Barium Titanate Lasers with the Localized Surface Plasmonic Effect of Silver Nano-Particles

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Abstract
Mini lasers have recently attracted attention in many such fields as optic communication, data storage, and imaging. The present study is concerned with the optical properties of nanoparticles of Perovskite barium titanate with the local surface plasmonic effect of silver nanoparticles. Using silver nanoparticles will evidently increase the absorption and photoluminescence of barium titanate nanoparticles. The present study shows that titanate Perovskites combined with such plasmonic materials as silver and gold can be promising candidates for high-efficiency electronic devices.
Keywords: Barium Titanate Lasers, Surface Plasmonic, Silver Nano-Particles, Mini laser, Fabry-Perot cavity.

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1. Introduction

One of the best instruments for detecting and quantifying entanglement is the Fabry-Perot cavity. Entanglement, a fundamental quantum physics phenomenon, has always been used as a valuable issue for quantum communication and information processing. Quantum entanglement has already been prepared and manipulated in a variety of physical systems, such as photons, individual atoms, ions, the relationship between an optical photon and a solid-state spin qubit, and so on. Optomechanical systems provide new levels of control over both light and matter's quantum states. By causing mechanical modes to become entangled. A Fabry-Perot cavity with one of the cavity's mirrors free to move is a common model for studying the interaction between optical cavities and mechanical objects. In fact, the moveable mirror in the Fabry-Perot cavity and similar cavities must provide both optical confinement and mechanical pliability. Membrane-in-Cavity designs remove the need to integrate good mirrors into good mechanical devices, however, this article focusses on preparation of lasers with localized surface plasmonic effect. [1]–[4]

On the other hands, In the broadest sense, lasers operate on the following principle. Laser light is generated by the stimulated emission of light from material in a cavity resonator that is continuously re-excited to keep the stimulated emission going.

Under optimal conditions, the cavity mode's state is a Poissonian mixture of Fock states.

$$\rho = e^{-\backslash\lambda^2} \sum_n \frac{\lambda^{2n}}{n!} |n\rangle\langle n|$$

Where λ is a real parameter This could, however, be rewritten using the following identity:

$$\rho \equiv \frac{1}{2\pi} \int d\phi |\lambda e^{i\phi}\rangle\langle\lambda e^{i\phi}|$$

where $|\lambda e^{i\phi}\rangle$ is a state of coherence. This implies that the cavity's condition is different from a coherent state with defined amplitude yet unknown phase.

The state of the light-beam that emerges from the cavity can then be written, to a first approximation:

$$\rho_{beam} = \frac{1}{2\pi} \int d\phi (|\lambda e^{i\phi}\rangle\langle\lambda e^{i\phi}|)^{\otimes N}$$

Where the light beam is treated as a series of N wave packets, each with a traveling mode function $u(x,y)S(z-ct,w)$ and the beam is assumed to be moving along the z-axis. The function $u(x,y)$ describes the beam's transverse profile, while $S(z,w) = 1$ describes a sawtooth function of width $\frac{w}{2} \leq z \leq \frac{w}{2}$.

Nanoscale lasers are now used in many commercial fields, such as optic communication [1], high definition medical imaging [2], and data storage.

Titanates are a class of perovskite oxides. The general chemical formula of titanates is $MTiO_3$. The site M can be occupied by various elements, e.g. Sr, Mg, Ca and Ba. Titanates are used mainly in photocatalysts. An important member of the titanates family is barium titanate.

Barium titanate ($BaTiO_3$) is an artificial crystal (not found in the nature) used in electromechanical converters and ceramic capacitors, sensors, etc. Barium titanate, as a metal oxide, has such properties as physical hardness, stability and adjustable electronic properties. In recent years, titanates have gained attention due to their significant optical and electronic properties [3-5] like adjustable band gaps, vast absorption spectrum, high vehicle mobility, and quantum photoluminescence efficiency. [5]–[9]

The Localized Surface Plasmon Resonance (LSPR) of metal nanoparticles (NPs) are of great interest due to their unique optic properties, e.g. energy transfer, metal fluorescence to improve optoelectronic devices performance. Metal nanoparticles have recently been utilized in various fields such as light-emitting diodes, solar cells, improving the photocatalytic efficiency and optical tracers. One of the contributing factors to the improved optoelectronic property is the connecting distance from the emitters and metal nanoparticles. Observations show that the best performance of optoelectronic devices can be achieved with a gap of 5-20 nm.

