Engineering Advances, 2023, 3(6), 465-468
https://www.hillpublisher.com/journals/ea/
ISSN Online: 2768-7961

The Role of Infrared Light in Cancer Therapy

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How to cite this paper: Wentong Wu. (2023) The Role of Infrared Light in Cancer Therapy. *Engineering Advances*, 3(6), 465-468.
DOI: 10.26855/ea.2023.12.005

Received: November 30, 2023
Accepted: December 27, 2023
Published: January 19, 2024

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Abstract

Rare earth luminescence has received widespread attention in recent years. The process of using low-energy light to generate high-energy photons is called up-conversion luminescence. In the 1950s, reports on upconversion (UC) luminescence began to slowly emerge. People are beginning to pay attention to this issue. Upconversion (UC) luminescence can be performed by low-power and incoherent excitation sources, such as continuous-wave lasers, standard xenon or halogen lamps, or even focused sunlight. In the treatment of cancer cells, photodynamic therapy is undoubtedly a research hotspot. In this paper, I will introduce the history and mechanism of rare-earth upconversion (UC) luminescence; these kinds of materials have a wide range of applications using light energy. In this paper, I will analyze how it can be applied to the Photodynamic therapy of cancer cells; building a temperature sensor and detecting the temperature of cancer cells and the surrounding environment through the light-emitting characteristics will also be introduced in detail.

Keywords

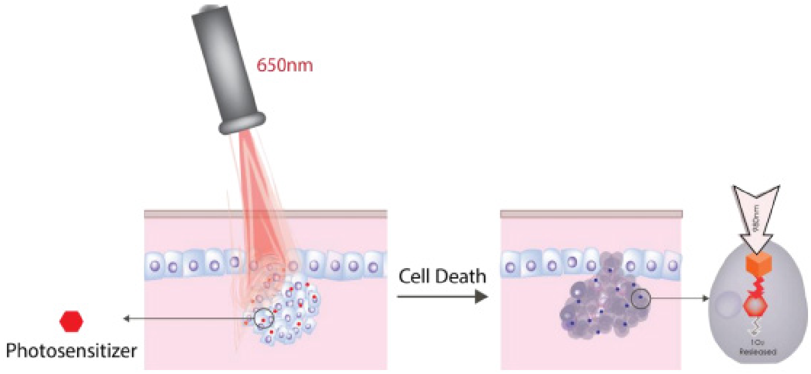
Upconversion, cancer therapy, infrared light

1. Background and context

In the 1950s, reports about upconversion (UC) luminescence began to appear. The initial discovery was that the ZnS polycrystalline sample was detected by visible green light under the excitation of 960nm laser. The phenomenon of radiating a shorter wavelength high-energy photon is called upconversion (UC) luminescence. The advantage is that the energy of the photon absorbed by the material is lower than the energy of the radiated photon, which can increase the utilization of light energy. In 1966, Auzel discovered that under the excitation of near-infrared light [1], co-doping with Yb3+ increased the visible light luminous intensity of Er^{3+}/Ho^{3+}/Tm^{3+}-doped ytterbium sodium tungstate glass by 100 times. According to this phenomenon, he officially proposed the concept of "up-conversion luminescence." Rare earth upconversion (UC) nanomaterials (UCNPs) emit higher energy light by absorbing two or longer wavelength low-energy light. Upconverting luminescent materials have received extensive attention in the biological field due to their excellent biocompatibility, adjustable size, and low background fluorescence interference [2].

2. Photodynamic Therapy

UCNPs can convert near-infrared light with greater tissue penetration depth into short-wave light that can be absorbed by traditional photosensitizers. The three basic Conditions for Photodynamic therapy include a specific wavelength of light [3], photosensitizer, and oxygen in the cells and tissues child. The primary method and process of the rare earth up-conversion nanomaterial photodynamic therapy is: After up-conversion nanomaterial excited by near-infrared light [4], ultraviolet and visible light with shorter wavelength and more potent energy would be emitted. When photosensitizers are exposed to ultraviolet or visible light, they can transfer the received energy to the surrounding oxygen molecules and produce cytotoxic reactive oxygen species. At the same time, the ground-state molecules are nearly excited as singlet oxygen or reactive oxygen species with high reactivity [5]. The singlet oxygen reactive oxygen species with high reactivity can kill the nearby cells. As an emerging tumor treatment method [6], it can selectively kill tumor cells and has the advantages of low trauma, low toxicity, repeatable treatment, and no visible damage to surrounding healthy tissues. One example of this can be seen in the main procedures of Photodynamic Therapy (PDT) treatment, which includes the following steps [7]. Firstly, the drug with the photosensitizer was injected into the delivery system. Once the delivery system spreads over a patient's body, the drugs remain in the tumor tissue longer than healthy tissues [8]. When a laser irradiates the tumor area, the photosensitizer will release harmful chemicals to kill tumor cells, as shown in Figure 1.



