EFFECTIVE DIELECTRIC CONSTANT OF PERIODIC COMPOSITE MATERIAL WITH SPHERICAL INCLUSION

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This is to certify that the thesis prepared by **Bayou Mamo** Graduate Studies entitled "**Effective Dielectric Constant of periodic Composite Material with spherical Inclusion**" in fulfillment of the requirements for the degree of **Master of Science** complies with the regulations of the University and meets the accepted standards with respect to originality and quality. .

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Abstract

We have studied the optical properties of nanospherical metal inclusions in dielectric host matrix. Both analytical and numerical methods are employed for analyzing this nano composite system. The real and imaginary part of the dielectric constant, refractive index and absorption coefficient the composite system as a function of the concentration of nanospherical metal inclusion is investigated. The result indicates that the magnitude of these optical constants are amplified with an increment of concentration nanospherical inclusions in the dielectric host matrix.

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Chapter 1

Background of the Study

1.1 Introduction

Over the recent years composites have received much attention particularly with the introduction of nanoparticles. One of the important properties of composites in general is their dielectric properties. The dielectric properties of composite materials is an interesting study in recent Years. It provides fundamental problems which are not completely answered[1, 2]. The dielectric properties of composites play an important role in areas such as microelectronic and optoelectronic packaging materials [3]. These include as medical use, geographical mapping and electromagnetic absorption cross section materials. The effective property of composite material depend on the intrinsic properties of the inclusions and the host matrix, as well as on the morphology of the composite. Dielectric constant is a function of the geometry, the volume fraction and the physical properties of the materials. The study of optical properties of the composite material is an interest both from the technological point view and from the basic physics view point[4, 5]. Most of these composite materials are fabricated with metallic nanoparticles embedded in a dielectric medium[6]. One of the most widely used method for calculating the dielectric properties of composite materials is the

Maxwell-Garnett approximation[7]. In 1904 Maxwell-Garnett has developed theory mixing formula gives the permittivity of this effective medium in terms of the permittivity and volume fraction of the individual constituents of the complex medium[8]. This originates from the fact that the effective permittivity of composite materials is basically an averaged property, where the average is taken over the ensemble of the realizations of disorder. Composites have been extensively studied for functional and structural applications. The effect of combining two or more materials together is to produce a resultant material with different properties. Some of the properties that may be of interest to a materials science include such things as the mechanical, thermal and electrical properties of composite materials. The scientist may wish to enhance or influence a combination of these properties in order to produce a desired effect which are interests for designing of metals in dielectric host matrix [9].

1.2 Statement of the Problem

Dielectric containing embedded metallic nanoparticles exhibit peculiar linear and nonlinear optical properties, mainly due to the surface plasmon resonances of the metallic inclusions. The nanoparticles shapes predominantly and characteristically determine the spectral positions and polarization dependence of the surface plasmon resonances in the visible and near infrared. Most research can be done on dielectric constant experimentally by using Maxwell-Garnet effective medium(Ref 10), to be more observable, I studied by using Drude effective models of Metals Dielectric Functions. Depending on Drude effective models, I studied the effect of the concentration of the nano metal inclusion in the dielectric host matrix. Moreover, the effective dielectric constant, the absorption coefficient and the refractive index of the intended system are described.

1.3 Basic Research Question

This study expected to find out the following leading question

1.How can we illustrate the effective dielectric function?

2.How can we determine the effect of concentration on the effective dielectric function of spherical metals inclusions in dielectric host matrix?

3.How can we determine the effect of concentration on the absorption coefficient of spherical metals inclusions in dielectric host matrix?

4.How can we determine the effect of concentration on the refractive index of spherical metals inclusions in dielectric host matrix?

1.4 Objective of the Study

1.4.1 General Objective

The general objective of this study is :-

To investigate the effective dielectric constant of periodic composite material with spherical inclusion.

1.4.2 Specific Objectives

The specific objective of this study are :-

- To identify the effective dielectric function.

- To determine the effect of concentration on the effective dielectric function of spherical metals inclusions in dielectric host matrix.
- To determine the effect of concentration on the absorption coefficient of spherical metals inclusions in dielectric host matrix.
- To determine the effect of concentration on the refractive index of spherical metals inclusions in dielectric host matrix.

1.5 Significance of the Study

In this thesis we want to know numerical result concerning the permittivity of periodic composite media as a function of the permittivity and volume fraction of constituent material. This study will contribute important information to researchers and experts who want to conduct in the area of effective dielectric constant.

1.6 Scope of the Study

Due to time constraint; the study is limited to theoretical analysis and calculation for the effective dielectric constant of periodic composite material with spherical inclusion.

1.7 Limitation of the study

The limitation of this study is a time constraint in analyzing the details with observational study and internet sites might be down or no longer available for study.

1.8 Thesis Outline

This study contains five chapters and organized as follows: In chapter one, we have discussed some background of dielectric constant, including the statement of the problem, objectives, significance and scope of the study. In Chapter two, We attempt to review some main ideas by different author, scholars and researchers in different times of reference in the concept of effective dielectric constant of periodic composite material with spherical inclusion such as, absorbtion coefficient and refractive index. In chapter three we introduce the analytical and numerical methods used to carry out the study. In chapter four, we calculate dielectric constant in terms of volume concentration, the absorption coefficients and refractive indexes of composite material with spherical inclusion are determined. Finally in chapter five, we draw some conclusions.

Chapter 2

Review of Related Literature

2.1 Introduction

Effective permittivity can be modeled using effective medium theory (EMT). EMTs are used to calculate effective properties of the resultant medium by taking into account the size, shape, fraction and dielectric constant of both the fillers and the host matrix. Dielectric constant of Ag is theoretically derived using the Drude-Lorentz model [10]. EMTs are generally valid only for low-volume fraction of the inclusions. For metallic inclusions of nanoparticles. Theoretical framework Dielectric function of metal Dielectric of any material consists of a real term and an imaginary term. For noble metals such as gold, silver complex dielectric function can be decomposed into two components [11]. One component is the Drude free-electron term, and the second component is the substantial contribution of the bound or inter-band electrons. Since the dielectric function is additive, it can be written as the sum of free electron and inter-band electron contributions [12]. The expression for dielectric function of bound electrons can be written using Lorentz oscillator model. The complex dielectric function for the free electrons is given by Drude model. Nanotechnology caused a breakthrough in material science, engineering and of course industrial applications.