In the present study, in the first place, barium titanate nanoparticles were prepared by the Cell-Gel method. Silver nanoparticles were then contained in the buffer layer PEDOT:PSS. After silver nanoparticles were used, the intensity of PL and barium titanate particles absorption improved. Therefore, it is believed that the coherent surface plasmonic effect of silver nanoparticles can have a great potential in improving the performance of other electronic devices, including solar cells, light-emitting diodes, optical tracers and laser. [10], [11]

2. Preparation and Characterization

Materials needed: barium nitrate, titanium tetra isoperoxide, silver nitrate, methanol, sodium borhydrate , indium tin oxide (ITO)

Procedure: 0.1 g of silver nitrate was added to 100 ml of deionized water and agitated for 15 minutes. 0.01 g of sodium dodecyl sulphate was added to the solution as surfactant and mixed for 20 minutes. Then, 1 ml of $NaBH_4$ solution was gradually added to the solution and mixed for 15 minutes. The resulting sediment was collected by centrifuge and rinsed with ionized water and subsequently dehydrated at 40 degrees centigrade. The glass mediums of indium tin oxide (ITO) (1 cm by 1 cm) were rinsed by deionized water, acetone and ethanol separately for 20 minutes and then dried by use of nitrogen gas. The glass was subjected to plasma for 20 minutes. Silver nanoparticles were mixed in PEDOT:PSS solutions and subsequently rotated on ITO glass at 2500 rpm for 30 seconds, and were subsequently annealed with the coats at 120 degrees centigrade.
To prepare barium titanate nanoparticles, 15 ml of water is first mixed with 0.5 g of barium chloride. Then, 0.6 g of titanium isoperoxide is solved in 15 ml of ethanol in a beaker and 0.5 cc of acid formic is added. Then, the solution of the first beaker is added to the contents of the second one and heat until its temperature reaches 75 degrees centigrade and a shite powder remains with the solvent eliminated. The resulting powder is calcinated at 600 degrees centigrade Silver nanoparticles were mixed in PEDOT:PSS solutions and subsequently rotated on ITO glass at 2500 rpm for 30 seconds, and were subsequently annealed with the coats at 80 degrees centigrade. This was repeated for different concentrations of silver.

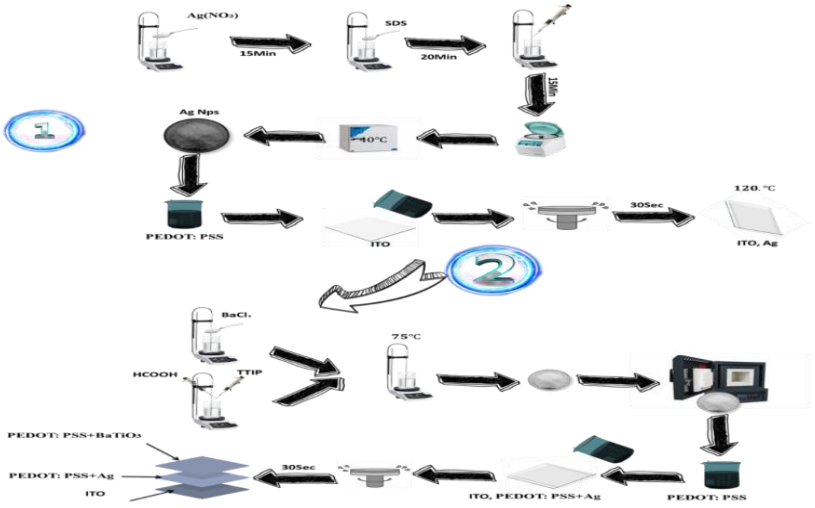

Figure 1: the Procedure of made PEDOT:PSS+ Barium titanate, Ag and ITO

Characterization: The x-ray diffraction patterns were examined by use of a Philips X-ray diffraction meter using CrKα radiation. Also, the size and morphology of the nanoparticles were examined by a wiping electronic microscope (Model KYKY-EM3200). The absorption was recorded at 400-600 nm by a spectrophotometer. The photoluminescence spectrometry (PL) was measured by use of a fluorescent spectrophotometer (Agilent Cary Eclipse Australia), which includes a Xe lamp (the visible region) as the stimulant.