Note. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4742858/

Figure 1. Illustration of PDT treatment as described above (2016).

3. Photothermal therapy method

Photothermal therapy (PTT) is the absorption of light energy by light absorbers [9], and the conversion of light energy into heat uses heat to kill cancer cells to achieve the purpose of treatment [10]. Effectiveness mainly depends on the effective conversion of light to heat—nanoparticles such as gold and silver [11]. The particles are usually used as light absorbers in PTT therapy, and the up-conversion nanoparticles are used in NIR. Accurate deep tissue temperature measurement for PTT is essential to avoid collateral damage to healthy cells [12]. Therefore, temperature measurement is another application of up-converting luminescent materials in cancer treatment. Compared to conventional contact thermal sensing based on metal or liquid expansion, optical thermometry based on the fluorescence intensity ratio technique provides high detection spatial resolution and precision, and excellent sensitivity. The fluorescence intensity ratio (FIR) technique is realized through the varied luminescence intensities of two thermally coupled levels at different environmental temperatures, which is almost unaffected by spectrum losses and pumping intensity fluctuations. When the ambient temperature varies, the relative intensity ratio I_2/I_1 of the two emission peaks from the thermal coupling level S_2/S_1 in the up-conversion temperature measurement material will regularly increase, so by recording the ratio of fluorescence intensity can we realize real-time detection of temperature. Simultaneously, upconversion (UC) luminescence activated by rare-earth ions with suitable thermal coupled levels has been widely used as a promising candidate for cancer cell treatment. During photothermal therapy, the intratumoral temperature variations can be monitored via non-contact thermometry to prevent insufficient or excessive heating effects [13].

Scholar Gregory reported earlier that PDT might be an effective treatment for intraductal bronchial lung cancer. In addition, at present, it has achieved excellent results in the treatment of intraluminal tumors such as the esophagus and bladder. It has been approved by authoritative institutions in Europe, America, and other countries; in the liver, lung (peripheral lung cancer or metastatic tumor), brain, and breast [14]. Among other solid tumors, it has been reported that the method of irradiation between tissues has also achieved excellent results. For PTT, real-time temperature monitoring plays a vital role in optimizing the treatment procedure. At present, there are more mature imaging technologies, such as magnetic resonance imaging, computed tomography, photoacoustic imaging, and infrared thermal imaging. The direction of UCNP research in the future is to design multifunctional UCNPs to build an integrated platform for the comprehensive realization of disease imaging, diagnosis, and treatment. The main problem of most UCNPs currently studied is low luminous efficiency. The efficiency of most up-converting luminescent materials is still less than 1%, so the development of UCNPs with higher luminous efficiency will be an urgent task. In addition, toxicity is another important factor affecting the application of upconversion (UC) nanomaterials in clinical practice, so whether it can be applied remains further studied [15].

4. Conclusion

At present, the treatment of cancer is an urgent problem. The unique anti-Stokes properties of up-conversion materials and the excellent penetration of near-infrared light on the skin play a significant role in the photodynamic and photothermal methods of cancer treatment. This is very important because, of how much convenience it provides for medical staff; researchers are still discovering more probabilities through profound experiments.

Annotated bibliography

Qin F (2016). The authors propose a deviation of the fluorescence intensity ratio techniques that give a better result for non-contact temperature monitoring. This can have an impact on the photothermal treatment, as accurate temperature control is mandatory. The authors are proposing a deviation of the fluorescence intensity ratio techniques, which gives better results for non-contact temperature monitoring. Therefore, this article argues that the techniques can impact the photothermal treatment, as accurate temperature control is mandatory. Therefore, this article is conclusive, as it tends to argue that accurate temperature control is mandatory when it comes to photothermal treatment. Thus, the temperature must be controlled. The article's credibility can be associated with its authors, who are also experts in the field. The article generally intends the audience to be healthcare practitioners, who wish to use the deviation of the fluorescence intensity ratio techniques to treat their patients. The article also opens for further research, as the authors invite further researchers to investigate the effectiveness of the deviation of the fluorescence intensity ratio techniques, in terms of controlling temperatures to achieve higher efficiency and effective treatment.