The use of this technology in enhancing electrical, mechanical and thermal properties of dielectrics has found a great interest from researchers and scientists. As the use of this technology with dielectrics is recent, there are several challenges facing researchers working in this area. Exact evaluation of the effective dielectric constant of nanofilled composites is one of these challenges. Therefore, the effective dielectric constant of nanofilled composites is of high concern in development of science and Technology. Permittivity is a very important physical quantity that depicts how the electric field affects and how it also affects the dielectric medium that it propagates through it. The ability of the dielectric material to polarize when the electric field acts on the medium and thereby reduce it is determined by the permittivity. One of the most basic examples is that of a capacitor, whose permittivity if increased allows the same amount of charge to be stored at even smaller electric fields. Enhancement of permittivity is possible by the use of novel materials which can be made using mixtures. The term nanospherical metal dielectric composite system refers to those materials incorporated into the metal dielectric host matrices are metals and semiconductors. Once they are mixed in, a host system is created that may have significantly different optical properties than the original dielectric and acquire different shape and different property when compared to their corresponding bulk material due to the confinement of charge carriers(electrons and holes)to sharper a nano-scales in two directions. The overall electric, magnetic, and optical properties were not only governed by the behavior of raw materials. In the non-diluted composites, individual metal inclusions contribute for the effective electromagnetic properties; however, propagation of electromagnetic wave in nano-metallic may show completely different behavior as compared with bulk metals. composites have a good strength to weight ratio and in certain cases, may be used to replace the more traditional materials used in the manufacturing of aircraft, space technology, cars, ships, or may be used for other potential applications where the ratio of strength to weight is an important factor. Depending on the application, the thermal and electrical properties may also be important factors which need to be considered when designing of composites. Knowledge of the frequency-dependent dielectric function gives insight into the underlying elementary excitations of materials, such as , free carrier absorption, super conducting gaps, plasmon resonances, excitons, or interband absorption. The dielectric function of silver together with that of other noble metals has played an important historical role in the understanding of the electronic structure of metals [13]. This role continues for understanding the ultra fast electron dynamics of metals. Silver in particular assume a special status due to its high optical conductivity and wide range of applications from mirrors to plasmonics and optical metamaterials. However, similarly to the case of gold [14], large variations exist among historical measurements of the dielectric function of silver, especially for the imaginary part near the interband transition in the visible/ultraviolet (visible/UV) region. Most of these measurements only cover a narrow energy range, making a direct comparison between the different experiments difficult. In addition, discrepancies between theoretical and experimental values of different optical and plasmonic properties of silver have raised concerns over the accuracy of some of the most widely used measurements of the dielectric function of silver. Accurate values for the dielectric function of silver are needed in the visible and infrared (IR) spectral ranges, because many important parameters, such as surface plasmon propagation length, plasmon lifetime, non radiative loss, are sensitively linked to small variations of the dielectric function.

2.2 Dielectric Material

Dielectric materials are electrically non-conducting materials. All dielectric materials are insulating materials. The difference between a dielectric and an insulator lies in their applications. If the main function of non-conducting material is to provide electrical insulation, then they are called as insulator. On the other hand, if the main function of non-conducting material is to store electrical charges then they are called as dielectrics. Generally, the dielectrics are non-metallic materials of high resistivity and they have a very large energy gap (more than 3eV). As there are no free electrons to carry the current, the electrical conductivity of dielectrics is very low. They have negative temperature coefficient of resistance and high insulation resistance. The dielectric materials can be classified into active and passive dielectric materials. When a dielectric material is kept in an external electric field, if it actively accepts the electricity, then it is known as active dielectric material. Thus, active dielectrics are the dielectrics, which can easily adapt themselves to store the electrical energy in it. But Passive dielectrics are the dielectrics, which restrict the flow of electrical energy in them so, these dielectrics act as insulators. A dielectric characteristic of a material is determined by its dielectric constant. Dielectric constant is a measure of polarization of the dielectrics. It is the ratio between absolute permittivity of the medium and permittivity of free space. The permittivity represents the dielectric property of a medium. It indicates easily polarizable nature of materia. The process of producing electric dipoles inside the dielectric by the application of an external electrical field is called polarization.

2.3 Composite System Theory

Composite is a material which is composed of two or more materials at a microscopic scale and has chemically distinct phase or constituent materials have significantly different properties. In a composite material, one of the constituents of a continuous matrix which were called a host matrix while the other dispersed in the host matrix was called inclusion or filler [15]. The properties of composite materials were related to the properties and fraction of the constituents. The electromagnetic properties of composite can be tailored by varying the properties and fraction of the constituents. The effective permittivity is a quality attributable to heterogeneous media to be able to introduce this concept, the sizes of the inclusions have to be considerably smaller than the wavelength of the operating electromagnetic wave field [16]. Over the recent years particulate composites have received much attention particularly with the introduction of nanoparticles. Nanoparticles offer improved mechanical, electrical, and thermal properties of composites at relatively low concentrations.

2.3.1 Composites With Periodic Microstructure

The theoretical discussion of the effective properties of composites with periodic microstructure is similar to the more general discussion of the effective properties of random media, except that the information on the microstructure is complete in the periodic case, whereas it is only partial in the random case. The question of the effective properties of a composite implicitly assumes that the problem contains two scales which are well separated. The microscopic scale (or local scale) is small enough for the heterogeneities to be separately identified. The effective properties at the macroscopic scale of the composite are determined from geometrical and material data available from the study of a representative volume element. For periodic composites, these data are completely specified from the geometrical and material properties of a unit cell which generates by periodic repetition the whole microstructure of the composite.

2.4 Maxwell Equation

The interaction between electromagnetic waves and dielectric material is ruled by Maxwell equation. The wave for electric and magnetic field in using the four electromagnetic equation[17]. Macroscopic aspect of the static and dynamic of the electromagnetic field of the Maxwell's equations in a material media are described as follow.

$$\nabla.\vec{D} = \rho_f \tag{2.4.1}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{2.4.2}$$

$$\nabla.\vec{B} = 0 \tag{2.4.3}$$

$$\nabla \times \vec{H} = \vec{J_f} + \frac{\partial \vec{D}}{\partial t} \tag{2.4.4}$$

where $\vec{D}$ is electric displacement, ρ_f is a free charge density, $\vec{B}$ is magnetic field intensity, $\vec{E}$ electric field, $\vec{H}$ is magnetic field and $\vec{J_f}$ is a free current density. The electromagnetic properties of material media may be taken in to account through relations, $\vec{D} = \epsilon\vec{E}$, $\vec{B} = \mu\vec{H}$ and $\vec{J} = \sigma\vec{E}$ is Known as constitutive relation. Where σ is electric conductivity, ϵ is electric permittivity, μ is magnetic permeability.

If there are N such molecules per unit volume the macroscopic polarization $\vec{P}$ is proportional to the applied field.

$$\vec{P} = N\vec{p} \tag{2.4.5}$$

$$\vec{P} = \epsilon\chi_e\vec{E} \tag{2.4.6}$$

$$\vec{D} = \epsilon(1+\chi_e)\vec{E} \tag{2.4.7}$$

Applying the curl operation to both sides of equation we obtain

$$\nabla \times (\nabla \times \vec{E}) = -\nabla \times \frac{\partial \vec{B}}{\partial t} = -\frac{\partial}{\partial t}(\nabla \times \vec{B}) \tag{2.4.8}$$

$$\nabla \times (\nabla \times \vec{E}) = \nabla(\nabla.\vec{E}) - \nabla^2\vec{E} \tag{2.4.9}$$

$$\nabla(\nabla.\vec{E}) - \nabla^2\vec{E} = -\mu\frac{\partial^2}{\partial t^2}(\epsilon_o\vec{E} + \vec{P}) \tag{2.4.10}$$

$$\nabla^2\vec{E} - \nabla(\nabla.\vec{E}) - \frac{1}{c^2}\frac{\partial^2\vec{E}}{\partial t^2} = \frac{1}{\epsilon_{oc^2}}\frac{\partial^2\vec{P}}{\partial^2 t} \tag{2.4.11}$$

Electromagnetic energy transformation whether it occurs reversibly or irreversibly is always the result of the electron interaction of electromagnetic waves with actual materials or dielectric composite system that perturbs the local distribution. This variation produces periodic electron separation within the particles, causing wave of the induced local dipole moment. This periodic wave act as a source of electromagnetic wave, that causing propagating [18].The resulting net dipole moment per unit volume is called the polarization.

