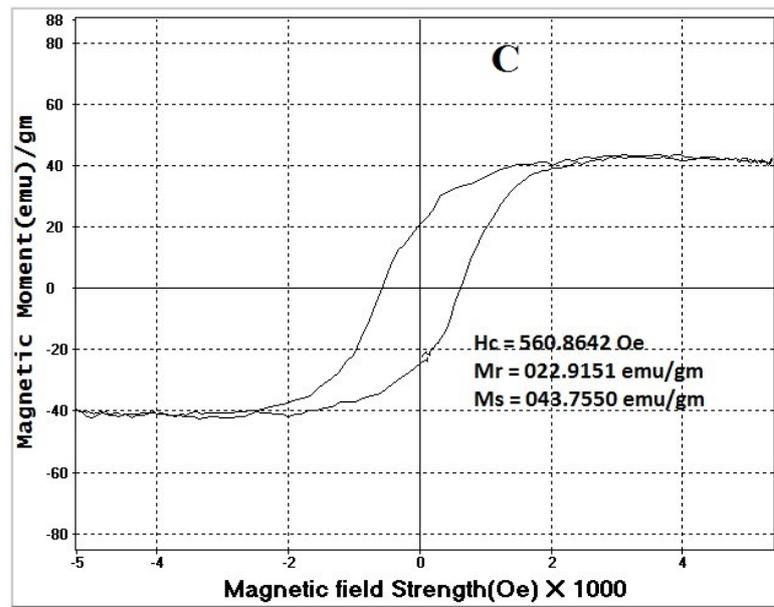


Fig. 4 Hysteresis loop of  $\text{Ni}_{0.6}\text{Cu}_{0.2}\text{Co}_{0.2}\text{Fe}_2\text{O}_4$

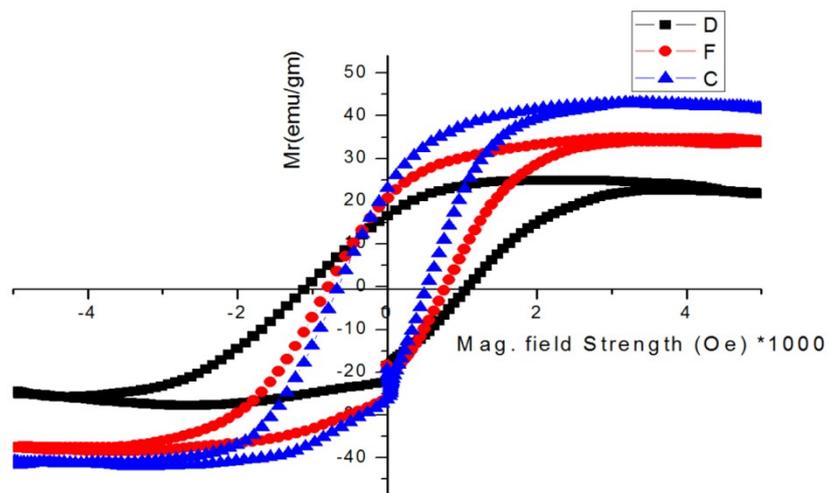


Fig. 5. Hysteresis Loop of of D, F and C respectively for  $[(\text{Ni}_{0.2}\text{Cu}_{0.6}\text{Co}_{0.2})\text{Fe}_2\text{O}_4]$ ,  $[(\text{Ni}_{0.4}\text{Cu}_{0.4}\text{Co}_{0.2})\text{Fe}_2\text{O}_4]$ ,  $[(\text{Ni}_{0.6}\text{Cu}_{0.2}\text{Co}_{0.2})\text{Fe}_2\text{O}_4]$ .

