Literature Review:-

In this paper the authors presents a CBD method was used in the deposition of CdCr$_2$S$_4$ and HgCr$_2$S$_4$ respectively. According to X-ray diffraction patterns CdCr$_2$S$_4$ films are polycrystalline with estimated band gap energy of 2.6 eV while HgCr$_2$S$_4$ films are amorphous with bandgap energy equal to 2.7 eV. SEM showed that the substrates were well covered with films and no cracks or pinholes were observed. Electrical resistivity of the CdCr$_2$S$_4$ and HgCr$_2$S$_4$ films was found to be $1.44 \times 10^5$ and $2.39 \times 10^5$ $\Omega$ cm at 350 0 k respectively. The n-type conductivity of these materials was confirmed from TEP measurements. [5]

In this present paper electrosynthesis method has been used by the author to study the thin films of CdCr$_2$S$_4$. The estimated deposition potentials are found to be dependent on pH, temperature and composition of bath. The XRD studies showed that the films are polycrystalline and of the composition corresponding to CdCr$_2$S$_4$. The optical bandgap is estimated to be 2.4 eV. The SEM study shows that the films are continuous on the substrates. [7]

In this paper the authors used CBD method for deposition of CdCr$_2$S$_4$ thin films with different thickness on glass substrate. The X-ray pattern confirmed polycrystalline with an estimated bandgap energy 2.61 eV. The electric free carrier susceptibility and the carrier concentration to the effective mass ratio were estimated according to the model of Spitzer and Fan [9].

In this paper the authors used alkaline chemical synthesis of CdCr$_2$S$_4$ thin films of different thickness using chemical bath deposition method. The structural and surface morphological properties using XRD, SEM AFM and TEM techniques are discussed. Monodispersed spherical grains are obtained for the 110 and 168 nm thicknesses, which are broken into porous elongated grains at 224 nm thicknesses. They also studied change in optical absorption with increasing in film thickness is responsible for decrease in band gap energy from 2.47 to 2.35 eV and decrease in electrical resistivity from 3.55 to $0.76 \times 10^5$ $\Omega$ cm. thermo-emf measurement confirmed n-type conducting of materials.[20]

In this paper, the research scholars used CBD method to study the thin films of crystalline HgCr$_2$S$_4$ has been deposited on glass substrate at low temperature. The typical of the deposited HgCr$_2$S$_4$ thin films was 264 nm. The X-ray diffraction analysis and the selected area electron diffraction analysis revealed the deposited thin films were polycrystalline with highly
preferential orientation. The uv-spectroscopy confirmed the direct band gap energy of 2.39 eV. The films showed high electrical resistivity $3.4 \times 10^{-3} \, \Omega \, \text{cm}$ at room temperature. [21]

In this paper, with the help of CBD method the authors demonstrates the influence of strain of HgCr$_2$S$_4$ on the surface wettability in crystalline films. The study revealed that the wetting properties of the crystalline surface can be controlled by changing strain energy. Further, strain was reduced by increasing the thickness of the films. It is found that: (a) an increase in film thickness resulted in improved grain size and a decrease in strain energy; (b) due to the increase in grain size, surface roughness increases, as seen in AFM studies and (c) a decrease in strain energy enhances the contact angle. There for this could provide a good basic for designing materials for applications in crystalline anti-reflection, optically transparent, super-hydrophobic and biologically compatible surfaces. [22].

The paper presents, the study of a room temperature chemical synthesis of HgCr$_2$S$_4$ films has been carried out using controlled precipitation method. The films were polycrystalline and exhibited P-type electrical conductivity. HgCr$_2$S$_4$ films were found to be productive in KI solution. The PEC studies of these films have been carried out using I-V, output characteristics, spectral speed, transient response and C-V characteristics. here the author has been used a simple chemical deposition method for crystalline of stoichiometric P-type HgCr$_2$S$_4$ films electrode consisting irregular and compact grains X-ray diffraction measurement confirmed the cubic structure. The PEC properties were studied in potassium iodide electrolyte. [23]

The present paper studies the origin of large magnetocapacitive effects in CdCr$_2$S$_4$ single crystals. The Raman scattering experiments on stoichiometric single crystals of CdCr$_2$S$_4$ prepared by Br transport reactions show pronounced phonon anomalies that are evidence for a symmetry reduction and Cr off-centering in the cubic unit cell. The resulting enhanced electronic is proposed as a microscopic mechanism for the observed large magneocapacitive effects. [24].

