Frontiers in Drug, Chemistry and Clinical Research

Research Article ISSN: 2631-5424

Wheeler-Feynman Time-Symmetric study of effectiveness and efficiency of terbium nanoparticles delivery mechanism in human cancer cells, tissues and tumors under synchrotron radiation

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Abstract

Terbium nanoparticles absorb energy of generation beam radiation and procreate some heat in the bit. The procreated heat transmitted to the circumambient environs and guides to enhance in temperature of adjoining dots to nanoparticles. Heat conversions can be established by heat transmission equation. When Terbium nanoparticles are subdued to generated beam radiation, a section of beam radiation distributed (transpiration procedure) and the other section absorbed (non-transpiration procedure). The value of energy waste in non-transpiration procedure for the most part has a rightful place to compound and mass of nanoparticles and it can be recognized by absorption cross section. On the other hand, however, transpiration procedure which its specifications are contingent on mass, configuration and plane specifications of nanoparticles illustrates by dispersion cross section. Aggregate of absorption and distribution procedure which guide to beam radiation waste is called overthrow cross section.

Introduction

Cancer is one of the malignant diseases and millions of people worldwide die from cancer annually. Breast cancer diagnosis requires the analysis of images and attributes as well as collecting many clinical and mammography variables. In diagnosis of breast cancer, it is important to determine whether a tumor is benign or malignant. The information about breast cancer risk prediction along with the type of tumor are crucial for patients and effective medical decision making. An ideal diagnostic system could effectively distinguish between benign and malignant cells; however, such a system has not been created yet. In this study, a model is developed to improve the prediction probability of breast cancer. It is necessary to have such a prediction model as the survival probability of breast cancer is high when patients are diagnosed at early stages. In recent decade, metallic nanoparticles have been widely interested due to their interesting optical characteristics [1-8]. Resonances of surface Plasmon in these nanoparticles lead to increase in synchrotron radiation emission as a function of the beam energy scattering and absorption in related frequency [9,10]. Synchrotron radiation emission as a function of the beam energy absorption and induced produced heat in nanoparticles has been considered as a side effect in plasmonic applications for a long time [11-15]. Recently, scientists find that thermoplasmonic characteristic can be used for various optothermal applications in cancer, nanoflows and photonic [16-22]. In optothermal human cancer cells, tissues and tumors treatment, the descendent laser light stimulate resonance of surface Plasmon of metallic nanoparticles and as a result of this process, the absorbed energy of descendent light converse to heat in nanoparticles [23-25]. The produced heat devastates tumor tissue adjacent to nanoparticles without any hurt to sound tissues [26,27]. Regarding the simplicity of ligands connection to Terbium nanoparticles for targeting cancer cells, these nanoparticles are more appropriate to use in optothermal human cancer cells, tissues and tumors treatment [28-74]. In the current paper, thermoplasmonic characteristics of spherical, core-shell and rod Terbium nanoparticles are investigated.

Materials and experimental methods

When Terbium nanoparticles are subdued to generated beam radiation, a section of beam radiation distributed (transpiration procedure) and the other section absorbed (non-transpiration procedure). The value of energy waste in non-transpiration procedure for the most part has a rightful place to compound and mass of nanoparticles and it can be recognized by absorption cross section. On the other hand, however, transpiration procedure which its specifications are contingent on mass, configuration and plane specifications of nanoparticles illustrates by dispersion cross section. Aggregate of absorption and distribution procedure which guide to beam radiation waste is called overthrow cross section [75-123].

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Key words: *terbium nanoparticles, scanning electron microscope (SEM), 3D finite element method (FEM), heat transfer equation, optothermal, heat distribution, thermoplasmonic, terbium nanorods, human cancer cells, tissues and tumors treatment, simulation, synchrotron radiation, emission, function, beam energy*

Received: December 23, 2019; **Accepted:** January 06, 2020; **Published:** January 13, 2020

Terbium nanoparticles absorb energy of generation beam radiation and procreate some heat in the bit. The procreated heat transmitted to the circumambient environs and guides to enhance in temperature of adjoining dots to nanoparticles. Heat conversions can be established by heat transmission equation [124-202].