2.5 Harmonic Oscillator Models

The Drude and Lorentz models were developed in the electronic kinetic theory of microscopic electrons to explain the optical properties of materials. The models were further extended in to the Drude-Lorentz model, which describes the dielectric properties of solid materials. A charge within a medium is treated as a harmonic oscillator, which is bounded with a nucleus. Under the excitation of an incident electromagnetic wave, the oscillator will oscillate in the oppositional phase relative to the electric field. From the dynamic point of view, the charge oscillation will lead to the charge redistribution, which will create an additional induced electric field. The induced field will restore the charge to its equilibrium position. The story of these plasma oscillations begins with Langmuir's observations in low pressure mercury vapor discharge tube. He observed that under a wide range of conditions, there were many electrons with abnormally large velocities, whose voltage equivalent is greater than the total voltage drop across the tube. There were an even larger number of electrons with Kinetic energies lower than the average KE, so the group as a whole has not acquired extra energy, but there has been a redistribution of energy. Dittmer obtained evidence pointing in this direction and Penning observed such oscillations of radio frequencies in low pressure mercury and argon vapor discharges. The interaction of metals with electromagnetic radiation is largely dictated by the free conduction electrons in the metal. According to the simple Drude model, the free electrons oscillate relative to the driving electric field. As a consequence, most metals possess a negative dielectric constant at optical frequencies which causes a very high reflectivity. Furthermore, at optical frequencies the metal's free electron gas can sustain surface and volume charge density oscillations, called Plasmon polaritons or plasmons with distinct resonance frequencies. The existence of plasmons is characteristic for the interaction of metal nanostructures with light. Similar behavior cannot be simply reproduced in other spectral ranges using the scale invariance of Maxwell's equations since the material parameters change considerably with frequency. Specifically, this means that model experiments with example microwaves and correspondingly. Exposure of a metal nanoparticle to an electric field results in a shift of the free conduction electrons with respect to the particle's metal ion-lattice. The resulting surface charges of opposite sign on the opposite surface elements of the particles produce a restoring local field within the nanoparticle, which rises with the increasing shift of the electron gas relative to the ionic background. The coherently shifted electrons of the metal particle together with the restoring field consequently represent an oscillator, whose behavior is defined by the electron density and the geometry of the particle. Throughout this text the nanoparticles' resonances are called surface plasmons on metal nanoparticles. In other words, plasmas frequencies equivalently behave as conductor or dielectric materials for electromagnetic wave and these behaviors were control by changed complex permittivity, or electron density and collision, which was associated with the electron plasma frequency and the electron elastic collisions frequency; this controllability and the time-varied manner for permittivity distinguish from composite to other electromagnetic media. The unique feature in which discharge composite for control of electromagnetic wave derived from permittivity and reveal in the Drude model; Lo and Coworkers [20] successfully observe the effective modification of electromagnetic waves propagation by metal-plasma composites.

2.5.1 Lorenz Local Field and Oscillatory Models

As a classical approach; the concept of a local field was originally introduced by Lorenz and effective electric field is known as the Lorenz local field. Linear optics considered the linear dependence of the polarization the electric field is expressed. The linear susceptibility is defined in terms of the macroscopic electric field $\vec{E}$ and polarization $\vec{P}$ of the medium but the polarization $\vec{P}$ of nanoparticle has to be defined in a microscopic form in terms of local or effective electric field E_{loc} at the site of the particle and its dipole moment $\vec{P}$.

$$\vec{P} = N\vec{p} \tag{2.5.1}$$

$$\vec{P} = \alpha E_{loc} \tag{2.5.2}$$

Based on the assumption of a spherical cavity which the molecule located at the center Lorenz obtained a relation between microscopic local field with the microscopic field as [21]

$$E_{loc} = \vec{E} + \frac{\vec{P}}{3\epsilon_o} \tag{2.5.3}$$

where N is the number of particle per unit volume and the equation is known as Lorenz-Lorenz relation. Then equation for dielectric function in terms of polarizability is written as.

$$\frac{\epsilon^{(1)} - \epsilon_h}{\epsilon^{(1)} + 2\epsilon_h} = \frac{N\alpha}{3} \tag{2.5.4}$$

The equation is known as Clauses- Mossotti relation where $\epsilon^{(1)}$ is dielectric function of small spherical particle and ϵ_h is the dielectric function of the embedding host material, is number of inclusion [22]. Lorenz describes optical properties of materials focus on electrons and ions of the medium where simple harmonic oscillators and neglected material properties such as the lattice potential and electron-electron interaction. Lorenz model is a theory in which electrons and ions in a material were treated as harmonic oscillators which are under the influence of deriving local electric field and damping force. Based on this consideration the expression for dielectric function of the particle can be obtained [23].

$$\epsilon^1 = \epsilon_\infty + \frac{\omega_p^2}{\omega_p^2 + \omega_o^2 - i\gamma\omega} \tag{2.5.5}$$

Where ω is the frequency of the applied field, ω_o is resonance frequency of the oscillatory and ω_p is the plasma frequency,γ is the damping parameter, ϵ_∞ is dielectric function when oscillation is at much higher frequencies.

2.5.2 Drude Effective Models of Metals Dielectric Functions

The complex dielectric of metals are investigated and described by Drude model[24]. This model deals about electrons not bound to a particular nucleus. From the simplest model of Drude dielectric function relation; the frequency depends on the dielectric function of metal and semi-conductors. Drude model was interested to note that an account of intra and inter band transition and electron mean free path dependence on the metal size. In this model the electrons do not interact with each other and are scatter randomly by ionic core. Then in a dielectric composite medium electrons are permanently bound to the metal inclusion of the medium. Applying sufficient electric field can displace an electron at a distance (r) from its equilibrium position. But can attracting force from nucleus also act on the electron of charge -e with mass m executed forced propagation in a time-periodic electric field. From the force balance the equation of motion for an electron bounded by harmonic force and acting on by an electric field [25].

$$F_{inertia} + F_{damping} + F_{repelsive} = F_{electrical} \tag{2.5.6}$$

Suppose that when Drude dielectric function have no free electrons in a metals dielectric constant, then an applied electric field can produce propagation with accordance to the time factor of $e^{-i\omega t}$. From equation (2.6.6) the differential equation of motion of electron has the form.

$$m\frac{\partial^2 r}{\partial t^2} + m\gamma\frac{\partial r}{\partial t} + \alpha r = -eE \tag{2.5.7}$$

Where m is effective mass of bound electrons, γ damping constant, α is the spring constant of the potential that keeps the electron in place.

$$m\frac{\partial^2}{\partial t^2}(r_o e^{-i\omega t}) + m\gamma\frac{\partial}{\partial t}(r_o e^{-i\omega t}) + \alpha r = -eE \tag{2.5.8}$$

constant, $\omega_o = \sqrt{\frac{\alpha}{m}}$ was propagation frequency of the bound electron (natural frequency)

$$(-\omega^2 - i\gamma\omega + \omega_{o)}^2 r = -\frac{eE}{m} \tag{2.5.9}$$

$$r = -\frac{eE}{m}\frac{1}{(\omega_o^2 - \omega^2 - i\gamma\omega)} \tag{2.5.10}$$

The dipole moment per unit volume is known as polarization becomes

$$P = -er = \frac{-e^2 E}{m}\left(\frac{1}{\omega_o^2 - \omega^2 - i\gamma\omega}\right) \tag{2.5.11}$$

