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(54) Title: HETEROGENIC MATERIALS

(57) Abstract: In accordance with one aspect of the present invention, there is provided a heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient is provided in the form of particles, said particles being cluster of atoms, nano-particles or micro-particles, said particles being of a material different than a material of a carrier and being distributed in the carrier in such a way that the average distance between said particles is less than, or has the same order of magnitude as, the cubic root of the polarisability of said particles when in said carrier. In a further aspect of the invention there is provided a heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient is provided in the form of particles, said particles being cluster of atoms, nano-particles or micro-particles, said particles being of a metal material which is different than a material of the carrier and introduced into carrier in such a way that there is a maximal peak in the polarisability frequency function at a predetermined frequency corresponding to plasmon resonance, said predetermined frequency corresponding to a wavelength of electromagnetic radiation at which said heterogenic material has a maximal effect, therein said particles have size which is approximately equal to or less than said wavelength.

Heterogenic Materials

Field of the Invention

The present invention relates to heterogenic materials, in particular, heterogenic materials that interact with electromagnetic fields to control and modify them, and methods of manufacture of such materials. The invention may be used to create materials with pre-defined optical, electrical and magnetic characteristics.

Background of the Invention

There is a known material to influence electromagnetic radiation, described in Certificate of Authors of the USSR No.1527199, based on a quartz (SiO_2) matrix activated by semiconductor ingredients that is used to make optical filters. A drawback of this material is the limitation of its functional capabilities to influence electromagnetic (optical) radiation – it allows only one part of electromagnetic spectrum to pass through and absorbs the rest of the spectrum.

There is also a heterogenic material – an optical glass, described in Russian Patent application No. 2002100006 dated 03.01.2002, which was developed by the inventors of the present invention, based on a transparent SiO_2 matrix and filtering ingredients in form of metallic nano-particles. A drawback of this material is also the limitation of its functional capabilities to influence electromagnetic radiation. This material cannot, for example, be used for effective transformation of electromagnetic radiation into electric current, or to reflect electromagnetic radiation or for other purposes.

An object of the present invention is to ameliorate the above drawbacks and to significantly widen the functional capabilities of heterogenic materials.

Summary of the Invention

In accordance with one aspect of the present invention, there is provided a heterogenic material including a carrier and an active ingredient introduced

into it, wherein said active ingredient is provided in the form of particles, said particles being clusters of atoms, nano-particles or micro-particles, said particles being of a material different than a material of the carrier and being distributed in the carrier in such a way that the average distance between said particles is less than, or has the same order of magnitude as, the cubic root of the polarisability of said particles when in said carrier.

A coherent interaction of the particles through the near field takes place if the average distance between the particles is less than, or has the same order of magnitude as the cubic root of their polarisability (which means that their space concentration in the carrier is high, usually 10 – 30%). This yields significant growth of the dielectric function of heterogenic material according to the invention compared to the dielectric functions of either of the material of particles and carrier individually.

Preferably, the ratio of the dielectric function of the heterogenic material according to the invention to the dielectric function of either, or both, of the material of particles and carrier individually is at least 10. More preferably, such ratio is 100 or more.

Note that the distance between the particles should be measured between the centres of mass of the particles.

In preferred embodiments of the invention, said carrier material is a solid material and said particle material is a solid material.

In preferred embodiments of the invention, said carrier material is a semiconductor material and said particle material is a metallic material.

In preferred embodiments of the invention, said carrier material is a dielectric material and said particle material is a metallic material.

In preferred embodiments of the invention, said carrier includes semiconductor layers of n-type and p-type with an n-p transition between them.

In preferred embodiments of the invention, said particle material is a semiconductor material.

In preferred embodiments of the invention, said carrier material is a semiconductor polymeric material of n-type and said particle material is a semiconductor material of p-type.

In preferred embodiments of the invention, said particle material is a superconductor material.

In preferred embodiments of the invention, said carrier material is a dielectric material and said particle material is a dielectric material.

In preferred embodiments of the invention, said carrier material is a dielectric material and said particle material is a segnetoelectric material.

In preferred embodiments of the invention, said carrier material is a segnetoelectric material and said particle material is a segnetoelectric material.

In preferred embodiments, said carrier material is a medium with the capability to invert a population of energy states.

In preferred embodiments of the invention, said carrier material is a liquid dielectric material and said particle material is a metallic material.

In a further aspect of the invention there is provided a heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient is provided in the form of particles, said particles being clusters of atoms, nano-particles or micro-particles, said particles being of a metal material which is different than a material of the carrier and introduced into carrier in such a way that there is a maximal peak in the polarisability frequency function at a predetermined frequency corresponding to plasmon resonance, said predetermined frequency corresponding to a wavelength of electromagnetic radiation at which said heterogenic material has a maximal effect, wherein said particles have a size which is approximately equal to or less than said wavelength.

