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Laser Dyes Types and Their Impact on Polymer Nanocomposites: A Review

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Abstract

This study addresses the classification of laser dyes and nanocomposites that are mixed with polymeric materials, as they are compounds that occupy a scientific position in laser applications and are of great importance in various applications. This review addresses the different types of laser dyes and the wavelengths at which they operate, as well as the polymers used in them, focusing on their thermal sensitivity, in addition to nanomaterial composites. The study included a review of previous research that is studied in this field and its review, especially studies that explore the areas of sustainable development and the practical applications of renewable energies aimed at improving the efficiency of solar cells and gas sensors. In this review, the properties and details of the wavelengths of laser dyes and different types of polymers were studied, and the sensitivity of these polymeric compounds to the heat added to them was addressed. In addition, the polymeric compounds were classified into groups according to their use, thus obtaining more accurate details about the process of improving methods of searching for more effective and more suitable materials in practical applications.

Keywords: Features, Dye Laser, Polymer Nano Composites.

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أنواع صبغات الليزر وتأثيرها على متراكبات البوليمر النانوية: مراجعة

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الخلاصة

تتناول هذه الدراسة تصنيف أصباغ الليزر والمتراكبات النانوية الممزوجة بالمواد البوليمرية، كونها متراكبات تحتل مكانة علمية في تطبيقات الليزر، وتتمتع بأهمية بالغة في مختلف التطبيقات. تم التطرق في هذه المراجعة الى مختلف انواع اصباغ الليزر والاطوال الموجية التي تعمل فيها، وكذلك البوليمرات التي تستخدم فيها والتركيز على تحسسها الحراري اضافة الى متراكبات المواد النانوية، وتضمنت الدراسة استعراضًا للأبحاث السابقة المدروسة في هذا المجال، واستعراضًا لها، وخاصة الدراسات التي تستكشف مجالات التنمية المستدامة والتطبيقات العملية للطاقات المتجددة، بهدف تحسين كفاءة الخلايا الشمسية ومستشعرات الغاز. تم دراسة خصائص وتفاصيل أطوال موجات أصباغ الليزر وأنواع مختلفة من البوليمرات، وتناولت الدراسة أيضا حساسية هذه المتراكبات البوليمرية للحرارة المضافة إليها. كما صُنفت المتراكبات البوليمرية إلى مجموعات حسب استخدامها، مما أتاح الحصول على تفاصيل أدق حول عملية تحسين أساليب البحث عن مواد أكثر فعالية وملاءمة للتطبيقات العملية.

الكلمات المفتاحية: المميزات، صبغات الليزر، متراكبات البوليمر النانوية.

Introduction:

The main work that materials science does in its research is how to improve and develop the properties of materials on which practical applications of technology depend. The efficiency of dye lasers depends on the type of active medium that generates the laser [1]. The active medium contains organic compounds that make up the active medium that contributes to obtaining the laser, and thus works to increase the efficiency and performance of the laser obtained from the dye that works as an active medium to generate a laser when an external light is shone to excite it [2]. Laser dyes used as an active medium for generating lasers are of two types: either composed of organic materials or composed of inorganic materials. They are used in a large number of industrial applications due to their high efficiency and good properties and consist of groups: pyrazolin, coumarin or rhodamine. The use of laser dyes and polymer nanocomposites is of great interest, as polymeric materials provide advantages such as low weight and flexibility, while composites enhance properties such as thermal and electrical conductivity [3].

Table 1, Previous studies

Polymer types	Dye	Applications	Reference
PMMA and PLA	Azophloxine dye	- Filters that include an optical edge that is used against harmful lasers. -Varieties in optical limiting responses and performance levels for different nanocomposite types.	[4]
Dye-Polymer Nanocomposites	Organic dyes	Z-scan technique optical limiting-	[5]
epoxy resin	Rhodamine 6G and B	-Tunable Laser Medium -speckle-free laser imaging and time-resolved microscopy.	[6]
polyethylene oxide (PEO)	carbon nanotubes, carbon black, and graphene	- Reducing equipment malfunctions and repair costs. - Working to improve the stability of optical power in applications.	[7]
copolymerized .nanocomposites	DCM laser dye	-Used in pressure sensitive emitters and optical gain media.	[8]
PVA	Organic dye Naphthol green B	-optical-active polymer.	[9]