In this paper authors used electrochemical deposition method to study CdCr$_2$S$_4$ thin films. Thin films of CdCr$_2$S$_4$ have been deposited on ITO substrates at various deposition potential and solution pH values using potentiostatic electrodeposition technique. X-ray diffraction pattern of the deposited films reveals the formation of films with polycrystalline nature with tetragonal structure. Surface morphology and film composition show that films with better quality and stoichiometry are obtained. The band gap value of the material obtained is this
work is found to be 2.38 eV. The value of refractive index & extinction coefficient are found to be 2.6 and 0.017. [25]

In this paper the authors study the discovery of CMR induced by the external field is reported in the geometrically frustrated spinel CdCr$_2$S$_4$ EFE induced CMR effect is unique and provides a novel venue for the interplay of electric and magnetic fields. This finding makes CdCr$_2$S$_4$ the only material known to show to CMC, CEC, CER and CMR altogether. The present results open a new venue for searching new materials to show CMR by tuning electric and magnetic fields [26]

In this paper the authors studied the recently discovered multiferroic material CdCr$_2$S$_4$ shows a coexistence of ferromagnetism and relaxor ferroelectricity together with a colossal magnetocapacitive effect. The complex dielectric permittivity of this compound and of structurally related CdCr$_2$S$_4$ was studied by means of broadband dielectric spectroscopy using different electrode materials. The observed magnetocapacitive coupling at the magnetic transition is driven by enormous changes of the relaxation dynamics included by the development of magnetic order. [27]

In this paper the dynamic properties were studies on newly discovered multiferroic spinel, CdCr$_2$S$_4$. When T < T$_c$, a dielectric relaxation components is observed, suggesting the magnetic ordering assists the release of charge dipoles. At T < 54 k, this relaxation component is suppressed by higher ac voltage, indicating the dipoles are freezed by higher voltage and a field induced phase is proposed. Since the complex electric properties are suggested to be arose from chlorine-based impurities or sulfur deficiency, these studies on different impurity content and the doping effect are in progress. [28]

In this research paper the study of magnetocaloric effect in CdCr$_2$S$_4$, investigated by magnetization and heat capacity measurements. CdCr$_2$S$_4$ is of a cubic spinel structure with soft ferromagnetism and performs reversible magnetic entropy in the whole experimental temperature range from 56 to 128 k . A large magnetic entropy change 7.04 J/Kg k and adiabatic temperature change 2.6 k are revealed for a field change of 0-5 T near the curie temperature of 87 k. [29]

In this paper the authors studied the sulfur based Cr spinels RCr$_2$s$_4$ with R=Cd and Hg exhibit the coexistence of ferromagnetic and ferromagnetic order is established , in HgCr$_2$S$_4$ a bond frustrated magnetic ground state is realized , which , however , easily can be driven towards a ferromagnetic configuration in weak magnetic fields. This paper shall review our
recent investigation for both compounds. Besides the characterization of the magnetic properties, the complex dielectric permittivity was studied by means of broadband dielectric spectroscopy as well as measurements of polarization hysteresis and pyro-currents.[30]

In this paper the authors studied of polycrystalline & single crystalline samples of the normal spinnel HgCr$_2$S$_4$ is reported. The structural refinement reveals enhanced values of the atomic displacement suggesting the closeness to a structural instability. Magnetization, electronic- spin resonance, and specific heat studies document strong ferromagnetic fluctuations close to 50 k and the occurrence of complex antiferromagnetic order at $T_N = 22$ k. He found highly unconventional behavior resembling properties of a noncolliner antiferromagnet and of a soft ferromagnet dependent on temperature and magnetic field. External magnetic fields disturb the antiferromagnetic order and strongly enhance the ferromagnetic correlation. The observed anomalies are related to bond frustration due to competing magnetic exchange interactions between the Cr$^+$ions. [31]