The set of functional capabilities of the suggested heterogenic material according to the invention is defined by the fact that polarisability of its particles of active ingredient in the carrier is modified when it is manufactured in such a way that there is a certain maximal amplification in the polarisability frequency function, that is to say plasmon resonance, that depends on form, type of metal,

concentration and dielectric function of a carrier. Plasmon resonance is caused by the coherent interaction of electrons through the local electromagnetic fields in metallic or other (e.g. superconductor material) particles. The frequency of said plasmon resonance of the particles depends on their size and material and can be calculated using well-known formulas.

In preferred embodiments of the invention, said carrier material is a solid material and said particle material is a solid material.

In preferred embodiments of the invention, said carrier material is a dielectric material.

In preferred embodiments of the invention, said carrier material is a semiconductor material.

In preferred embodiments of the invention, said carrier includes semiconductor layers of n-type and p-type with an n-p transition between them.

In preferred embodiments of the invention, said carrier material is a semiconductor polymeric material of n-type and said particle material is a semiconductor material of p-type.

In preferred embodiments, said carrier material is a medium with the capability to invert a population of energy states.

In preferred embodiments of the invention, said carrier is a liquid dielectric material, whereas said particles material is a metallic, superconductor, or segnetoelectric material.

The set of functional capabilities of the suggested heterogenic material is defined by the fact that its dielectric function is controlled when it is manufactured, this function being the decisive characteristics of the interaction of material with electromagnetic field.

Further aspects of the invention relate to methods of manufacture of a heterogenic material in accordance with the above aspects.

Further features and advantages of the invention will become apparent from the following description of preferred embodiments of the invention, given by way of example only, which is made with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 shows an image, produced by an atomic force microscope, of the distribution of the nano-particles in a heterogenic material produced according to an embodiment of the invention.

Figure 2 illustrates the absorption spectra of heterogenic materials produced according embodiments of the invention.

Figure 3 illustrates the absorption spectra of Figure 2, scaled so as to remove the absorption spectrum of SiO_2 with PVP film.

Figure 4 shows the absorption spectrum of gold nano-particles in water, produced according to an embodiment of the invention.

Detailed Description of Embodiments of the Invention

Heterogenic materials according to embodiments of the invention contain a selected combination of solid particles of an active ingredient and a solid or liquid carrier.

The carrier may be a semiconductor, or the carrier may be in the form of semiconductor layers of n-type and p-type with an n-p transition between them, or the carrier may be formed of a semiconductor polymeric material of n-type that contains semiconductor nano-crystals of p-type, or the carrier may be a segnetoelectric material, or the carrier may be a medium with the possible inverse population of energy states, for example, by adding ingredient atoms, or the carrier may be a dielectric (and may be liquid).

The particles may be formed of at least one of a metallic superconductor, dielectric or segnetoelectric material. The particles may consist of clusters of atoms, nano-particles or micro-particles. Herein, it should be understood that clusters of atoms have a diameter of up to approximately 10 nm, nano-particles have a diameter between approximately 10 nm and approximately 100 nm, and micro-particles have a diameter between approximately 100 nm and approximately 100 μm.

A coherent interaction of the particles through the near field takes place if the average distance is less than, or has the same order of magnitude as the cubic root of their polarisability (which means that their space concentration in the carrier is high, usually 10 – 30%). This yields significant growth of the dielectric function of heterogenic material according to the invention compared to the dielectric functions of either of the material of particles and carrier individually.

Preferably, the ratio of the dielectric function of the heterogenic material according to the invention to the dielectric function of either, or both, of the material of particles and carrier individually is at least 10. More preferably, such ratio is 100 or more.

Let us consider a heterogenic material according to the invention with the particles that are located in the carrier according to a geometry close to that of a cubic lattice. Using the Clausius-Mosotti formula for the location of the particles in a heterogenic material according to the invention and the Lorentz-Lorenz formula for the correction of the local field of particles of an ellipsoidal shape, we derived formula (1) below to calculate the dielectric function ϵ_η of a heterogenic material according to the invention:

$$(\epsilon_\eta-1)/(\epsilon_\eta+2) = (\epsilon_c-1)/(\epsilon_c+2) + \eta[(\epsilon_p-1)/(1+n(\epsilon_p-1)) - (\epsilon_c-1)/(1+n(\epsilon_c-1))]/3 \quad (1)$$

where:

ϵ_c is the value of the dielectric function of the carrier material;

ϵ_p is the value of the dielectric function of the particle material;

n is the de-polarisability factor of the particles, which depends on the ratio of the lengths of their semi-axes, with $(0 < n < 1)$; and

η is the space concentration of the particles of the active ingredient in the carrier.

The polarisability α_p of a particle, for example, for a rotational ellipsoid of the volume of V, is defined by formula (2) below:

$$\alpha_p = (1/4\pi)V[(\epsilon_p/\epsilon_c-1)/(1+(\epsilon_p/\epsilon_c-1)n)] \quad (2)$$

The calculations show that for different cases the value of the dielectric function of a heterogenic material according to the invention can exceed the values of the dielectric function of the carrier and the values of the dielectric function of the particles by factor of 10 to 100, or more. For example, for a $BaTiO_3$ segnetoelectric carrier and $(PbLaBaS)(ZrTi)O_3$ segnetoelectric particles the value of dielectric function of this heterogenic material according to the invention exceeds the value of dielectric function of $(PbLaBaS)(ZrTi)O_3$ (this material has one of the highest known values of ϵ_η) by a factor of 100 to 200.