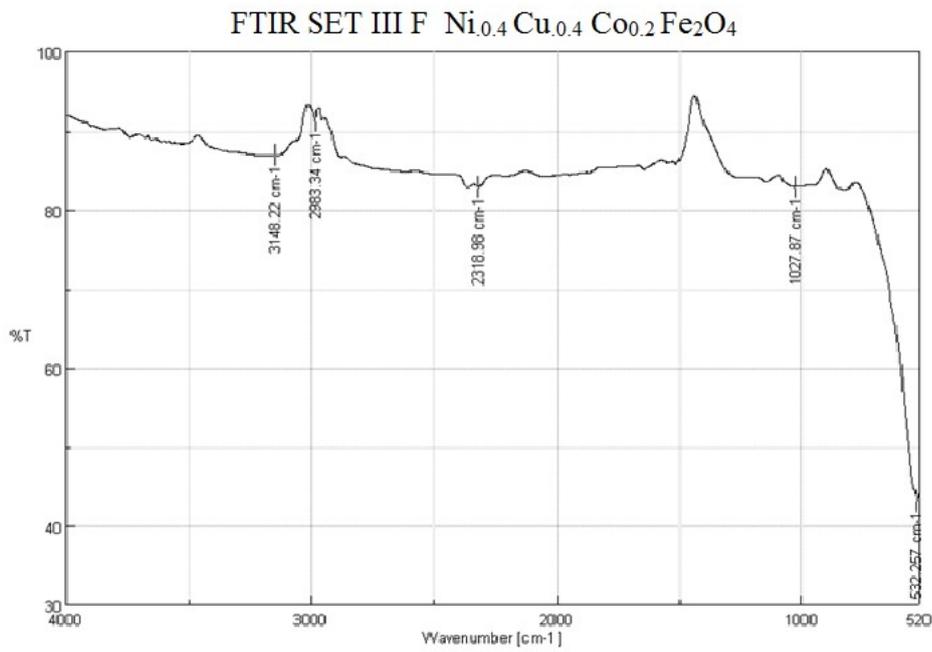
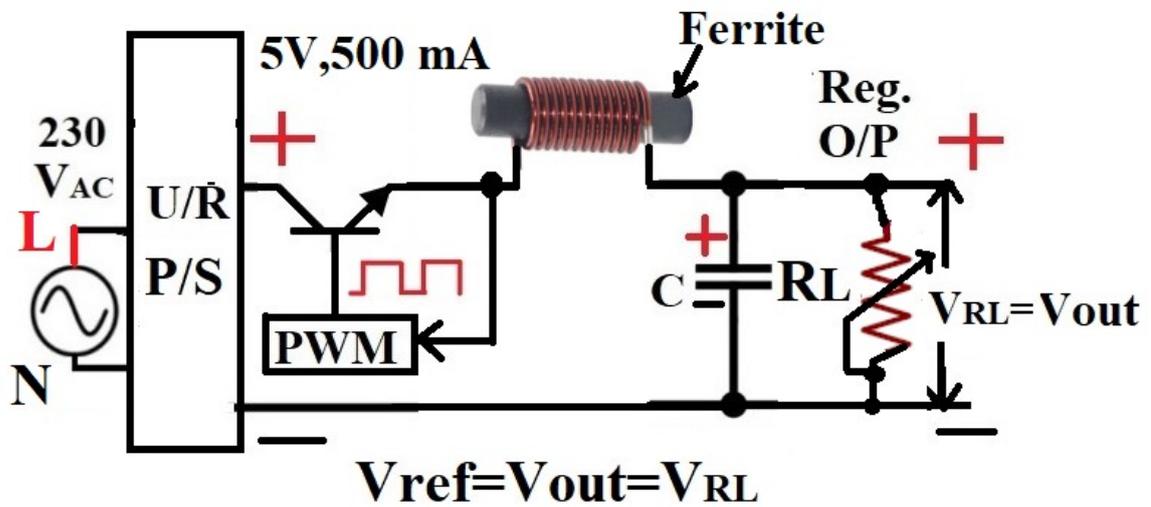
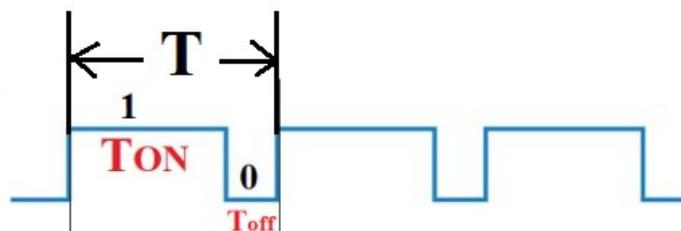


Fig. 6. FT-IR spectra of SET-III (F) Ni<sub>0.4</sub> Cu<sub>0.4</sub> Co<sub>0.2</sub> Fe<sub>2</sub>O<sub>4</sub>