If there are N electrons per unit volume (fi) with binding frequency ωi and damping constant γi, polarization by this equation

$$P = -np = \frac{-ne^2 E}{m}\sum_i fi\left(\frac{1}{\omega_o^2 - \omega_i^2 - i\gamma\omega}\right) \tag{2.5.12}$$

The contribution from bound electrons to the dielectric function ϵ_c was quite similar to the corresponding resonance in dielectric materials, and these can be written in Lorentz form as

$$\epsilon_{free}(e) = 1 + \sum_i \left(\frac{fi\omega_p^2}{\omega_i^2 - \omega^2 - i\gamma\omega}\right) \tag{2.5.13}$$

There is the interaction of light with matter the main effect of matter incoming light is to make electrons oscillation their response depend on the interactions with the atomic solid in which they live and with each other. As a starting point, we consider only the effects of the free electrons and apply the Drude-Sommerfeld model for the free-electron gas by considering damping factor i.e

$$\frac{m_e\partial^2 r}{\partial t^2} + m_e\gamma\frac{\partial r}{\partial t} = -e\vec{E} \tag{2.5.14}$$

let E=$E_o e^{-i\omega t}$,r=$r_o e^{i\omega t}$

when we combining the above let equation with equation 2.6.14 result in

$$-\omega^2 mr - i\omega m\gamma r = -e\vec{E} \tag{2.5.15}$$

$$r(t) = \frac{e}{m(\omega^2 + i\gamma\omega)}E(t) \tag{2.5.16}$$

$$P = -ner = \frac{-ne^2}{m(\omega^2 + i\gamma\omega)}E(t) \tag{2.5.17}$$

$$\vec{D} = \epsilon_o\vec{E} + P = \epsilon_o\epsilon E \tag{2.5.18}$$

solving these two equation (2.6.18) and (2.6.19) result in

$$\vec{D} = \epsilon_o\left(1 - \frac{ne^2}{\epsilon_o m(\omega^2 + i\gamma\omega)}\right)E \tag{2.5.19}$$

$$\vec{D} = \epsilon_o(1 - \frac{\omega_p^2}{\omega^2 + i\gamma\omega})E \tag{2.5.20}$$

from equation 2.6.16 and 2.6.20 we get the dielectric function of the free electrons gas

$$\epsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2 + i\gamma\omega} \tag{2.5.21}$$

$$\epsilon(\omega) = (1 - \frac{\omega_p^2}{\omega^2 + i\gamma\omega}) \times (\frac{\omega^2 - i\gamma\omega}{\omega^2 - i\gamma\omega}) \tag{2.5.22}$$

$$\epsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2 + \gamma^2} + \frac{i\gamma\omega_p^2}{\omega(\omega^2 + \gamma^2)} \tag{2.5.23}$$

Equation (2.6.23) show that the real and imaginary component of dielectric function

2.6 Effective Concentration of Metal Dielectric Composite

Effective medium theories and other mean-field like theories are physical models based on properties of individual components and their fractions in the composite [26]. Effective medium theories define an effective dielectric function for a composite material in terms of the dielectric function of its components and their geometrical arrangement[27,28]. The applicability of effective medium theories is restricted by the size of the structures composing the mixture: sufficiently large to preserve locally their own electromagnetic behavior and small enough for the composite to appear homogeneous compared to the wavelength of the interacting radiation. Over the last century numerous effective medium theories have been proposed, being the Maxwell-Garnett and the Bruggeman expressions the most successful to explain the effective behavior of a large number of composites. Composite nanostructures are often made from two or multiple materials in either an arbitrary fashion or ordered patterns. Among them, the host materials are often electromagnetically continuous media, while a small number of inclusions or particles are incorporated in host materials. For the composite nanostructures made from metallic and dielectric components, the over all optical properties may be significantly different from those of constituent host materials, and also differ greatly from its inclusions. It is hard to develop a universal method to analyze the optical properties of such arbitrary nanostructure materials. In general composite nanostructures are designed based on one of two strategies: The random metal-dielectric composites and well-structured building block. In both of these cases, the dimensional sizes of the constituted structures are designed intentionally smaller than the wave length. In such a condition, the composite nanostructure is assumed to be an effective continuum medium. The overall effective optical effects can be described by the previously known dielectric functions of individual components and their volume fractions. There are several analytical approaches to derive the effective electromagnetic response of the composite materials, which are often known as the effective medium approach. In the effective medium theory, the electromagnetic responses of the composites are assumed to be electric dipoles, and the collective responses of the electric dipoles take on an overall dielectric response of the matter. When the relative concentration of inclusion particles embedded in the host material is small and the inclusions have well-defined shapes, this type of composite topology is called Maxwell-Garnett geometry. When the percentage compositions of two constituent materials are almost identical to each other, the two compositions play comparable roles in its optical parameters. This type of heterogeneous topology is called Bruggeman geometry. Corresponding to these topology geometries are two effective medium approaches that are widely used to obtain the effective parameters, i.e Maxwell-Garnett theory (MGT) and Bruggeman effective medium theory. Based on the Bruggeman formula, self-similar composite argument was shown to fit remarkably for non-dilute composite system [29]. The nearest neighbor interaction in an effective medium were treated by Sheng [30] used a "pair-cluster" theory of the effective medium theory inclusion threshold occurs at a fractional volume of small size that direct transport signal behavior is not greatly affected by nearest neighbor interaction depends on the material properties, but it appears more depend on the composite material, then immediately an electromagnetic wave propagation come across a variety of microscopic boundary conditions due to the inclusion made up of the composite system, since absorption always depend on the area of the electric field intensity. The local field variations have been very strong effect on the energy absorption at such boundaries. The relation of complex wave number and complex wave frequency was well investigated [31] in the field of microelectronics.

2.6.1 The Maxwell-Garnet effective medium theory

Maxwell-Garnett effective medium approximation is the easiest and widely used model for calculating effective dielectric quantities of composite materials consisting of many components [32]. These effective medium theory satisfactory predict the linear optical properties, Which is applicable to linear medium with inclusion whose size is very small compared to the wave length of light waves in the effective medium. The electric field in the inclusions is assumed to be uniform and the inclusion is separated by large distance in other words their concentration is very dilute so the particles are assumed to be non-interacting. At a higher fill fraction of the Maxwell

Garnett theory is inadequate. The metal particle close to each other and begin to interact, more over the nanoparticles can aggregate, and in order to the model the response of the structure that they form it is necessary to take in to account electric multiple order higher than dipole. There is no yet an accurate and experimentally confirmed theory for high fill fraction composites. Many of the proposed theories that treat composites in which the fill fraction of each component may be large are effective medium calculations [33]. The effective dielectric constant ϵ of a D-dimension Maxwell Garnett composite medium is there by found to be given by the relate

$$\frac{\epsilon - \epsilon_h}{\epsilon + (D-1)\epsilon_h} = f \frac{\epsilon_{i-\epsilon_h}}{\epsilon_{i+(D-1)\epsilon_h}} \tag{2.6.1}$$

Where ϵ is dielectric constant (permittivity) of a medium ϵ_h is the dielectric constant of host matrix, f is fraction of inclusion in a composite,ϵ_i is the dielectric constant of metallic inclusions. This model the embedded materials where considered as host medium and the input components was considered as inclusions.