A maximum in the dielectric function for a heterogenic material according to the invention is achieved for a certain frequency of the field, which depends on the material of the particles, the material of the carrier and the shape, space concentration and geometry of locations of the particles in the carrier. The set of functional capabilities of a heterogenic material according to the invention is ensured by the fact that the polarisability of the particles of the active ingredient in the carrier is modified when the heterogenic material is manufactured in such a way that there is a certain maximal amplification in the polarisability frequency function, that is to say plasmon resonance, that depends on form, type of metal, concentration and dielectric function of a carrier. Plasmon resonance is caused by the coherent interaction of electrons through the local electromagnetic fields in metallic or other (e.g. superconductor material) particle. The frequency of the plasmon resonance of the particles depends on their size and material and can be calculated using well known formulas.

When the space concentration of the particles in the carrier is small (up to 1-5%) their interaction through the local fields is weak and does not contribute significantly into the dielectric function of a heterogenic material. However, the dielectric function is influenced by the growth of polarisability of the particles when they interact with an electromagnetic field of a frequency close to the plasmon resonance frequency of the particles, and in this case it

increases in value by the factor of at least 10, and preferably 100 or more, compared to the value of dielectric function for the material of the carrier. This effect occurs if the average size of the particles is less than the wavelength of the electromagnetic field.

Note that the frequency function of the polarisability typically varies due to temperature fluctuations affecting the polarisability. However, the maximum peak is significantly larger than, and in any case at least twice as large as, the level of temperature fluctuations of the polarisability.

In order to find the maximum as a function of the frequency of the field the formula above for α_p (or similar formulas for different shapes of particles) is examined. In particular, α_p has a maximum for the frequency when the following condition applies:

$$1 + Re[(\epsilon_p/\epsilon_c)-1]n = 0 \qquad (3)$$

In the above, ϵ_p and ϵ_c may be complex numbers; *Re* is the real component of a complex number.

As the depolarisability factor n is in the interval $0 < n < 1$, such maximum can be achieved for metallic particles in dielectric matrix, i.e. when $Re\epsilon_p < 0$; $Re\epsilon_c > 0$, as well as when the material of the particles is a superconductor or segnetoelectric material and the carrier material is a solid material, or the carrier is a dielectric, or the carrier is a semiconductor, or the carrier is semiconductor layers of n-type and p-type with an n-p transition between them; or the carrier is formed of a semiconductor polymeric material of n-type that contains semiconductor nano-crystals of p-type; or the carrier is a media with the possible inverse population of energy states, for example, by adding ingredient atoms; or the carrier is a liquid dielectric.

Because the value and frequency distribution of dielectric function is controlled when it is manufactured, the suggested heterogenic material according to the invention can be used to make optical devices, including lasers,

mirrors, filters, lenses, fibres etc., as well as optical-electronic transformers and energy batteries and many other devices. As the value of the dielectric function for a heterogenic material according to the invention is 10 to 100, or more, times higher than for the known materials, the devices based on heterogenic material according to the invention will have much improved functional capabilities.

Particles of heterogenic materials according to the invention are substantially uniformly distributed across an at least two dimensional area (e.g. in a two dimensional layer formation). More preferably, the particles of heterogenic materials according to the invention are substantially uniformly distributed across a three dimensional volume (e.g. in a volumetric layer formation). The particles may be distributed substantially randomly, or may be distributed in a lattice-type structure. For ease of manufacture, the particles are preferably distributed substantially randomly.

Examples of methods for the manufacture of heterogenic materials according to the invention are described below.

One method is based on mixing of particles of active material with a melted carrier in a proportion appropriate to achieve the space concentration desired.

Cylindrical nano-particles may be made by spraying a particle material onto a nuclear filter with an appropriate channel size and then dissolving the material of the filter (which may, for example, be formed of an organic material).

Particles of a different shape (e.g. one close to a rotational ellipsoid) are made by dragging the particles with the help of a rod of passive chemical material from a melted particle material whilst gradually decreasing the temperature of the melted material. In order to obtain the desired shape the rod may be rotated. The size and shape of the particles may be controlled by an atomic force microscope. In order to achieve a desired orientation of particles, the particles may be put onto the carrier layer in an electric field and then covered by a further layer of the carrier.

Various further examples of methods to make heterogenic materials according to the invention are described below.