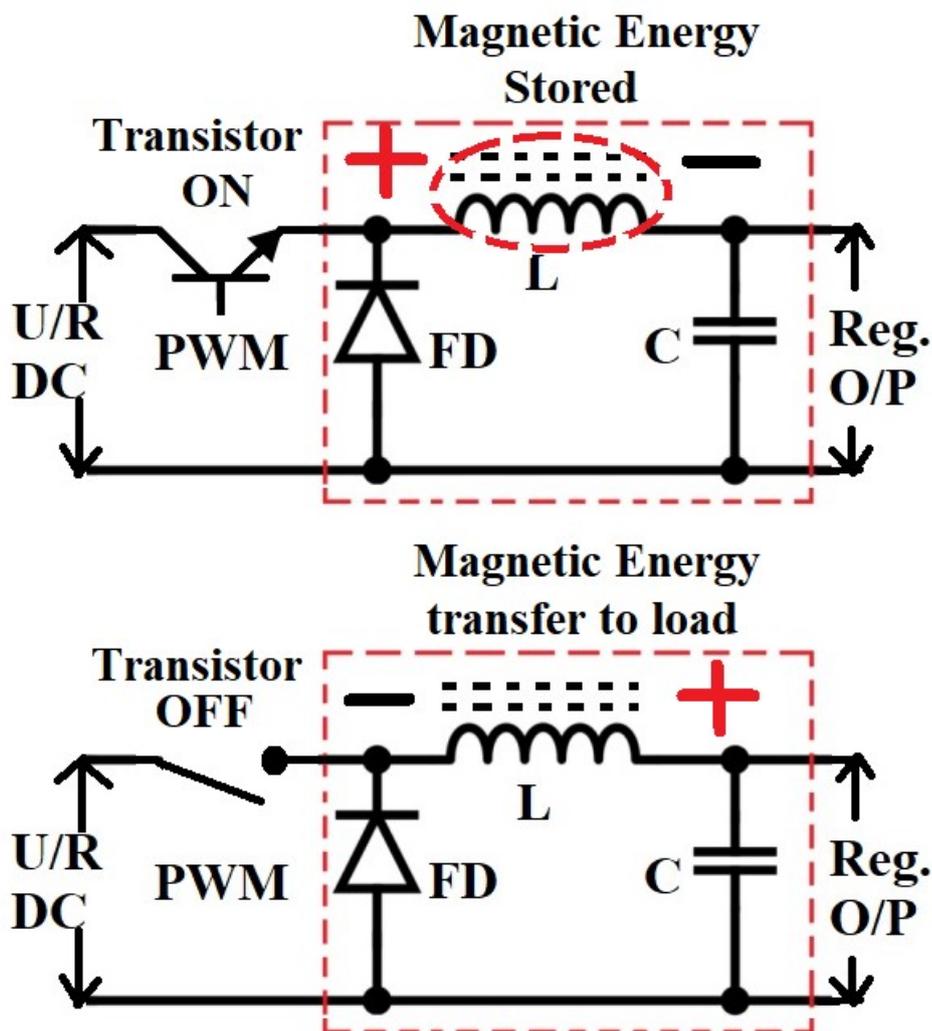
V. CIRCUIT DIAGRAM



$$\text{Duty Cycle \%age} = \frac{T_{ON}}{T_{ON} + T_{OFF}} \times 100\%$$



Duty Cycle 95% for Maximum Load



It is observed that the magnetic energy stored in ferrite material gets transfer to load resistor when the maximum load of 100 ohm is applied. The voltage across load resistor is maximum for the Duty cycle of square wave generated at the Output of Pulse Width Modulator (PWM) Circuit of 95 percent. Therefore, we can save the electric energy up to 5 percent by using ferrite as core material for an Inductor coil. Here ferrite core is fabricated by using, (C)  $Ni_{0.6}Cu_{0.2}Co_{0.2}Fe_2O_4$ .

## VI. CONCLUSIONS

The nano crystalline ferrite samples  $[(Ni_{0.6}Cu_{0.2}Co_{0.2})Fe_2O_4]$   $[(Ni_{0.4}Cu_{0.4}Co_{0.2})Fe_2O_4]$ ,  $[(Ni_{0.2}Cu_{0.6}Co_{0.2})Fe_2O_4]$  have been successfully prepared by sol-gel auto combustion technique. All the prepared samples show the single phase cubic spinel structure of the samples. It clearly shows that the size of the ferrite particles was in the nano-meter range. It is observed that value of Magnetic Saturation  $[M_s(\text{emu/gm})]$  and Magnetic moment  $[M_r(\text{emu/gm})]$  initially increases with increase in substitution  $x$  of  $Cu^{2+}$  in Ni Co up to  $x=0.4$  and then decrease with further increase in of  $Cu^{2+}$  substitution  $x=0.6$ . The material C  $[(Ni_{0.6}Cu_{0.2}Co_{0.2})Fe_2O_4]$  is soft ferrite. The ferrite fabricated can be use as energy storage and energy saving material.

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