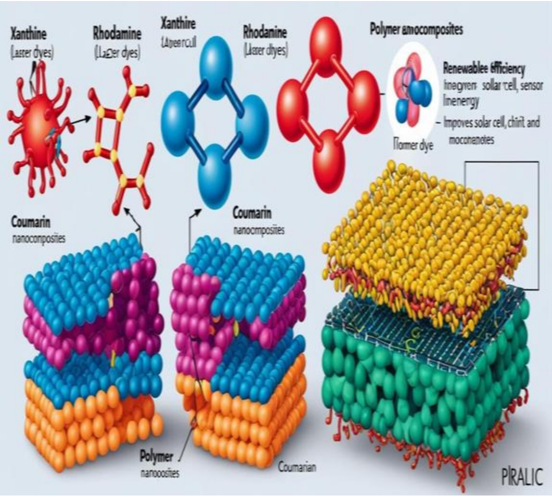

Fig. (1): types of laser dyes used with polymer Nano composites.

This article focuses on the importance of laser dyes that are the main part in the laser formation process, especially laser dyes that work in sustainable solar energy technology such as solar cells in which the active media are dyes (DSSCs), as well as in gas sensors, displays, and communication devices.

Laser Dyes

Laser dye compounds are characterized by their stability and also their distinctive specifications when added to different types of polymeric compounds, and for this reason they are suitable for multiple purposes of laser applications [10-13]. Organic compounds are classified into two basic categories: the first category has a single bond and is called saturated organic compounds, and the second category has a double bond that alternates with single bonds and is called (chromophore) and is (unsaturated). This category is characterized by having a broad absorption spectrum in the visible and ultraviolet range. When these compounds are added to different types of polymers, they are stable and have distinctive properties. For this reason, they are widely used in various laser applications [9-12]. Laser compounds are shown in Table (2).

Table 2, Types of Laser Compounds

Dyes	Aromatic Compound	Heterocyclic Compound
Chlorophyll	Cyclic molecules e.g. (naphthalene ,and pyrene)	coumarin and its derivatives (e.g. C102, C153, ….)
Merocyanine	Diene compounds (stilbene)	quinolone , and its derivatives
Acridine, Azine		Oxyl compounds
Rhodamine (6G,B)		Furan compounds

Dyes are often classified into groups according to the wavelength of the radiation they emit, as each group emits a specific range of the spectrum ranging between: (400 - 1000) and these groups are

The most important types of laser dyes

1- Rhodamine dyes: The most important types are Rhodamine G6 and Rhodamine B. The specifications of these dyes are that they have high efficiency in terms of their fluorescence, and they have optical stability and a wide range of absorption. They are suitable for various important applications in lasers because they are compatible with various polymer complex matrices.

2- Pyro methane dyes: These dyes occupy a wide spectrum of emission wavelengths, and in addition to this feature, they have good photo stability.

3- Cyanine dyes: These dyes are water-soluble and organically soluble, and have a wide spectrum of wavelengths. They are characterized by their high fluorescence, which makes them important and preferred in sensing technologies in addition to biological applications.

4- Fluorescein dyes: These dyes have a high fluorescence spectrum and are also optically stable.

5- Coumarin dyes: In the ultraviolet region as well as in the visible region of the electromagnetic spectrum, this dye has a high absorption spectrum. This characteristic is a distinctive feature of it in addition to its thermal stability. Therefore, its uses are multiple in wide areas in solid-state laser systems due to its high ability to fluoresce, and it has important compounds including: 480, 153, 2.

6- Bodibay dyes: This formula is one of the dyes that have solubility and are also characterized by high optical stability. In addition, the fluorescence spectrum of this dye is a sharp spectrum, which is why this dye is widely used in biomedical imaging.

7- Anthracene and its derivatives: This dye is used in organic light-emitting diodes (OLEDs) because it has the property of thermal stability and stability. Because of the emission spectrum of this dye, which is in the blue region of the electromagnetic spectrum, it is used in many applications related to polymeric compounds. Its high optical and thermal stability makes it suitable for applications that have high performance.

Polymer Nanocomposites

Polymer Nano composites are defined as a polymer base material with nanomaterials added to it at a concentration not exceeding 5% as fillers. Classification of polymer nanocomposites with laser dyes and types of nano additives and their applications.

1.3 Classification based on the polymer matrix as follows: 1. Thermosetting polymers: These polymers undergo irreversible hardening upon processing. Examples include epoxy and phenolic resins. 2. Thermoplastic polymers: These polymers have the ability to repeatedly melt and reform. Examples include polyethylene, polypropylene, and polystyrene (PS)[14-16].