Example 1

A 100 nm thick polythiophene film is put onto a SiO_2 wafer. A colloidal solution of silver is put onto the surface of this film. Then a deposition of 70 nm silver particles having an approximately spherical shape onto the film is made using the well known Zol-Gel method. When the film is heated, the particles sink by gravitation into the film to a depth similar to their size. The amount of silver in the colloidal solution is selected to provide an approximately 10% space concentration of particles in the film. The average distance between the particles is approximately 100 nm. The polarisability of the spherical silver particles in polythiophene is equal to approximately 1.8×10^6 nm^3; the cubic root of this value is equal to 122 nm. Therefore, the heterogenic material according to the invention made in this process meets the conditions of the average distance being less than, or having the same order of magnitude as the cubic root of their polarisability.

Example 2

A silver steam created above a melted mass of silver is cooled to achieve saturation, and condensation starts to create spherical drops due to surface tension effects. The drops are taken from the condensation area by a flow of argon and are directed to a rotating disk covered with a polystirol layer. The rotational velocity is controlled in such a way that only approximately 70 nm solid silver drops reach the disk and are sunk into the layer. According to calculations, the plasmon resonance of spherical silver particles is in the region of 1.9×10^{15} Hz. The space density of silver particles in the layer is regulated by the velocity of the argon flow and by the time needed for the particles to drop onto the disk and is equal to approximately 2%. A heterogenic material according to the invention made in this way influences electromagnetic radiation with a maximum peak at a wavelength of around 500nm.

Example 3

A 100 nm layer of Poly(2/vinyl pyridin) (PVP) is placed onto a quartz (SiO_2) disk, which is polished and 1mm in thickness. Then metallic nano-particles (gold) of diameter 10-20 nm are settled from the colloidal solution onto a rotating disk to achieve the desired space concentration. The nano-particles are deposited into the PVP at a temperature of 200° C. Thus, the nano-particles are settled into a carrier at a desired space density.

Figure 1 shows an image, produced by an atomic force microscope, of a distribution of the nano-particles for inclusion in a heterogenic material produced according to this example.

Figure 2 illustrates the absorption spectra of heterogenic materials produced according to this example, measured using a spectrophotometer, in the wavelength band 300-800 nm.

The absorption spectrum indicated with reference numeral 1 is the absorption spectrum of SiO_2 alone. No maximum corresponding to plasmon resonance is seen.

The absorption spectrum indicated with reference numeral 2 is the absorption spectrum of SiO_2 and the PVP film together. No maximum corresponding to plasmon resonance is seen.

The absorption spectra indicated with reference numerals 3 to 5 are the absorption spectrum of SiO_2 and the PVP film together with gold nano-particles inserted therein. A maximal peak corresponding to plasmon resonance is seen. The maximal peak also occurs in the polarisability frequency function at a predetermined frequency corresponding to plasmon resonance; this predetermined frequency corresponding to the wavelength of radiation at which said heterogenic material has a maximal effect, which can be seen to be, in this case, in the region of 540 to 550 nm. The gold particles used in this example have a size which is approximately equal to or less than the wavelength at which said heterogenic material has a maximal effect.

Figure 3 illustrates the absorption spectra of Figure 2, scaled so as to remove the effect of the absorption spectrum of SiO_2 and the PVP film.

Example 4

A 10 nm polymeric layer of Poly(2/vinyl pyridin) is put onto a semiconductor layer, and then metallic nano-particles (silver) are settled from colloidal solution onto a rotating disk to achieve the desired space concentration.

Example 5

Nano-particles of silver at a temperature of approximately 800° C are inserted into a melted SiO_2 dielectric matrix. The particles are made as follows. A polymeric-based nuclear filter that has a pore diameter of 30 microns for metallic (silver) nano-particles is saturated with a solution of Silver Nitrate ($AgNO_3$). Then it is reduced back to metallic silver by radiating it with ultra-violet light, and pores in the polymeric material are filled with silver to make 100 nm nano-particles of up to 30 microns in length. After drying and gluing onto solid smooth surface they are processed by diamond grinding. Nano-particles are then released by etching of polymeric substance in alkali and inserted into the melted SiO_2 matrix.

Example 6

A transparent conducting polymeric layer of 10 nm is put on top of a rotating disk covered with a doped semiconductor with an n-p transition therein. Metallic (silver) nano-particles made by the Zol-Gel method from a colloidal solution are settled to obtain a desired space concentration. Nano-particles are covered with a thin polymeric layer. The total thickness of the heterogenic material produced is approximately 80 nm.

Example 7

Semiconductor nano-particles are made by synthesizing from initial agents in solution and stopping the process when the desired size of nano-

particles is achieved. For example, semiconductor CdS particles are synthesized by mixing two solutions:

$Cd(ClO_4)2 + Na_2S = CdS + 2NaClO_4$

The growth of CdS nano-particles is stopped by increasing the pH factor of the solution. Nano-particles are then settled into a polymeric film that has been previously formed on a carrier. The polymeric wafer is then removed during the process of inserting the nano-particles into the carrier.

Example 8

A 40 nm layer of polythiophene polymeric semiconductor of n-type is put onto a heated metallic plate. Then a layer of silver nano-particles is put on top by thermal sputtering through a nuclear filter with a desired pore diameter. Then a separately grown semiconductor p-type (GaAs) nano-crystals layer is put on top and then a 30 nm polythiophene layer is put on top.