Leasing test: To measure the leasing, a femtosecond amplified laser system was used as the source of pumping. All the tests of this section were conducted at room temperature. [12]–[17]

3. Results

An electronic microscope image (SEM) of the silver nanoparticles is shown in Picture 1a. As shown by the image, it is made of spherical nanoparticles measuring 50 nm. The ultraviolet-visible absorption spectrum of silver nanoparticles is shown in picture 1b. Picture 1b shows an intense absorption peak at the wavelength of 527 nm [18], [19], which is due to the LSPR stimulation. In addition, the low concentration of the silver nanoparticles at the buffer layer PEDOT:PSS with the volume ratio of 1.00:0.20 prevents the oxitons from turning off (through the silver nanoparticles surface).

Picture 2a shows the x-ray diffraction of the layers both with and without silver nanoparticles. It consists of titanate barium and silver phases. It shows the low intensity peaks of silver nanoparticles, which will have no effect on the photoluminescence properties of barium titanate. The wiping electronic microscope images of the barium titanate nanoparticles are shown in picture 2b. The barium titanate nanoparticles in their synthesized form measure about 500 nm. Picture 2c shows the x-ray spectrometry for barium titanate along with silver nanoparticles. The atomic ratio of barium-titanium-oxygen-silver is 5-55-20-21, which agrees with the stoichiometry of the materials. In addition, the identical measurement has made these nanoparticles high-quality single-phase lasers.

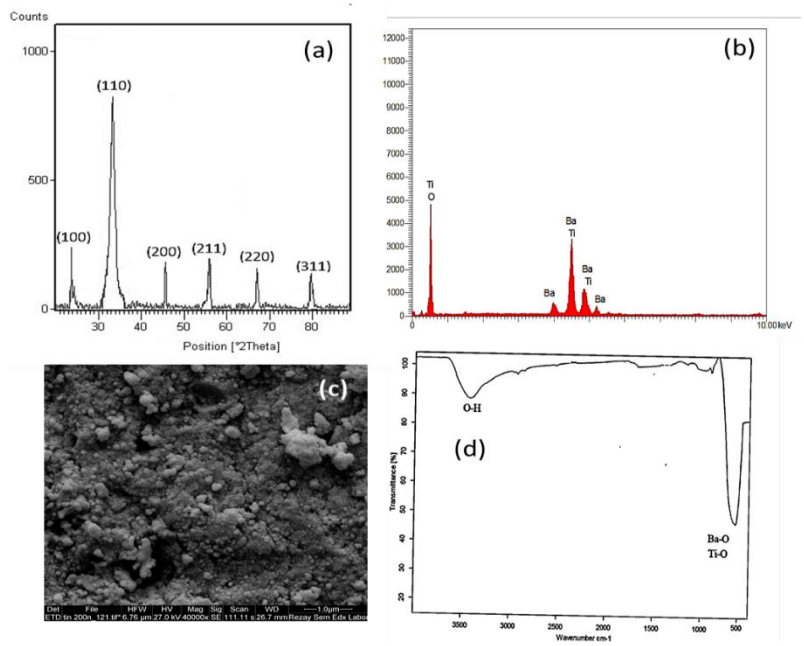

Figure 2: a) An electronic microscope image (SEM) of the AgNPs. b) depicts the ultraviolet-visible absorption spectrum of AgNPs c) shows the x-ray spectrometry for barium titanate along with silver nanoparticles. d) The atomic ratio of barium-titanium-oxygen-silver is 5-55-20-21 and measurement has made these nanoparticles high-quality single-phase lasers.