Classification based on the nanomaterial added to the polymer nanocomposite as follows:

1.Carbon-based nanofillers, which consist of carbon nanotubes (CNTs), graphene, and fullerene [17].

2. Metallic nanofillers: These include metal nanoparticles such as silver, gold, and platinum [18].

3. Ceramic nanofillers: These consist of nanoparticles of materials such as silica, alumina, and titania [19].

4. Organic nanofillers: These include natural or synthetic organic materials such as cellulose nanocrystals [20].

4 Classification polymer nanocomposites based on applications [21, 22]

1. Optical applications: As they are used in many devices such as lasers,

optical sensors, and photonic crystals.

2. Electrical applications: As they are widely used in conductive coatings as well as in electromagnetic fields in addition to energy storage devices.

3. Mechanical applications: As when polymer composites are combined to enhance both strength, hardness, and corrosion resistance.
4. Biomedical applications: As they are used in drug delivery systems, tissue engineering, and biological sensors.

Properties of Nanocomposite Polymers Mixing nanocomposite polymers and laser dyes improves all their properties [13, 23, 24].

1. Improving optical properties: As laser dyes help improve both the color and optical concentration of polymers, which makes them ideal for use in optical device applications.

2. Increased strength and flexibility: Laser dyes are added to polymers to improve their mechanical properties, such as increased strength and flexibility.

3. Thermal and chemical stability: These compounds help increase the stability of polymers under the influence of both heat and chemistry, thus extending their life.

4. Environmental uses: These composites are considered a better environmental option than some traditional chemical dyes that may be polluting.

Versatility in Applications: Enhanced properties make these materials suitable for use in telecommunications, medical diagnostics, light-emitting devices, and sensor technology.

Chemical Resistance: Doping with certain dyes can also impart improved resistance to various chemicals and environmental conditions, increasing longevity and performance reliability.

Advantages of Laser Dyes in Polymer Composites

Laser dyes improve many properties of polymer nanocomposites and thus expand their uses. They also improve the efficiency of optical conversion, in addition to their use in sensors and biomedical devices, and increase thermal stability. That is also used in medical diagnostics, as they reduce the cost of the prepared devices and their small size. Among their most important features are [25-29]:

1. Improving optical properties: The addition of laser dyes to polymer nanocomposites enhances the properties of both the absorption and emission spectra, which leads to improving their performance in laser applications. It causes an increase in optical conversion efficiency and reduces the laser threshold. Since laser dyes have an emission spectrum that extends over a wide range of wavelengths. Choosing specific dyes to be incorporated into the polymer matrix, the polymer composites develop and emit light in the visible and near-infrared spectral range, allowing wavelength tuning in applications such as sensors and bio imaging.

2. Enhanced thermal stability to the chemical stability of laser dyes, this has improved their thermal properties, in addition to their uses in thermal applications, and has increased the lifespan and reliability of devices. Biocompatibility Specific laser dyes, especially natural product derivatives, with Nano polymer composites have led to their use in medical applications, such as bio imaging, which has led to the development of advanced diagnostic tools with minimal toxicity. Processing composites can be easily done in different shapes and sizes. The addition of laser dyes enhances the optical properties without complicating the processing procedure.

Conclusions

Laser dyes used with polymer nanocomposites have proven to be widely used in many applications, especially in the fields of sustainable development and renewable energy, thus enhancing the efficiency of solar cells and sensors. This review has addressed the types of laser dyes, their operating wavelengths, and the polymers used, with a focus on their thermal sensitivity and the integrated nanomaterials. The importance of laser dyes is evident in dye-sensitized solar cells (DSSCs) due to their ability to enhance light absorption and electron transfer, ultimately enhancing the overall performance of solar cells. Common laser dyes, such as rhodamine, pyromethane, and cyanine, are characterized by their fluorescence efficiency and compatibility with polymer matrices. Polymer nanocomposites are classified based on polymer matrixes, their applications and nanofillers such as carbon nanofillers and those containing metals or organic materials in high proportions. The process of mixing laser dyes improves their mechanical strength, optical properties and thermal stability, which is why these compounds are good to use in wired and wireless communications devices, in diagnostic processes in medical devices and many other fields, this is due to the biocompatibility of some laser dyes, which allows them to be used with very little toxicity. Therefore, this integration process of laser dyes represents many solutions for their uses in this medical field, in addition to being environmentally friendly in this field of applications related to advanced materials.

Conflict of Interest:

The authors declared no conflict of interest.

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