Example 9

Superconductor nano-particles are made in melted metals (for example, alloys of Nb) in a desired proportion to have a desired space concentration of nano-particles. Spherical or other shapes of nano-particles are obtained by dragging from the melted substance with the help of a platinum rod whilst gradually decreasing the temperature. Then the superconductor nano-particles are settled onto a polymeric film based on the carrier. The polymeric wafer is then removed during the process of inserting the nano-particles into the carrier.

Example 10

Dielectric nano-particles are made by oxide grinding (for example, Al_2O_3) to achieve a desired size and then by centrifuging. The dielectric nano-particles are then mixed with a melted dielectric carrier (for example, SiO_2).

Example 11

Segnetoelectric nano-particles are made from a colloidal solution of oxides of initial components by calcination in a crucible and dragging from the melted substance with the help of a platinum rod whilst gradually decreasing the temperature. The rod rotates to obtain the desired shape of nano-particles. The size and shape of the nano-particles is monitored by an atomic force microscope. The segnetoelectric nano-particles are then mixed with the melted dielectric carrier (SiO_2). The dielectric function of the heterogenic material produced is measured by an MIM-spectrometer.

Example 12

A BaTiO3 segnetoelectric layer is put by high-frequency dispersing process on top of a metallic wafer obtained by dispersing an AgPd alloy in a vacuum. Nano-particles of other chemical substances are obtained from colloidal solution of oxides of initial components at the melting temperature by dragging from the melted substance with the help of platinum rod whilst gradually decreasing the temperature. Segnetoelectric nano-particles thus obtained are put into a $BaTiO_3$ film layer.

Example 13

In order to create quantum dots geometry elements (two-layer systems with the capability to invert a population of energy states) a lithographic structure with side restrictions is made on the surface of a thin semiconductor layer. This is achieved with the help of electron-beam lithography and liquid-phase etching. This structure is then covered with conducting a polymeric layer, and then metallic (silver) nano-particles of desired size, shape and concentration are settled into the polymeric layer.

Example 14

Metallic, dielectric or segnetoelectric nano-particles are put into a liquid dielectric carrier, for example, water. Their size is controlled so as to provide a

density close to that of the carrier, in order to obtain a substantially uniform space distribution of the particles through the carrier.

Figure 4 shows the absorption spectrum of a heterogenic material in accordance with the invention, consisting of gold nano-particles, having an average diameter of 14-17 nm, dispersed in distilled water, produced according to an embodiment of the invention. In this example, the number of gold particles per cubic centimeter is 10^{12}. As can be seen, there is a maximal peak in the polarisability frequency function at a predetermined frequency corresponding to plasmon resonance at between 530 nm and 540 nm in wavelength. The gold particles have a size which is significantly less than the 530-540 nm wavelength.

Example 15

Segnetoelectric nano-particles are inserted into a melting dielectric media (for example, borosilicate glass) with a low boiling temperature.

Example 16

A BaTiO3 segnetoelectric layer is put by high-frequency dispersing process on top of a metallic wafer obtained by dispersing of an AgPd alloy in vacuum. Nano-particles, clusters or micro-particles are inserted into segnetoelectric carrier to provide a maximal amplification in the polarisability frequency function or plasmon resonance. The frequency at which the maximum occurs depends on the form, type of metal, concentration and dielectric function of the carrier.

Note that, with reference to the above description, the term "particles" includes particles of various shapes, including nano-particles of elongate cylindrical shape.

The above embodiments and examples are to be understood as illustrative examples of the invention. Further embodiments of the invention are envisaged. It is to be understood that any feature described in relation to any

one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

Claims

1. A heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient is provided in the form of particles, said particles being clusters of atoms, nano-particles or micro-particles, said particles being of a material different than a material of the carrier and being distributed in the carrier in such a way that the average distance between said particles is less than, or has the same order of magnitude as, the cubic root of the polarisability of said particles when in said carrier.

2. A heterogenic material according to claim 1, wherein said carrier material is a solid material and said particle material is a solid material.

3. A heterogenic material according to claim 2, wherein said carrier material is a semiconductor material and said particle material is a metallic material.

4. A heterogenic material according to claim 2, wherein said carrier material is a dielectric material and said particle material is a metallic material.

5. A heterogenic material according to claim 1, 2 or 3, wherein said carrier includes semiconductor layers of n-type and p-type with an n-p transition between them.

6. A heterogenic material according to claim 1 or 2, wherein said particle material is a semiconductor material.

7. A heterogenic material according to claim 6, wherein said carrier material is a semiconductor polymeric material of n-type and said particle material is a semiconductor material of p-type.

8. A heterogenic material according to claim 1 or 2, wherein said particle material is a superconductor.

9. A heterogenic material according to claim 1 or 2, wherein said carrier material is a dielectric material and said particle material is a dielectric material of different chemical content.

10. A heterogenic material according to claim 1 or 2, wherein said carrier material is a dielectric material and said particle material is a segnetoelectric material.