Tosi D. (2018) The article shows the trend around the sensors used in photodynamic tumor treatment and is written by an expert in electronics. An expert in electronics, Tosi Daniel, discusses the trend around the sensors used in photodynamic tumor treatment. The article's premise argues that the Fiber Bragg Gratings have found significant use in healthcare, as they make it possible to detect spatially resolved variations of temperature or a strain with the resolution, hence why they can easily be applicable in photodynamic tumor treatment. Therefore, the article reviews the emerging trends in the CFBG sensors, focusing on all aspects of the sensing element of the technology, and outlining how the technology is applied in this treatment, with case scenarios for which CFBG sensors have been demonstrated in the treatment. This article is therefore intended for the audience who would wish to evaluate the effectiveness of this technology, including healthcare professionals and researchers whose concern is to treat tumors using photodynamic technologies treatment and especially to apply the FBGs.

The authors investigate a method to apply photothermal therapy with a limited adverse effect by monitoring the microscopic temperature in real time. This article aims to investigate a method to apply photothermal therapy with limited adverse effects, by monitoring in real-time the microscopic temperature in, just like the article by Qin et al. (2016, this article seeks to find out the significance of controlling temperature during photothermal therapy, to reduce the negative impact. However, in the article by Qin et al. (2016), the investigation was conclusive, where the article argued that the control of temperature was mandatory, which is not the case in this article. On the contrary, this article is an investigative study on the best method to apply photothermal therapy, with limited adverse effects, by monitoring real-time tie microscopic temperature The audience intended for this research, therefore, are researchers, who may wish to use this article as foundational knowledge to monitor the real-time temperature in a photothermal treatment. The article may also be used by medical professionals, whereby they may aim at controlling the temperatures of their patients during treatment.

Yoon I., Li J., Shim Y. (2013) Written by experts in oncology, the authors of this article aimed to demonstrate through experimentation that the progress in light delivery has increased the efficiency of clinical applications of photodynamic therapy. Thus, using practical experiments on the gold Nanoparticles, the article seeks to find the effectiveness of light delivery concerning their clinical effectiveness and their application in photodynamic therapy. The article is thus based on real-time experiments, which makes it credible from exerts and useful foundational knowledge for researchers wishing to research the topic. The audience intended for this article includes the researchers, as the article is investigative, and not conclusive of the results to affirm its application in healthcare facilities. The knowledge in the article may, however, further be used by medical experts, with controlled use on patients as its effectiveness is notable.

The authors are chemical and biomedical researchers, reviewing the impact of different photodynamic therapy factors, especially the effect of the drug delivery system on the photosensitizer. The authors of this article are chemical and biomedical researchers, who seek to review the impact of different factors on photodynamic therapy, especially the effect of the drug delivery system on the photosensitizer. The article focuses on cancer tumor treatment using this therapy. The article concluded that the therapy's effectiveness is based on two significant factors, which included the photosynthesizer delivery and the targeting ability. The article thus reviewed the various drugs that would be used to improve the effectiveness and efficiency of the treatment and focused the study on the photosynthesizer. This article is unique in its review compared to other articles, as it focuses on the effect of the drug delivery system on the photosynthesizer. The audience of this article may include researchers as it is investigative, and its credibility can be associated with the authors who are chemical and biochemical experts.

During a clinical study, the author verified that photodynamic treatment has no drawbacks and has a potential role in the curative and palliative setting. This conclusion needs to be confirmed on a larger scale study (only ten patients were considered for this study). The role of this article is to evaluate the role of photodynamic therapy in primary tracheal carcinomas. With data for the study obtained from patients treated with photoprint, the author verified during a clinical study that photodynamic treatment has no drawback effect and has a potential role in the curative and palliative setting. The article used an experimental approach to the study, where ten patients were involved in the study. Of the ten patients, it was concluded that photodynamic treatment did not have side effects, as all of the ten patients showed a positive response to the treatment. However, it is notable that only ten patients were involved in this case, which makes this research open for further research, in order to confirm the hypothesis. Therefore, this research's audience included both healthcare professionals and researchers, who may need to carry out further investigations concerning the article.

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