2.6.2 Bruggeman Medium Theory

The Maxwell-Garnett theory only predicts the approximation of equivalent dielectric function in the dilute two-phase composite. In fact, with the increasing of the volume fraction of inclusions, the deviation between the effective properties predicted by the Maxwell-Garnett formula and by Lord Rayleigh become obvious. Bruggeman proposed a widely known mean-field theory to evaluate the effective dielectric function of composite media. In the Bruggeman theory, the inclusions and the surrounding medium are weighted symmetrically using the volume fraction of the individual components.

2.7 Mie Theory

In 1908 Mie [34] proposed a solution Maxwell equation for spherical particles interacting with plane electromagnetic waves, which explains the origin of surface Plasmon resonance (SPR) in the extinction spectra and coloration of metal collides. SPR occurs when the electron and light waves couple with each other at a metal-dielectric interface. The Mie theory is a theoretical approach concerning the optical properties of the nanoparticles When the nanoparticle dimension is smaller than the wavelength of the incident light, such theory predicts that the extinction caused by a metallic nanosphere is estimated in the quasi-static.

2.8 Absorption Coefficient

Depending on the shape and size of the particle, an electromagnetic field incident is characterized by nanospherical metals inclusion in dielectric host. The metallic nanosphere can strongly increase the absorption coefficient of electromagnetic wave in dielectric host. For example small metal diameter embedded in dielectric composite system; the wave of depolarized uniform electric field much less than the before incident electric field. For this reason, the frequency is enhanced. Absorption is a process by which the exited element of charge transforms electric into the incident electric field much. For this reason, the frequencies are enhanced. Absorption was a process by which the exited elements of charges transform in to the incident electromagnetic radiation. When nanoparticles are bounced by electromagnetic wave. The interaction between electromagnetic and nanospherical metal takes place between the optical electric field and the conduction band of an electron in dielectric host matrix. Some of the electromagnetic energy transferred into dielectric host in the form of heat via collisions.

2.9 Refractive Index

In composite medium the refractive index depend on the plasma frequencies that can propagate electromagnetic wave and electromagnetic wave so the different plasma frequencies can propagate in different speeds. In optical medium, the refraction index (n) is a dimensionless number that describes how electromagnetic radiation can propagates through that medium. It is defined as the ratio of the speed of electromagnetic wave in vacuum to the speed of electromagnetic wave in the composite medium. Refractive index is a function of angular frequency ω and wave vector K. In Vacuum, refractive index is not a function of the angular frequency i.e (0,k) of the incident electromagnetic wave ;but in a composite medium it depends on the angular frequency ω of the electromagnetic wave that propagates through it n(ω,0). To see how the composite of a medium affects the propagation of electromagnetic wave in nanospherical metals can be characterized by optical constants of the refractive index (n) and the absorption coefficient(K), that result in the complex refractive index in medium[35].

$$n(\omega) = n + iK \tag{2.9.1}$$

$$n(\omega)^* = n - iK \tag{2.9.2}$$

for absorption and propagation respectively. The refractive index was defined as the ratio of phase velocity of electromagnetic in metal to the phase velocity of electromagnetic in the host medium. Refractive index is increase as the wavelength λ is decrease and the Plasmon propagation at longer wavelengths were dominated by the electromagnetic wave inside the inclusion between sphere of radius(r) and the metal dielectric host. A larger host is required for the offset of reduced wavelength inside the higher index material. In general the refractive index (n) of a medium was a complex quantity, and its real part related with propagation of the electromagnetic field in the medium. For the choice of the noble metals which depends on the application wavelength, because the wavelength is dependent on the dielectric constants of metals. It is better for the dielectric constant of the metal has a high absolute value for the real part and a small imaginary part, which determines the absorption of the metal. Dielectric constant of metal can be written as a function to the plasma frequency; in first approximation it results: medium with a small attenuation.

Chapter 3

Materials and Methodology

This study has been carried out by using the following procedures. These are: study site and period, method of approach, materials used, and ethical considerations.

3.1 Study Site And Period

The study has been conducted at Jimma University, department of physics from September 2019 to January 2020.

3.2 Method of Approach

To achieve the stated objectives and problem, analytical methods for the dielectric function,the refractive index and the absorption coefficient of the composite system with graphical analysis be used.

3.3 Materials

Computers, books, standard journals, published papers, thesis, and the international science conferences report (dissertation) was a materials and resources for the goal of the thesis.

3.4 Methodology

3.4.1 Analytical

In this thesis one of the method or approach used to solve the problem is analytical method. Based on the theoretical concepts, this study was analyzed by the derive equations for real and imaginary part of dielectric constant function, absorption coefficient and refractive index was derived analytically.

3.4.2 Numerical

Based on the numerical optical parameters, We interpreted the result by graph with the help of MATIMATICA.

3.5 Ethical Issues

To be legal for collecting all the information and materials for the purpose of the study, it is important to have a permission letter. Therefore, I have got a letter of permission from ethical committee of the college.

Chapter 4

Results and Discussion

4.1 Propagation of Electromagnetic Wave in Nano Spherical Metal Dielectric composite

The optical properties of metallic nano particles are governed by the surface plasma resonance which are strongly depend on the nano particle size, shape and concentration. Moreover, the spatial distribution and the properties of the surrounding matrix affect the optical properties of metallic nanoparticles. These nonocomposite materials become a promising media for the development of novel nonlinear materials, nono devices and optical elements. In this study we are interested to describe a composite material with nano spherical metallic particles in a transparent dielectric host matrix. Propagation of electromagnetic waves in composite media is often treated by assigning an effective dielectric constant to the composite medium.

4.2 Optical Properties of Nano Composite With Spherical Nano Metal Inclusion

Exposure of a spherical nano metal to electro-magnetic radiation results in a shift of the free conduction electrons with respect to the particles metal-ion lattice. The resulting surface charges of opposite sign produce a restoring local field with in the nano particle which rises with increasing shift of the electron gas relative to the ionic background. The resulting surface charges of opposite sign produce a restoring local field with in the nano particle which raises the increasing shift of the electron gas relative to the ionic back ground. The coherently shifted electrons of the spherical nano metal together with a restoring field consequently describe on oscillatory, whose behavior is defined by the election density and the geometry of the particle. The theoretical description of surface plasmons of spherical nano particles is part of Mie's theory for scattering and absorption of light by spheres. In this study the applied field of electromagnetic radiation is considered as homogenous and not retarded over the particle's volume. In this case the polarizability α and induced dipole moment $\vec{P}$ of nano metallic sphere embedded in a dielectric host matrix can be derived from the electric potential. In the limit of quasi-static approximation the electric potential in the metal core and dielectric host matrix can be written as follows(35).

$$\phi_c = -E_o Ar\cos\theta, r < a \tag{4.2.1}$$

$$\Phi_h = -E_o(r - \frac{Ba^3}{r^2})cos\theta, r > a \tag{4.2.2}$$

where E_o is a uniform external electric field, a and r is a radius of a spherical nano metalic particle and dielectric host, θ gives the direction of the scattered wave with respect to the propagation direction of the source. A and B can be determined from the boundary conditions. The boundary condition are, the normal component of the dielectric displacement ($\vec{D}$) is continious at the boundary, that is

$$\epsilon_c \frac{\partial\Phi_c}{\partial r}|_{r=a} = \epsilon_h \frac{\partial\Phi_h}{\partial r}|_{r=a} \tag{4.2.3}$$

Moreover the tangential component of the electric field ($\vec{E}$) is continous at the boundary, that is

$$\frac{\partial \Phi_c}{\partial \theta}|_{r=a} = \frac{\partial \Phi_h}{\partial \theta}|_{r=a} \tag{4.2.4}$$