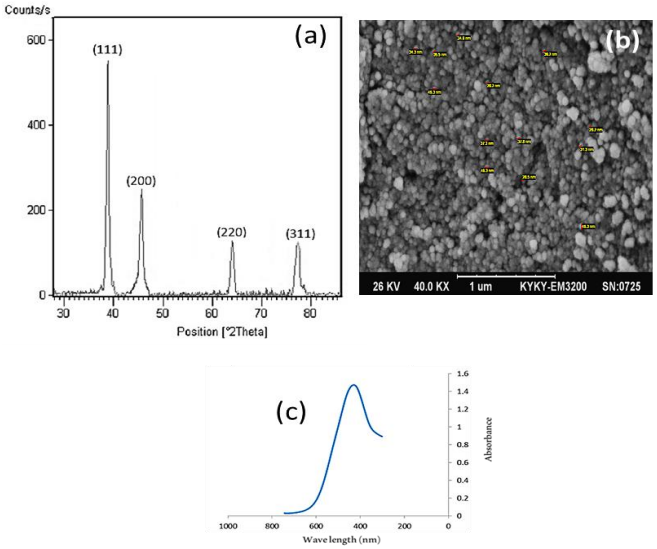

Figure 3: illustrates the X-ray diffraction of the layers with and without AgNPs and the absorption increasing with the merger of silver nanoparticles ~23.

The absorption spectrum of barium titanate nanoparticles in the buffer layer PEDOT:PSS with (red line) and without silver nanoparticles is given in picture 3a, the absorption increasing with the merger of silver nanoparticles ~23. In addition, the related PL spectrum of the barium titanate nanoparticles is shown in picture 3b. Both samples show the radiation of a green light commonly at about 410 nm. The PL intensity of barium titanate nanoparticles shows a significant increase with silver nanoparticles as compared to pure barium titanate nanoparticles, And with increasing amount of silver in the prepared multilayer film, the peak intensity increases. The results show that the silver nanoparticles increase the PL and the absorption properties of barium titanate nanoparticles.

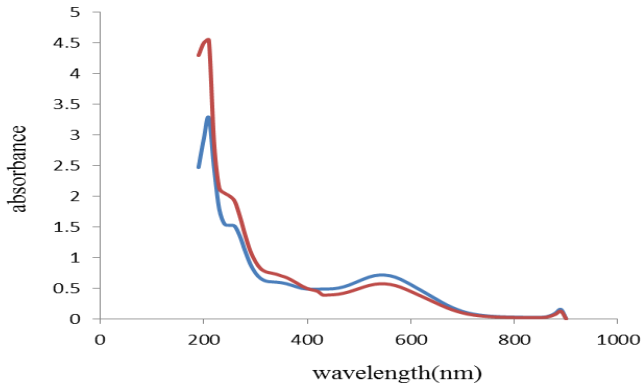

Figure 4: illustrates the absorption spectrum of BaTiO3 NPs in the buffer layer

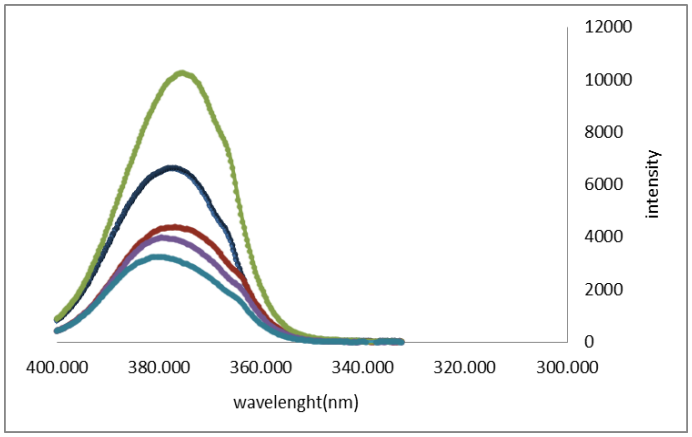

Figure 5: Intensity of BaTiO3 NPs represents a significant increase with AgNPs as compared to pure BaTiO3 NPs

Conclusion

Barium titanate (BaTiO3) is a crystal with specific properties, which these properties motivate us to use it to provide the light beam. The SHG increases light intensity, omitting the phase-match and polarization of particular directions. However, controlling the intensity of light, wave-shifting, and changing polarization of light with our proper direction is not satisfying by this crystal. When plasmonic is combined with this crystal, all conditions of interaction light with atom will be satisfied and fulfilled. The nanoparticle has one characterize to change the shape of the metal used in LSP, the noble metal, especially silver and gold, has the property that can change the peak of the absorption, because of the ability to change shape and peak of absorption, the LSP can change the wavelength to blue-shift. Additionally, the LSP changes the polarization, phase, increase intensity and wave packet. The result of all these characteristics of the LSP is the laser beam interacts with the probe system (atom) coherently with correct polarization, phase, energy, and high probability

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