Results and discussion

The breast cancer is the leading cause for cancer-related deaths in women. Due to modern lifestyle, number of diagnosed patients with breast cancer in the developed countries are on the top of the list around the world [1-7]. The most common type of breast cancer is ductal carcinoma, which begins in the cells of the ducts. Breast cancer can also begin in the cells of the lobules and in other tissues in the breast [9-19]. In the U.S., breast cancer is the second most common cancer in women after skin cancer. It can occur in both men and women, but it is rare in men. Each year there are about 100 times more new cases of breast cancer in women than in men. In this project we applied several machine learning techniques on the Wisconsin Diagnostic Breast Cancer data set to classify the cancer based on the feature extracted from images as benign or malignant [20-25]. To calculate the generated heat in Terbium nanoparticles, COMSOL software which works by Finite Element Method (FEM) was used. All simulations were made in 3D. Firstly, absorption and scattering cross section areas were calculated by optical module of software. Then, using heat module, temperature variations of nanoparticles and its surrounding environment were calculated by data from optical module [203-283]. In all cases, Terbium nanoparticles are presented in water environment with dispersion coefficient of 1.84 and are subjected to flat wave emission with linear polarization. Intensity of descendent light is 1 mW/μm2. Dielectric constant of Terbium is dependent on particle size [284-321].

Firstly, calculations were made for Terbium nanospheres with radius of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 nanometers. The results show that by increase in nanoparticles size, extinction cross section area increases and maximum wavelength slightly shifts toward longer wavelengths. The maximum increase in temperature of nanospheres in surface Plasmon frequency is shown in Figure 1.

According to the graph, it can be seen that the generated heat is increased by increase in nanoparticles size. For 100 nm nanoparticles (sphere with 50 nm radius), the maximum increase in temperature is 83 k. When nanoparticles size reaches to 150 nm, increase in temperature is increased in spite of increase in extinction coefficient. In order to find the reason of this fact, ratio of absorption to extinction for various nanospheres in Plasmon frequency is shown in Figure 2.

Figure 2 shows that increasing the size of nanospheres leads to decrease in ratio of light absorption to total energy of descendent light so that for 150 nm nanosphere, scattering is larger than absorption. It seems that although increase in nanoparticles size leads to more dissipation of descendent light, the dissipation is in the form of scattering and hence, it cannot be effective on heat generation.

Heat distribution (Figure 3) shows that temperature is uniformly distributed throughout the nanoparticles which are due to high thermal conductivity of Terbium.

In this section, core-shell structure of Terbium and silica is chosen. The core of a nanosphere with 45 nm radius and silica layer thickness of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 nanometers are considered. The results show that increase in silica thickness leads to increase in extinction coefficient and shift in Plasmon wavelength of nanoparticles, to some extent.

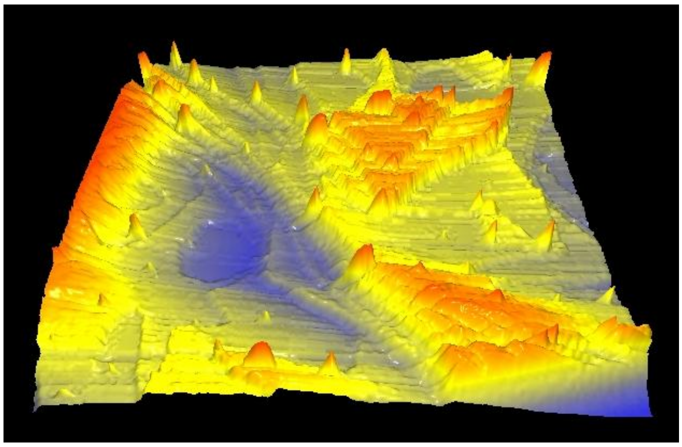

Figure 1. Maximum increase in temperature for Terbium nanospheres

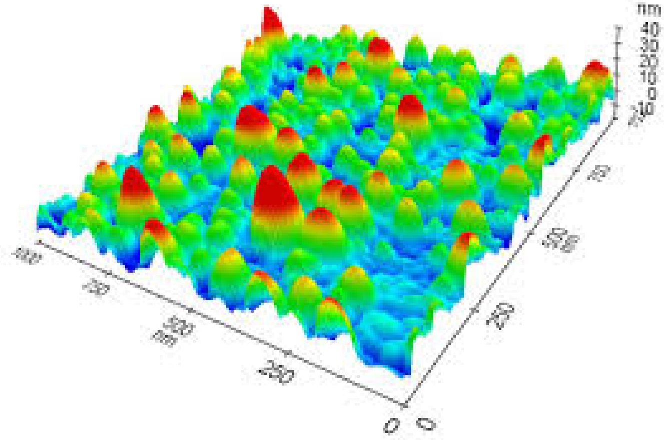

Figure 2. Variations of absorption to extinction ratio and scattering to extinction ratio for Terbium nanospheres with various radiuses