11. A heterogenic material according to claim 1 or 2, wherein said carrier material is a segnetoelectric material and said particle material is a segnetoelectric material of different chemical content.

12. A heterogenic material according to claim 1 or 2, wherein said carrier material is a medium with the capability to invert a population of energy states therein.

13. A heterogenic material according to claim 1, wherein said carrier material is a liquid.

14. A heterogenic material according to claim 13, wherein said carrier material is a liquid dielectric material and said particle material is a metallic material.

15. A heterogenic material according to claim 1 or 2, wherein said particle material is a segnetoelectric material.

16. A heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient is provided in the form of particles, said particles being clusters of atoms, nano-particles or micro-particles, said particles being of a metal material which is different than a material of the carrier and introduced into carrier in such a way that there is a maximal peak in the polarisability frequency function at a predetermined frequency corresponding to plasmon resonance, said predetermined frequency corresponding to a wavelength of electromagnetic radiation at which said heterogenic material has a maximal effect, wherein said particles have a size which is approximately equal to or less than said wavelength.

17. A heterogenic material according to claim 16, wherein, at said maximal peak, the ratio of the dielectric function of the heterogenic material to the dielectric function of either, or both, of the material of particles and carrier individually is at least 10.

18. A heterogenic material according to claim 17, wherein the ratio is 100 or more.

19. A heterogenic material according to any of claims 16 to 18, wherein said carrier material is a solid material and said particle material is a solid material.

20. A heterogenic material according to any of claims 16 to 19, wherein said carrier material is a semiconductor material.

21. A heterogenic material according to claim 20, wherein said carrier is semiconductor layers of n-type and p-type with an n-p transition between them.

22. A heterogenic material according to claim 20, wherein said carrier is semiconductor polymeric material of n-type that contains semiconductor nano-crystals of p-type.

23. A heterogenic material according to any of claims 16 to 19, wherein said particle material is a superconductor.

24. A heterogenic material according to any of claims 16 to 19, wherein said carrier material is a dielectric material.

25. A heterogenic material according to any of claims 16 to 19, wherein said carrier material is a medium with the capability to invert a population of energy states therein.

26. A heterogenic material according to claim 16, wherein said carrier material is a liquid.

27. A heterogenic material according to any of claims 16 to 19, wherein said carrier material is a segnetoelectric material.

28. A method of manufacture of a heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient is provided in the form of particles, said particles being clusters of atoms, nano-particles or micro-particles, said particles being of a material different than a material of the carrier and the method comprising introducing the particles into the carrier in such a way that the average distance between said particles is less than, or has the same order of magnitude as, the cubic root of polarisability of said particles when in said carrier.

29. A method of manufacture of a heterogenic material including a carrier and an active ingredient introduced into it, wherein said active ingredient

is provided in the form of particles, said particles being clusters of atoms, nano-particles or micro-particles, said particles being of a metal material which is different than a material of the carrier and the method comprising introducing the particles into the carrier in such a way that there is a maximal peak in the polarisability frequency function at a predetermined frequency corresponding to plasmon resonance, said predetermined frequency corresponding to a wavelength of electromagnetic radiation at which said heterogenic material has a maximal effect, wherein said particles have a size which is approximately equal to or less than said wavelength.