In addition to this, the electric potential is continues every where. Using equation (4.2.3) and (4.2.4)

$$\epsilon_c A = \epsilon_h (1 + 2B) \tag{4.2.5}$$

$$A = 1 - B \tag{4.2.6}$$

Solving these two equations (4.2.5) and (4.2.6) simultaneously then, result in

$$A = \frac{3\epsilon_h}{2\epsilon_h + \epsilon_c} \tag{4.2.7}$$

$$B = \frac{\epsilon_c - \epsilon_h}{\epsilon_c + 2\epsilon_h} \tag{4.2.8}$$

The polarizablity α and induced dipole moment $\vec{P}$ of a nano metalic sphere are given by:

$$\alpha = 4\pi a^3 \frac{\epsilon_c(\omega) - \epsilon_h}{\epsilon_c(\omega) + 2\epsilon_h} \tag{4.2.9}$$

The induced dipole moment $\vec{P}$ in general can be defined as:

$$\vec{P} = \alpha \epsilon_o \vec{E}_o(\omega) \tag{4.2.10}$$

Solving these two equation (4.2.9) and (4.2.10) result in

$$\vec{P}(\omega) = 4\pi \epsilon_o a^3 \frac{\epsilon_c(\omega) - \epsilon_h}{\epsilon_c(\omega) + 2\epsilon_h} \vec{E}_o(\omega) \tag{4.2.11}$$

where a is the radius of the nano particle, E_o the electric field strength of the incident electromagnetic wave, ϵ_o the electric permittivity of vacuum, $\epsilon_c(\omega)$ and ϵ_h are the relative complex electric permittivity of the metal and host matrix respectively.

The effective dielectric constant $\epsilon_{eff}(\omega)$ of a composite material with spherical metal inclusions having a filling factor $f = V_{metal}/V_{total}$ is given by

$$\epsilon_{eff}(\omega) = \epsilon_h \frac{(\epsilon_c(\omega) + 2\epsilon_h) + 2f(\epsilon_c(\omega) - \epsilon_h)}{(\epsilon_c(\omega) + 2\epsilon_h) - f(\epsilon_c(\omega) - \epsilon_h)} \tag{4.2.12}$$

Separating the real and imaginary part of the effective dielectric constant

$\epsilon'_{eff} = \epsilon_h\epsilon'_c(\epsilon'_c + 2\epsilon_h) - f\epsilon_h\epsilon'_c(\epsilon'_c - \epsilon_h) + 2\epsilon_h^2(\epsilon'_c + 2\epsilon_h) - 2f\epsilon_h^2(\epsilon'_c - \epsilon_h) + 2f\epsilon_h(\epsilon'_c - \epsilon_h)(\epsilon'_c + 2\epsilon_h) - 2f^2\epsilon_h(\epsilon'_c - \epsilon_h)^2 + \epsilon_h\epsilon''^2_c(1 - f)(1 + 2f)/([(\epsilon'_c + 2\epsilon_h) - f(\epsilon'_c - \epsilon_h)]^2 + \epsilon''^2_c(1 - f)^2)$

$\epsilon''_{eff} = \epsilon_h\epsilon''_c(\epsilon'_c + 2\epsilon_h)(1 + 2f) - f\epsilon_h\epsilon''_c(\epsilon'_c - \epsilon_h)(1 + 2f) - \epsilon_h\epsilon'_c\epsilon''_c(1 - f) + 2\epsilon_h^2\epsilon''_c(1 - f) + 2f\epsilon_h\epsilon''_c(1 - f)/([(\epsilon'_c + 2\epsilon_h) - f(\epsilon'_c - \epsilon_h)]^2 + \epsilon''^2_c(1 - f)^2)$

With respect to Drude-Sommerfeld formula, dielectric function of spherical nano metal is gives as

$$\epsilon_c(\omega) = \epsilon_\infty + 1 - \frac{\omega_p^2}{\omega^2 + i\gamma\omega} \tag{4.2.13}$$

The real and imaginary part of dielectric function of spherical nano metal is

$$\epsilon'_c(\omega) = \epsilon_\infty + 1 - \frac{\omega_p^2}{\omega^2 + \gamma^2} \tag{4.2.14}$$

$$\epsilon''_c(\omega) = \frac{\omega_p^2\gamma}{\omega(\omega^2 + \gamma^2)} \tag{4.2.15}$$

where ϵ'_c and ϵ''_c are the real and imaginary parts of ϵ_c respectively, Using dimensionless variable, $z = \frac{\omega}{\omega_p}$ and $\Gamma = \frac{\gamma}{\omega_p}$

$$\epsilon'_c(\omega) = \epsilon_\infty + 1 - \frac{1}{z^2 + \Gamma^2} \tag{4.2.16}$$

$$\epsilon_c''(\omega) = \frac{\Gamma}{z(z^2 + \Gamma^2)} \tag{4.2.17}$$

The absorbtion coefficient α and refractive index n of the composite system with respect to effective dielectric constant ϵ_{eff} can be expressed as

$$\alpha(\omega) = \frac{2\omega}{c}\sqrt{\epsilon''_{eff}(\omega)} \tag{4.2.18}$$

$$n(\omega) = \sqrt{\epsilon'_{eff}(\omega)} \tag{4.2.19}$$

The refractive index can be expressed in terms of the effective dielectric constant as $n^2 = \epsilon$, $\epsilon = \epsilon' + i\epsilon''$. Explicitly, this yield $\epsilon' = n^2 - k^2$, ϵ''=2nk, $k = \frac{\epsilon''}{2n}$

$$n^2 + k^2 = \sqrt{\epsilon'^2 + \epsilon''^2} \tag{4.2.20}$$

$$n^2 - K^2 = \epsilon' \tag{4.2.21}$$

From equation(4.2.20) and(4.2.21) the value of n where obtained as

$$n(z) = \frac{1}{2}(\epsilon' + \sqrt{\epsilon'^2 + \epsilon''^2})^{\frac{1}{2}} \tag{4.2.22}$$

$$n(z) = [\frac{1}{2}(\epsilon' + \sqrt{\epsilon'^2 + \epsilon''^2})]^{\frac{1}{2}} \tag{4.2.23}$$

From equation(4.2.20) and(4.2.21) the value of k where obtained as

$$k = [\frac{1}{2}(\sqrt{\epsilon'^2 + \epsilon''^2} - \epsilon')]^{\frac{1}{2}} \tag{4.2.24}$$

The absorbtion coefficient become to:

$$\alpha = \frac{2\omega k}{c} = \frac{2\omega}{c}[\frac{1}{2}(\sqrt{\epsilon'^2 + \epsilon''^2} - \epsilon')]^{\frac{1}{2}} \tag{4.2.25}$$

where c is the light velocity

4.3 Optical Properties and Graphical Results of Metal Dielectric Composite

In this section, we discussed the dielectric functions of the composite system that was described graphically. In order to understand the origin of the system in dielectric host medium we consider homogeneous spherical metal embedded in host medium. Therefore, at more intense incident electromagnetic fields, it is necessary to consider the effect of dielectric functions of the metal and the host material. From the theoretical point of view: propagation relation of electromagnetic wave in spherical metal dielectric composite is interpreted by graph. The mathematical expression of spherical metal nano inclusions in dielectric of volume fraction is present in the host system. Dielectric constant of the host is complex, but for simplicity we take it real. Typical metals that support the surface plasmons are silver. From Drude-Sommerfeld equation of dielectric function of the metal inclusion becomes:-

$$\epsilon_c'(\omega) = \epsilon_\infty + 1 - \frac{1}{z^2 + \Gamma^2} \tag{4.3.1}$$

$$\epsilon_c''(\omega) = \frac{\Gamma}{z(z^2 + \Gamma^2)} \tag{4.3.2}$$

4.4 Real and Imaginary Part of Dielectric Function

The variation of the effective concentration of nano spherical metal inclusions are demonstrated graphically and numerically. The real and imaginary parts depending on the equation (4.2.12) which us rewrite as follow

$$\epsilon_{eff}(\omega) = \epsilon_h \frac{(\epsilon_c(\omega) + 2\epsilon_h) + 2f(\epsilon_c(\omega) - \epsilon_h)}{(\epsilon_c(\omega) + 2\epsilon_h) - f(\epsilon_c(\omega) - \epsilon_h)} \tag{4.4.1}$$

when the number of inclusion increase, the electronic collision frequency is also increase. The real part of the dielectric constant (ϵ') describes refraction of electromagnetic wave propagation.