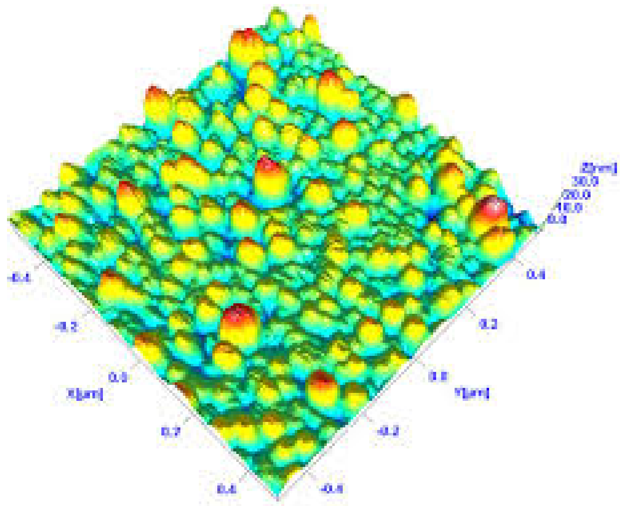

Figure 3. Maximum increase in temperature for spherical nanoparticles with radius of 45 (nm) at Plasmon wavelength of 685 (nm)

According to Figure 4, silica shell causes to considerable increase in temperature of Terbium nanoparticles but by more increase in silica thickness, its effects are decreased. Heat distribution Figure 5 shows that temperature is uniformly distributed throughout metallic core as well as silica shell. However, silica temperature is considerably lower than core temperature due to its lower thermal conductivity. In fact, silica layer prohibits heat transfer from metal to the surrounding aqueous environment due to low thermal conductivity and hence, temperature of nanoparticles has more increase in temperature. Increasing the thickness of silica shell leads to increase in its thermal conductivity and hence, leads to attenuate in increase in nanoparticles temperature.

Figure 6 is drawn. This graph shows that variation of nanorod dimension ratio leads to considerable shift in Plasmon wavelength. This fact allows regulating the Plasmon frequency to place in near IR zone. Light absorption by body tissues is lower in this zone of spectrum and hence, nanorods are more appropriate for optothermal human cancer cells, tissues and tumors treatment methods.

Variations of temperature in Terbium nanorods with two effective radius and various dimension ratios are shown in Figure 7. By increase in length (a) to radius (b) of nanorod, temperature is increased.

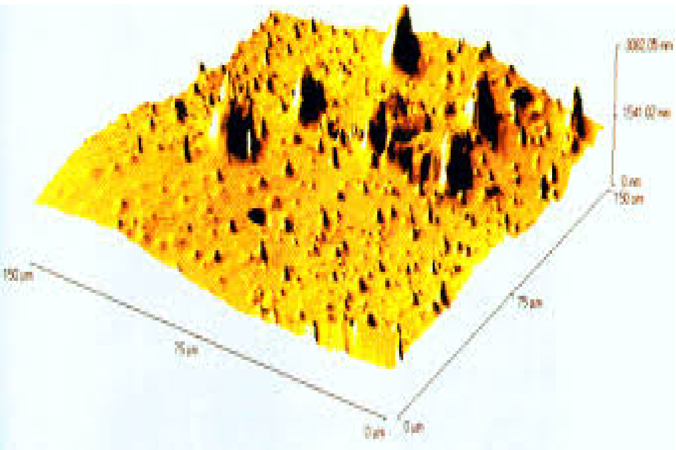

Figure 4. Maximum increase in temperature for core–shell Terbium nanospheres with various thicknesses of silica shell

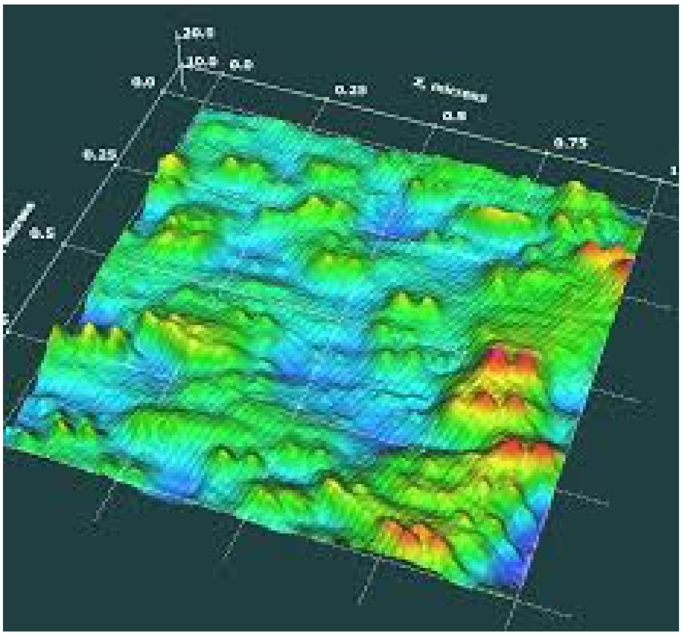

Figure 5. Maximum increase in temperature for core–shell nanoparticles with radius of 45 (nm) and silica thickness of 10 (nm) at Plasmon wavelength of 701 (nm)