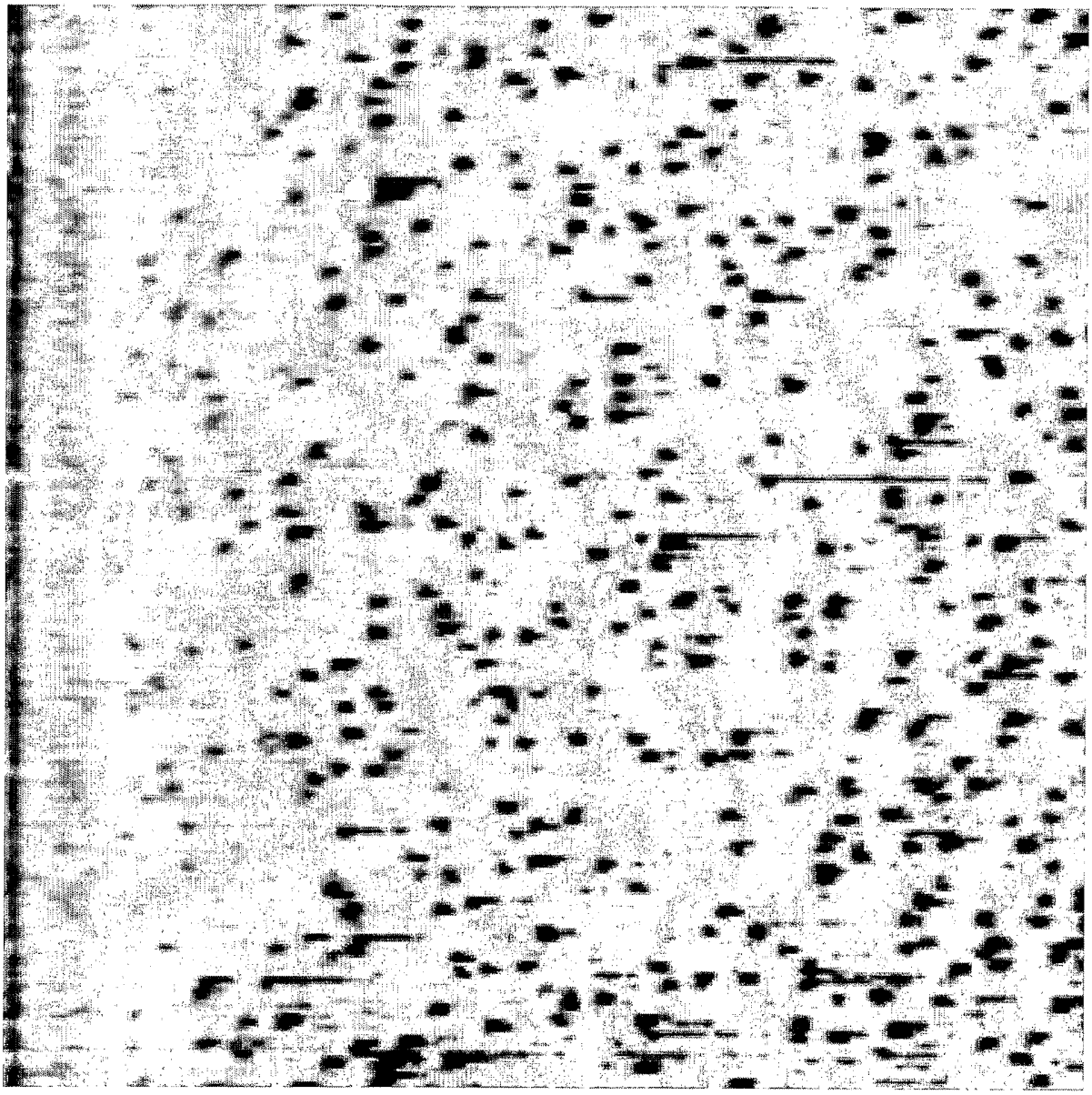
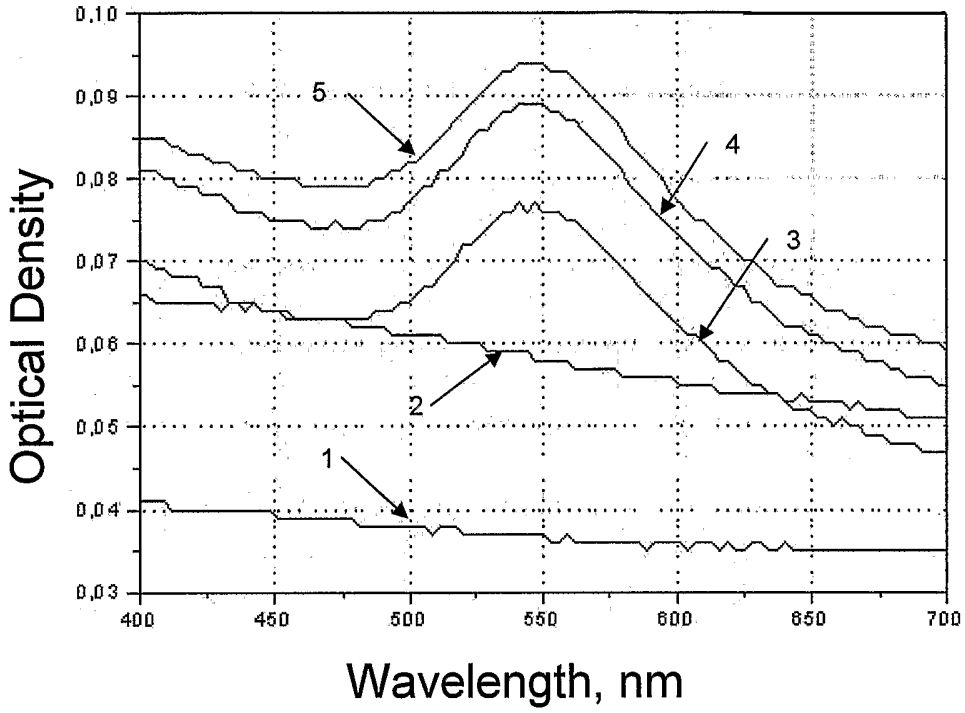


