Visible and Infrared emission from Erbium Oxide nanoparticle, for optical and biomedical applications

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ABSTRACT

The present work reports light emission from erbium doped in aluminum nitride host and erbium oxide nanoparticles. Thin films, deposited by rf magnetron sputtering, show green light emission from erbium. The nanoparticles, with 43 nm diameter, were obtained in the form of nano-powder with 99.9% purity. These nanoparticles were characterized for their light emission under a 532 nm Nd:YAG laser excitation. A Photoluminescence (PL) system, made by Princeton Instrumentation, was used to detect fluorescence emission from the nanoparticles. The PL system consisted of Pixis brand CCD camera with a range of 300 to 2000 nm. The erbium oxide nanoparticles were also mixed in distilled water to obtain spectrum. Two emission peaks were observed around 554 nm and 813 nm from the erbium oxide nanoparticles. The green emission at 554nm was obtained as a result of $^4I_{15/2} \rightarrow ^4S_{3/2}$ transition, and the near infrared emission from $^4I_{15/2} \rightarrow ^4I_{13/2}$ transition. This luminescence from the erbium oxide nanoparticles shows their potential importance in the optical devices and biomedical applications.

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Keywords: Nanoparticles, luminescence, erbium,

1 INTRODUCTION

Light emission from optical materials play an important role in the optical devices fabrication, display technologies, laser and biomedical physics applications like laser surgeries, and cancer detection. These light emitting materials can be produced in the form of thin films, nanoparticles, and quantum wells. Rare-earth elements and transition metals are famous for their light emission in ultraviolet, infrared, and visible range. These materials have been used by many investigators, and a number of useful devices are invented based on the emission of light from these rare-earth elements and transition metals [1-4]. Nanoparticles made of rare-earth elements or transition metals can be used for a number of advanced technological applications. Their use in making nanophotonic devices and laser cavities is getting attention for future applications. These nanoparticles can also be used directly or indirectly in cancer detection.

There are two main types of nanoparticles being studied in the detection of cancer cells. The first types of nanoparticles are gold nanoparticles. The gold nanoparticles attach themselves to a protein found in cancer cells called Epidermal Growth Factor Receptor (EGFR). The gold nanoparticles are put into a conjugated nanoparticles solution. The solution is then put onto the healthy cells as well as the cancerous cells. The area is then examined with a normal microscope. The gold nanoparticles bond with the cancerous cells and can be viewed with a microscope. The cancerous cells look shiny due to the bonding with the gold nanoparticles, as opposed to the healthy cells, which do not look shiny. This method makes the detection of cancer very easy, as the cancerous cells visually stand out from the healthy cells [5, 6].The second type of nanoparticles being studied for cancer detection is magnetic iron oxide nanoparticles. These particles are encased in a "biocompatible material" which sticks to the tumor. The tumor cells then act as magnets and can be attracted to a biopsy needle, making their removal simpler [5, 6].

In the present work we have studied thin films and nanoparticles made of erbium. This films of erbium doped in aluminum nitride host were studied for their light emission to find the region of visible and infrared spectrum where erbium can emit light. Erbium oxide nanoparticles were then obtained in the form of nanopowder and studied for their light emission properties. The purpose is to use the light emitting erbium oxide nanoparticles in making optical devices and possibly in cancer detection.

2 MATERIALS AND METHODS

Thin films of AlN:Er were prepared by rf magnetron sputtering of an aluminum target of 99.999% purity in a pure nitrogen atmosphere. Doping of thin films with Erbium (Er) was accomplished by drilling a small hole (0.5 cm. diameter) in the aluminum target (4.2 cm diameter) and placing a slug of Er in the hole. Er was then co-sputtered with the aluminum. The rf power was varied between 100 and 200 watts. All films were deposited onto 2 cm ×2 cm, or less, p-silicon (111) substrates. The background pressure in the chamber was $< 3 \times 10^{-5}$ Torr.
The nanoparticles, with 43 nm diameter, were obtained in the form of nanopowder with 99.9% purity. These nanoparticles and the deposited films were characterized for their light emission under a 532 nm Nd:YAG laser excitation. A Photoluminescence (PL) system, made by Princeton Instrumentation, was used to detect fluorescence emission from the nanoparticles. The PL system consisted of Pixis brand CCD camera with a range of 300 to 2000

nm. The erbium oxide nanoparticles were also mixed in distilled water to obtain spectrum.

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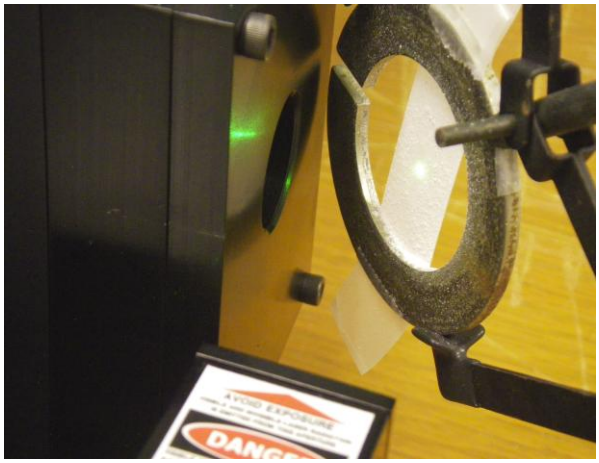
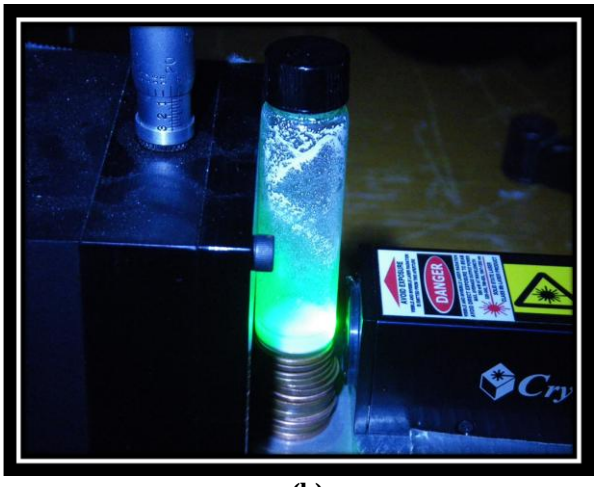
3 RESULTS AND DISCUSSION