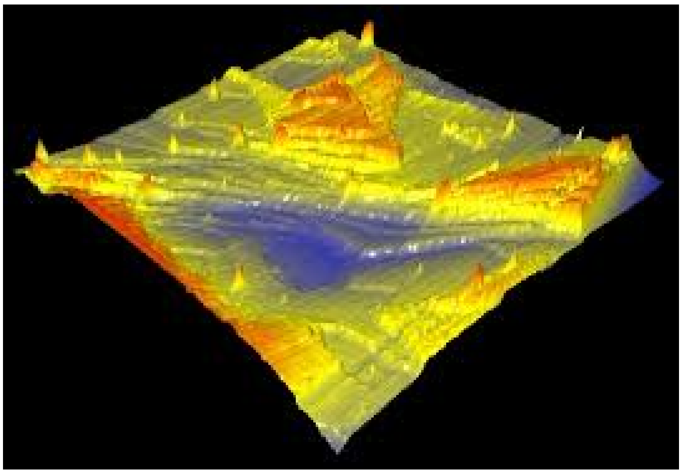

Figure 6. Extinction cross section area for Terbium nanorods with effective radius of 45 (nm) and various dimension ratios

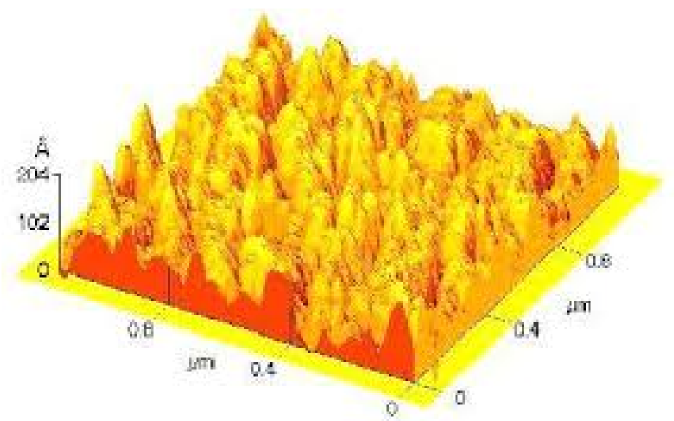

Figure 7. Maximum increase in temperature for nanorods with effective radius of 20 and 45 (nm) and various dimension ratios

Conclusion and summary

In the current age, pancreatic cancer is one of the worst forms of cancer. The complications of pancreatic include five types of pancreatitis, benign tumors, malignant tumors, benign cysts and malignant cysts. This cancer has a few clinical symptoms than other cancers. Also, if not treated in a timely manner, it also causes other organs of the body and the patient chance of survival is greatly reduced. One of the ways to detect this disease is to use CT scan images. But the appearance of pancreatic complications is very different in a similar category, and their tissue is very similar to healthy abdominal tissues. For this reason, it's very difficult to identify the range of complications. In this study, the data contained 151 CT scan images. These images are divided into five classes of pancreatitis, malignant tumors, benign tumors, malignant cysts, benign cysts and a healthy class. The pancreatic complications are varied and different, if the diagnostic system is based on simple experts; the possibility of achieving high detection accuracy is not possible. According to the results of this study, lonely no classification can detect all diseases and combining these methods is the best option. Therefore, in this study we have achieved high accuracy in prediction by combining the perception, convolution and SVM neural networks. The calculations showed that in Terbium nanoparticles, light absorption in Plasmon frequency causes to increase in temperature of the surrounding environment of nanoparticles. In addition, it showed that adding a thin silica layer around the Terbium nanospheres increases their temperatures. Calculations of nanorods showed that due to ability for shifting surface Plasmon frequency toward longer wavelength as well as more increase in temperature, this nanostructure is more appropriate for medical applications such as optothermal human cancer cells, tissues and tumors treatments.

Acknowledgements

Authors are supported by an American International Standards Institute (AISI) Future Fellowship Grant FT1201009373432. We acknowledge Ms. Isabelle Villena for instrumental support and Dr. Michael N. Cocchi for constructing graphical abstract figures. We gratefully acknowledge Prof. Dr. Christopher Brown for proof reading the manuscript. Synchrotron beam time was awarded by the National Synchrotron Light Source (NSLS-II) under the merit-based proposal scheme.

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