In this paper the research scholar present the study of temperature dependence of eigen frequencies and intensities of the infrared (IR) active modes have been investigated for the antiferromagnetic chromium spinel compounds CdCr$_2$S$_4$, ZnCr$_2$O$_4$, ZnCr$_2$Se$_4$ and HgCr$_2$S$_4$ by IR spectroscopy for temperatures from 5 to 300 k. At the transition into the magnetically ordered phase and driven by spin-phonon coupling, most compounds reveal significant splitting of the phonon modes. This is true for geometrically frustrated CdCr$_2$S$_4$ & ZnCr$_2$O$_4$ for band frustrated ZnCr$_2$Se$_4$ and for ZnCr$_2$Se$_4$ which is also bound frustrated but dominated by ferromagnetic (FM) exchange. The pattern of splitting is different for the different compounds and crucially depends on the nature of frustration and of the resulting spin order. HgCr$_2$S$_4$ which is almost FM, exhibits on splitting of the eigen frequencies but shows significant shifts due to FM spin fluctuations. [32]

In this paper the authors studied the absorption edge and diffuse reflectance spectrum of HgCr$_2$S$_4$ have been measured between 20 $^0$ k & 400 $^0$ k. The anomalous edge shifts observed below the Curie-Wess temperature in all ferromagnetic chromium spinels can be qualitatively understood in terms of magnetoelastic volume strain. [33]

In this paper the research scholars discussed cadmium selenide thin film were deposited on glass substrate using chemical bath technique for different bath temperature 313 k, 333 k and 353 k. Polycrystalline nature of the material was confirmed by X-ray diffraction technique and
various structural parameters were calculated. The spherical shaped clusters and the presence of elemental constituents were characterized using SEM and energy dispersive X-ray analysis (EDAX). The optical properties were revealed by uv-visible transmittance spectra and the bandgap energy was determined. [34]

In this present paper the authors addressed the question of an impurity related origin of the colossal magnetocapacitive effect in the spinel system CdCr$_2$S$_4$. Here the author demonstrates a strong variation in the dielectric constant below the magnetic translation temperature or in external magnetic fields also in crystals prepared without chlorine. This excludes that an inhomogeneous distribution of chlorine impurities at the surface or in the bulk material gives rise to the unusual effects in spinel multiferroics. In addition, authors show that colossal magnetocapacitive effects can be also generates in chlorine free ceramic samples of CdCr$_2$S$_4$, doped with indium. [35]

In this present paper the authors studied the infrared reflectance spectra of hot-pressed CdCr$_2$S$_4$ and CdCr$_2$Se$_4$ and have been measured at temperatures above and below the Curie temperature. Two strong reflectance peaks are observed for these materials. These reflectance peaks are attributed to the reststrahlen bands due to the ionic bonds between the positive metals ions and the negative chalcogen ions. From the reflectance spectra, the transverse and longitudinal optical phonon frequencies and the static dielectric constants are calculated. [36]

In this paper the authors present detailed study of the electric and charge transport properties of the antiferromagnetic cubic spinel HgCr$_2$S$_4$. Similar to the finding in ferromagnetic CdCr$_2$S$_4$, the dielectric constant of HgCr$_2$S$_4$ becomes strongly enhanced in the region below 60-80 k which can be ascribed to polar relaxational dynamics triggered by the one set of ferromagnetic correlations. In addition, the observation of polarization hysteresis curves indicates the development of ferroelectric order below about 70 k. Moreover, the investigations in external magnetic fields up to 5 T reveal the simultaneous occurrence of magnetocapacitance and magnetoresistance of truly colossal magnitudes in this material. [37]

The paper presents the effect of deposition parameters of CdS thin films developed by chemical bath deposition technique. The deposition parameters such as speed of rotation of substrate, temperature of chemical bath, pH of solution and deposition time were optimized. The structural surface morphology of as deposited CdS thin films were characterized by XRD, SEM. The material was confirmed as single cubic phase. The average grain size obtained of CdS in the
film was 10 nm to 22 nm. The physical condition was kept identical while growing the sample. The investigation of the effect of the synthesis method on the grain size and the effect of the grain size on the properties of semiconductor is under consideration. [38]

In this paper the authors study the multiferroic materials, which reveal magnetic and electric order, are in the focus of recent solid state research. Here they present measurements on a simple cubic spinel with unusual properties. It shows ferromagnetic order and simultaneously relaxor ferroelectricity. They attribute the relaxor properties to geometric frustration which is well known for magnetic moments, but here is found to impede long range order of the structured degrees of freedom. [39]