FIG. 1


Optical Density
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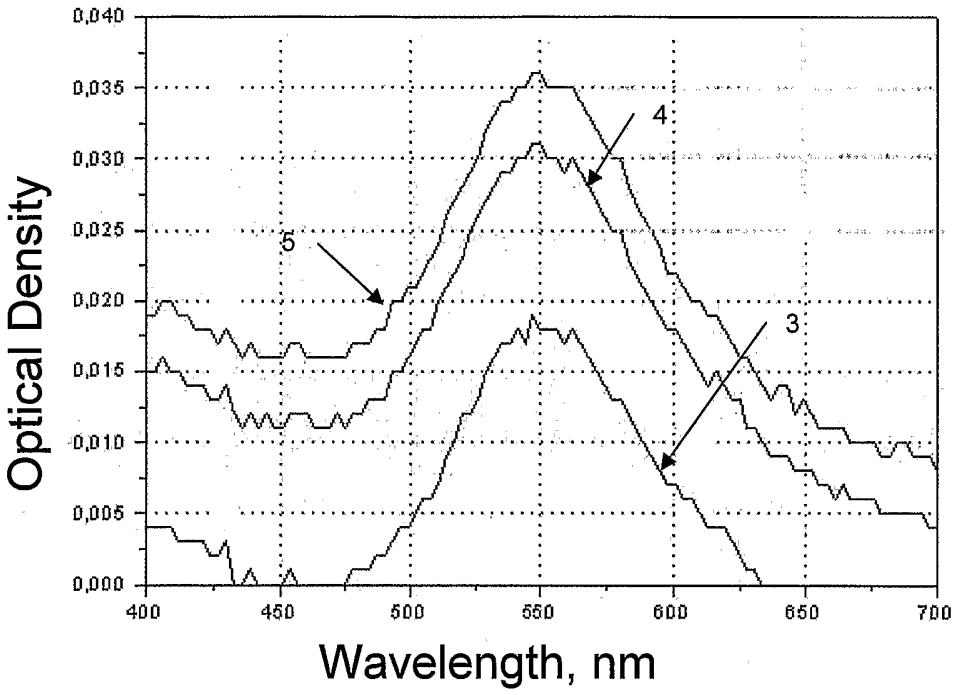
0,08
0,07
0,06
0,05
0,04
0,03
400
450
500
550
600
650
700
Wavelength, nm
1
2
3
4
5

FIG. 2


Optical Density
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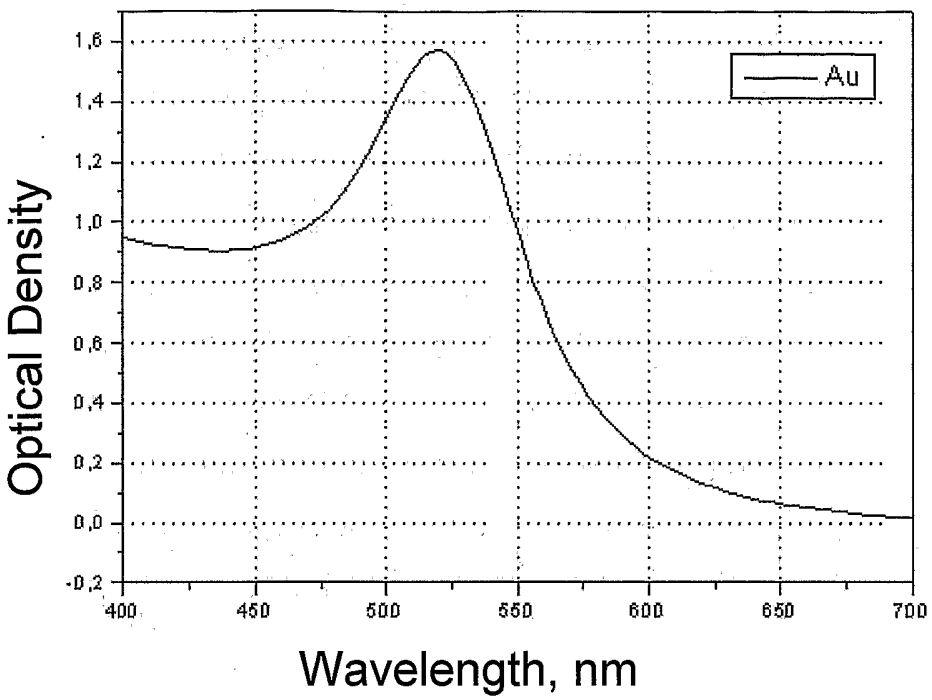
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,000
400
450
500
550
600
650
700
Wavelength, nm
4
5
3

FIG. 3


Optical Density
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1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
400
450
500
550
600
650
700
Wavelength, nm
Au

FIG. 4

INTERNATIONAL SEARCH REPORT

PCT/GB2004/003544

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C08K3/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C08K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/032709 A1 (KAMEI KOHSUKE ET AL) 13 February 2003 (2003-02-13) page 5; example 1 claims 1-24	1-12, 15-29
X	US 2002/145132 A1 (KANG YONG SOO ET AL) 10 October 2002 (2002-10-10) page 5; example 18 claims 5,7	1-12, 15-29
X	EP 0 488 321 A (MITSUBISHI RAYON CO) 3 June 1992 (1992-06-03) examples 2,12-15 claims 1-8	1-29

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 December 2004	21/12/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Siemens, T

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INTERNATIONAL SEARCH REPORT

Information on patent family members

PCT/GB2004/003544

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