Figure 1 shows excitation of erbium oxide nanoparticles by NdYAG laser with emission wavelength of 532 nm. In figure 1(a) nanoparticles are glowed to a clear scotch tape and laser beam is allowed to fall on the nanoparticles. The spectrum of light emitted by the nanoparticles is collected after subtracting the spectrum of scotch tape without nanoparticles glowed on it. Figure 1(b) gives the NdYAG laser excitation of the erbium oxide nanoparticles dissolved in distil water.



(a)



(b)

Figure 1. Laser excitation of erbium oxide nanoparticles (a) in solid form (b) dissolved in distil water.

Figure 2 shows the green emission from AlN:Er thin films. A strong and intense peak is obtained at 554 nm with a relatively weak peak at 561 nm. These peaks are obtained due to the $^2H_{11/2} \rightarrow {}^4I_{15/2}$ and $^4S_{3/2} \rightarrow {}^4I_{15/2}$ transitions. The $^4I_{15/2}$ is the ground state of Er^{+3}. Both peaks are in the green region of visible spectrum showing that Er^{+3} can be used for a number of green emission applications. We deposited these films in multiple thicknesses between 200 nm and 400 nm and found that the film thickness does not have any effect on the luminescence due to these two transitions.

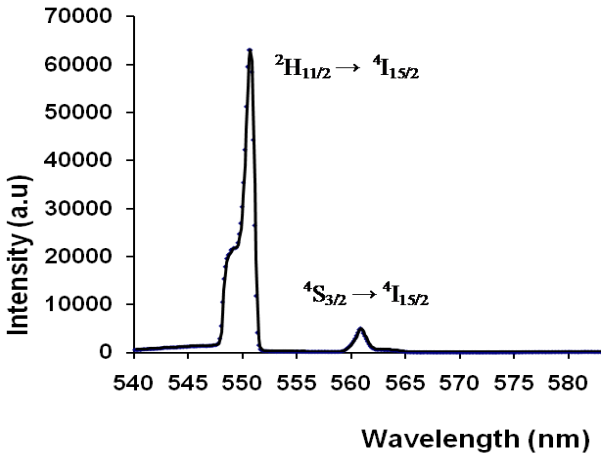


Figure 3 shows the emission spectrum of erbium oxide nnoparticles. These nanoparticles emit at 554 nm and 813 nm when excited by a 532 nm Nd:YAG laser. These peaks correspond to $^4I_{15/2} \rightarrow {}^4S_{3/2}$ and $^4I_{15/2} \rightarrow {}^4I_{13/2}$ transitions respectively.

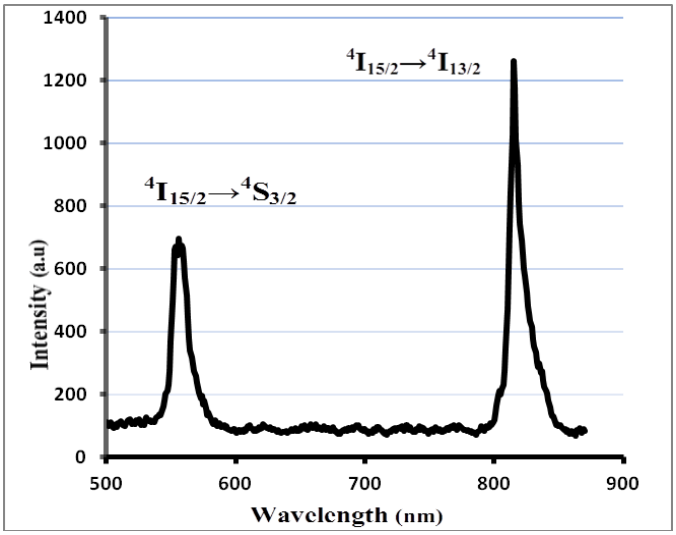


Figure 3. Light emission from erbium oxide nanoparticles under NdYAG laser excitation.

Light emission from thin films deposited on flat substrate guides us towards the green emission from erbium. This fact leads to search for a similar emission from erbium

oxide nanoparticles. When nanoparticles were investigated under similar circumstances it was figured out that green emission also appears from the nanoparticles of erbium. In addition to the green emission the nanoparticles are gives strong emission in the near infrared. The green emission can certainly be used in nanophotonics and nanotechnological applications in making opticald evices on nanometer scale. This emission can also be used in biological spectroscopy of human tissue and can make erbium oxide nanoparticles very suitable in internal body visualization and cancer detection of tumors close to the body surface. The near infrared emission is also very interesting. Near infrared region of the spectrum has the highest ability of penetration in human body. Thus, the infrared emission from erbium oxide nanoparticles may be used in cancer detection in relatively deeper tissies of the body.

4 CONCLUSION

Erbium oxide nanoparticles and thin films of erbium doped in aluminum nitride were investigated for their luminescence. Green emission at 554 nm from both erbium oxide nanoparticles and flat thin films of erbium and infrared emission at 813 nm from nanoparticles shows that erbium oxide nanoparticles are very good candidate for their use in nanophotonic devices, nanotechnology and possible cancer applications.

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