$\epsilon'_{eff} = \epsilon_h\epsilon'_c(\epsilon'_c+2\epsilon_h) - f\epsilon_h\epsilon'_c(\epsilon'_c-\epsilon_h) + 2\epsilon_h^2(\epsilon'_c+2\epsilon_h) - 2f\epsilon_h^2(\epsilon'_c-\epsilon_h) + 2f\epsilon_h(\epsilon'_c-\epsilon_h)(\epsilon'_c+2\epsilon_h) - 2f^2\epsilon_h(\epsilon'_c-\epsilon_h)^2 + \epsilon_h\epsilon''^2_c(1-f)(1+2f)/([(\epsilon'_c+2\epsilon_h) - f(\epsilon'_c-\epsilon_h)]^2 + \epsilon''^2_c(1-f)^2)$

The numerical calculation is made using the following optical parameter (ϵ_∞ =4.5, ϵ_h = 2.5,γ=0.095) considering nanospherical silver particle.

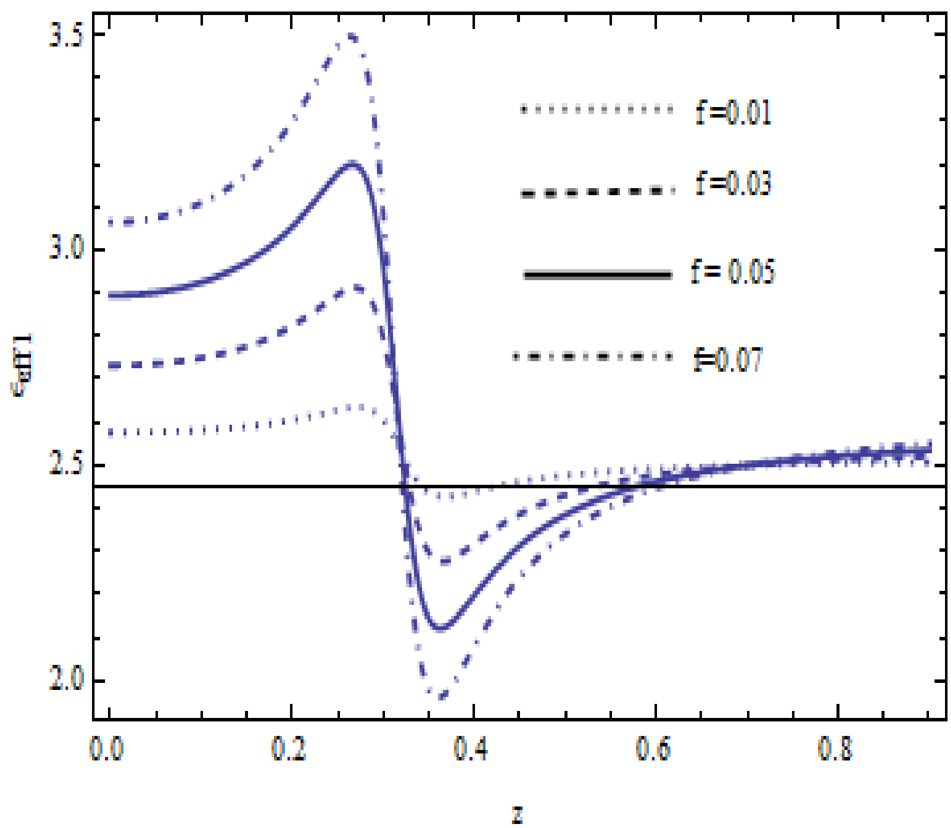

Figure 4.1: Real dielectric constant function of the nano spherical particle inclusions in the dielectric host matrix for different concentration

Fig. 4.1 show the real part of the effective dielectric constant for a given fractional concentration of f = 0.01, 0.03, 0.05, and 0.07. The numerical calculation shows the real dielectric constant increase as the fractional concentration of metals increase in dielectric host matrix, With similar parameters we can express the imaginary parts

$\epsilon''_{eff} = \epsilon_h\epsilon''_c(\epsilon'_c + 2\epsilon_h)(1+2f) - f\epsilon_h\epsilon''_c(\epsilon'_c - \epsilon_h)(1+2f) - \epsilon_h\epsilon'_c\epsilon''_c(1-f) + 2\epsilon_h^2\epsilon''_c(1-f) + 2f\epsilon_h\epsilon''_c(1-f)/([(\epsilon'_c + 2\epsilon_h) - f(\epsilon'_c - \epsilon_h)]^2 + \epsilon''^2_c(1-f)^2)$

The numerical calculation is made the following optical parameters ($\epsilon_\infty = 4.5$, ϵ_h= 2.5, γ= 0.615) considering nano spherical silver.

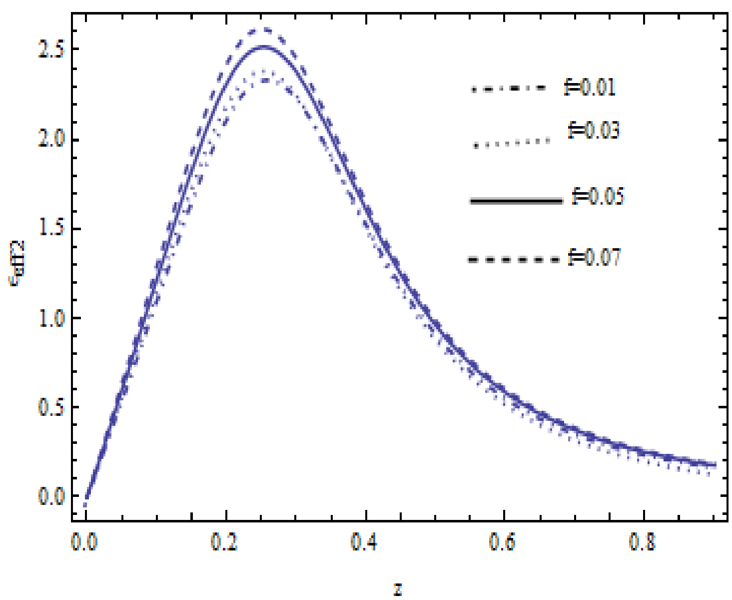

Figure 4.2: Imaginary dielectric constant function of the nano spherical particle inclusions in the dielectric host matrix for different concentration

Fig. 4.2 describe the imaginary parts of the dielectric constant for different concentration of nano spherical inclusions. We obtain that the magnitude of the imaginary dielectric constant increase as the fractional concentration of nano spherical metal particles increase in dielectric host matrix. This clearly reveal that one can vary the magnitude of real and imaginary part of dielectric constant by varying the concentration of metals. This composite system makes a novel material for developing various optical devices and technological applications.