In this paper the authors studied the optical properties of antiferromagnetic ZnCr$_2$Se$_4$ by infrared spectroscopy up to 28,000 cm$^{-1}$ and for temperatures from 5 to 295 k. At the magnetic phase transition at 21 k, one of the four phonon modes reveals a clear splitting of 3 cm$^{-1}$ as a result of spin-phonon coupling, the other three optical eigen modes only show shifts of the eigen frequencies . At higher energies the authors observed a broad excitation band which is dominated by a two-peak-structure at about 18,000 cm$^{-1}$ and 22,000 cm$^{-1}$, respectively. These energies are in good agreement with the expected spin-allowed crystal-field transitions of the Cr$^{3+}$ ions. [40]

In this paper discussion of the recent results in physics and technology of ternary magnetic oxide and chalcogenide spinels AB$_2$X$_4$ (A= Fe, Mn, Co, Cd, Zn, Hg, B=Cr, Co, Sc, Al; X= O, S, Se) are reviewed. Using magnetic susceptibility, specific heat, thermal expansion, electro-spin resonance, neutron diffraction, broad-band dielectric spectroscopy, and infrared optical spectroscopy, the spin, charge, orbital, and lattice correlations in these compounds were investigated. [41]

In this paper the study of materials showing simultaneous ferromagnetic and magnetic ordering are attracting a great deal of interest because of their unusual physics and potential applications. Hemberger et al have reported relaxor-like dielectric properties and colossal magnetocapacitance (in excess of 500 %) for the cubic spinel compound CdCr$_2$S$_4$ and related isomorphs, concluding that CdCr$_2$S$_4$ is a multiferroic relaxor. We argue here, however, that their results might also be explained by a conductive artifact. [42]

This paper the authors discussed CdCr$_2$S$_4$ is a good representative of the few known Heisenberg 3D ferromagnets. Authors present here a complete study of its structural and
magnetic properties as a function of temperature. They give a direct estimate of the magnetic coupling constants extracted from measurement of the magnon dispersion curve.[43]

In the present paper authors have studied the dielectric properties of the ferromagnetic spinel CdCr$_2$S$_4$ from first principles. Zone-center phonons and born effective charges were calculated by frozen-phonon and Berry phase techniques within LSDA+U. We find that all infrared-active phonons are quite stable within the cubic space group. The calculated static dielectric constant agrees well with previous measurements. These results suggest that the recently observed anomalous dielectric behavior in CdCr$_2$S$_4$ is not due to the softening of a polar mode. We suggest further experiments to clarify this point. [44]

In this paper the study of Cadmium selenide (CdSe) thin films were deposited on a glass substrate using the chemical bath deposition method at room temperature is done by the authors. The films were deposited using cadmium acetate as a Cd$^{2+}$ ion source and sodium selenosulfate as a Se$^{2-}$ ion source. The 'as-deposited' CdSe thin films are red in colour and specularly reflective. The 'as-deposited' CdSe layers grew with nanocrystalline cubic phase along with some amorphous phase present, with an optical band gap $E_g$ of 2.3 eV and electrical resistivity of the order of $10^5$–$10^6$ Ω cm. The 'as-deposited' film is annealed in air at 673 K for 4 h and the effect of annealing on structural, morphological, optical and electrical properties is studied .[45]

In this paper, the authors based on the results of field-dependent dielectric and magnetic measurements, they observe several interesting behaviors and phase transitions in this geometrically frustrated spinel system CdCr$_2$S$_4$. A glassy dipolar state occurs near $T_C K \sim 85$, which is induced by the onset of ferromagnetic ordering. (2) A ferroelectric ordering occurs near $T_p K \sim 56$, which is enhanced by externally applying electric field. (3) Both the magnitude and step-up temperature of dielectric constant ($\varepsilon'$) near $T_C$ are suppressed by an electric field yet are increased by the magnetic field. (4) Both electric and magnetic fields colossally enhance the magnitude of dielectric constant ($\varepsilon'$) near $T_p$. (5) a clear dip of magnetization under various electric fields is observed near $T_p$ indicating the different spin-dipole interactions near $T_C$ and $T_p$. [46].