4.5 Absorption Coefficient and Refractive Index of composite

The real part of the dielectric constant function related with the refractive index of the incident electromagnetic wave whereas the imaginary part of the dielectric constant function related with the absorption coefficient of the incident electromagnetic wave. We have performed frequency-resolved measurements of the linear absorption coefficient of metal dielectric composite materials for a large range of fill fractions. The variation of the absorption coefficient with concentration of nano spherical metal inclusions are obtained graphically and numerically using (4.2.19). In this work we compute a range of fill fractions between 0.01 and 0.08 at frequencies around the plasmon resonance. We have obtained that the composite material acts as a saturable absorber at this fractional concentration of nano spherical metal in dielectric host matrix and frequencies for which we have drawn graph. Re-write equation (4.2.29) and interpret absorbtion coefficient by using figure (4.3) as follow

$$\alpha = \frac{2\omega k}{c} = \frac{2\omega}{c}[\frac{1}{2}(\sqrt{\epsilon'^2 + \epsilon''^2} - \epsilon^{'})]^{\frac{1}{2}} \tag{4.5.1}$$

The numerical calculations is made using the following optical parameters ($\epsilon_\infty = 4.5$, ϵ_h= 2.5, γ= 0.615) considering silver nano spherical particles.

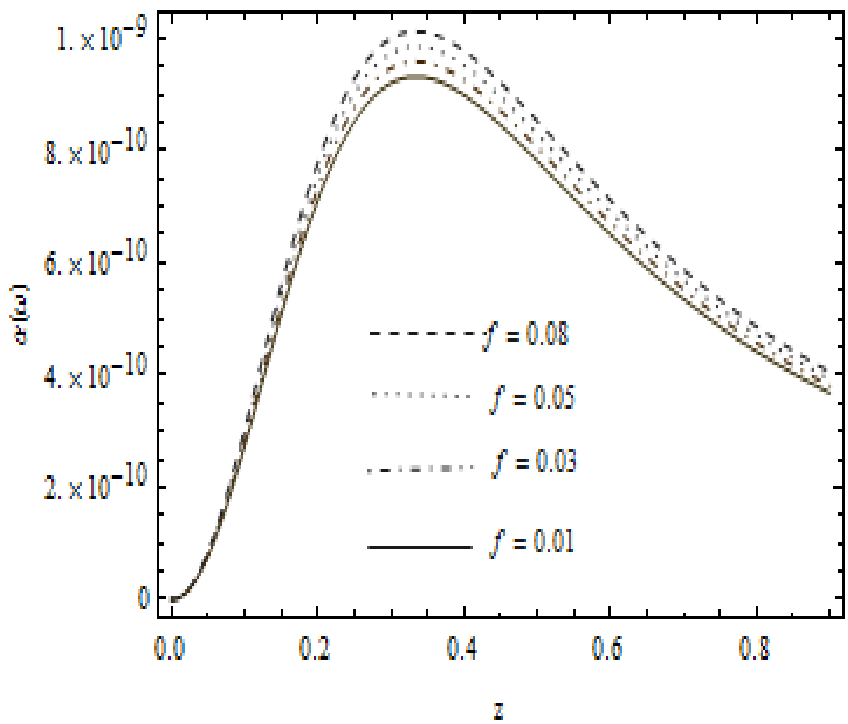

Figure 4.3: Absorption coefficient of nano spherical particle inclusions in the dielectric host matrix with difference concentration

Fig. 4.3 show the absorption coefficient in spherical metal dielectric composite system. The numerical calculation indicate that the magnitude of the absorption coefficients amplify as the function of concentration of nano spherical metals increases in dielectric host matrix for a given fractional concentration of, f = 0.01, 0.03, 0.05 and 0.08. This can vary the magnitude of absorption coefficient by varying the concentration of the metal inclusions. The composite material is found to act as a saturable absorber that corresponds to having a negative value of (α) for all fill fractions and at all frequency for which a measurement was performed. The linearity first grows and then decreases as a function of fill fraction; this behavior can clearly be seen in

Re-write equation (4.2.27) and interpret index of refraction by Fig. 4.4 as follow

$$n(z) = [\frac{1}{2}(\epsilon^{'} + \sqrt{\epsilon'^2 + \epsilon''^2})]^{\frac{1}{2}} \tag{4.5.2}$$

The numerical calculation is made the following optical parameters ($\epsilon_\infty = 4.5$, $\epsilon_h = 2.5$, $\gamma = 0.095$) considering nano spherical silver particles.

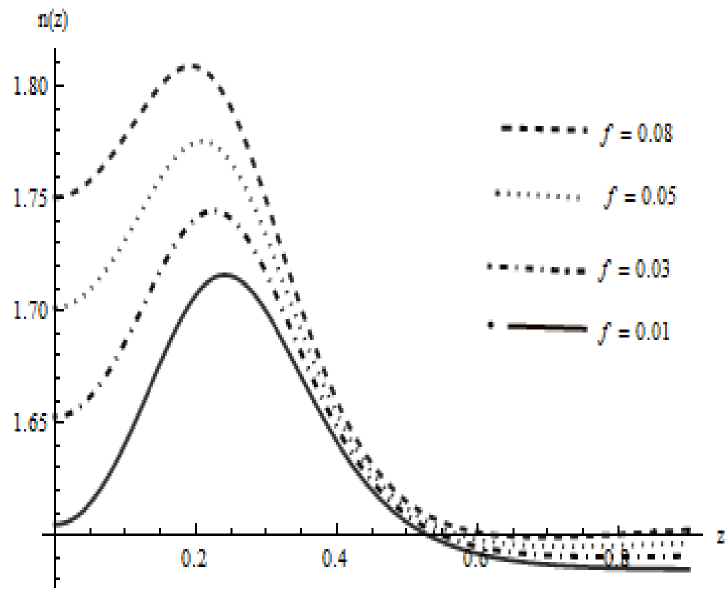

Figure 4.4: Refractive index of nano spherical particle inclusions in the dielectric host matrix with different concentrations

Fig. 4.4 describe that the refractive index of composite for different values of concentration. For f = 0.08, the refractive index varies between 1.6 and 1.81 on different sides of the SP resonance. From the numerical calculation we observed that the magnitude of the refractive index increases, as the number of nanospherical metal particles increases in the dielectric host matrix.

Chapter 5

Conclusion

We have investigated effective dielectric constant of composite with spherical inclusion. The real and imaginary part of dielectric constant, absorption coefficient and refractive index of composite material with spherical inclusion was determined analytically and numerically. From the numerical calculation, We observed that the magnitude of the maxima of the real and imaginary part of dielectric constant, the absorption coefficient and the refractive index of the composite system is amplified as the concentration of nano spherical inclusion increase in the host matrix. This clearly reveals that one can vary the magnitude of absorbtion coefficient and refractive index by varying the concentration of metal inclusion. This result confirms that the nano composite system can be used for developing a novel device by varying the concentration of nano spherical in a dielectric host matrix. Decreasing filling factor leads to slightly shift of the sp band maximum at shorter wave length. This compitable to Drude-Sommerfeld dielectric function.

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