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Study of Characteristics of Semiconductor GaAs Nanoparticles Prepared by Laser Ablation Method

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Gallium arsenide GaAs nanoparticles are prepared in water using laser ablation method. The optical properties and energy gap of the colloidal solution are investigated using UV-visible spectrometer; the absorption peaks are observed between 200 and 300 nm wavelength, and the energy gap is calculated of about 1.86 eV. Zeta potential value is of about −22.18 mV that gives the impression of acceptable stability of the colloidal solution.

Наночастинки арсеніду Ґалію GaAs було одержані у воді методом лазерної абляції. Оптичні властивості й енергетичну заборонену зону колоїдного розчину було досліджено за допомогою УФ-оптичного спектрометра; піки вбирання було спостережено в діяпазоні довжин хвиль від 200 до 300 нм, а енергетичну заборонену зону було розраховано приблизно у 1,86 еВ. Значення дзета-потенціялу становило приблизно −22,18 мВ, що створює враження прийнятної стабільности колоїдного розчину.

Key words: gallium arsenide GaAs, laser ablation, zeta potential, optical properties of GaAs.

Ключові слова: арсенід Ґалію GaAs, лазерна абляція, дзета-потенціял, оптичні властивості GaAs.

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1. INTRODUCTION

Studying the optical properties of the semiconductors gives a clear indication to determine the nature of the use of a substance semiconductor, and to understand the mechanism of electronic transfers between energy bands by measuring the absorption of radiation by the semiconductor and its transmittance. All semiconducting materials share an important and distinctive feature in a scheme of absorption, which is the increase in absorbance when the absorbed radiation energy becomes equal to the gap energy and this point has been called the fundamental absorption edge [1].

Progress in solid-state physics has been characterized by a shift in dealing with large crystals to dealing with small crystals that are characterized by the length of at least one of their dimensions being within the range (100–1 nm). The change in dimensions affects the properties of the electron in the semiconductor, such as the Broglie wavelength and the wave behaviour of the particle; particles behave wave-like. In addition, the decrease in the size of the crystals leads to a greater separation of the energy levels and an increase in the effective energy gap, which leads to the appearance new physical properties due to quantum effects such as quantum Hall effects, quantum conductance oscillations [2, 3].

Nanotechnology is any technology that is accomplished on a nanometer scale and has many applications. Nanotechnology includes the production and application of physical, chemical, and life (biological) systems on a scale that extends from a single atom or molecules to dimensions of a fraction of a micron, as well as the integration of the resulting nanostructures into systems [4].

The process of manufacturing materials on the nanoscale can be done in two ways, the first is self-assembly, or called a bottom-up approach, in which nanomaterial are built atom by atom (atom-by-atom), the second method is called top-down approach, in which materials are sculpted to obtain their nanosize [5, 6].

The concept of the assembly method was derived from natural biological processes where molecules combine to form a more complex compound with nanoscopic dimensions. In this method, the secondary units assemble and organize into a final structure characterized by the lowest possible free energy, and this process is directed according to the properties of the secondary units. The nanostructure or microstructure can be obtained from one or more building components. For example, the superlattice resulting from the assembly of magnetic and semiconducting nanoparticles, in which the nanocrystal contains two construction components and is characterized by specifications, which differ from the properties of separate universes, as seen in Fig. 1 [3, 7].

2. EXPERIMENTAL METHOD

Laser ablation method has been used to prepare GaAs nanoparticles. The nanoparticles have been extracted from GaAs plate immersed in water and using Nd:YAG laser with 1064-nm wavelength, 1.32 J/cm^2, 8-cm lens' length and 5-min. ablation time.

The extracted GaAs nanoparticles were predicated in the water as shown in Fig. 2.

The water colour was changed to a light brown colloidal solution of GaAs nanoparticles as shown in Fig. 3.

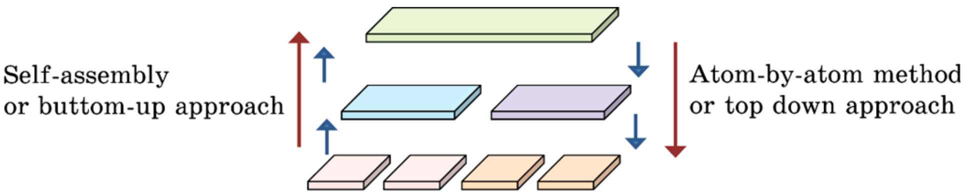

Fig. 1. Manufacturing materials on the nanoscale methods.

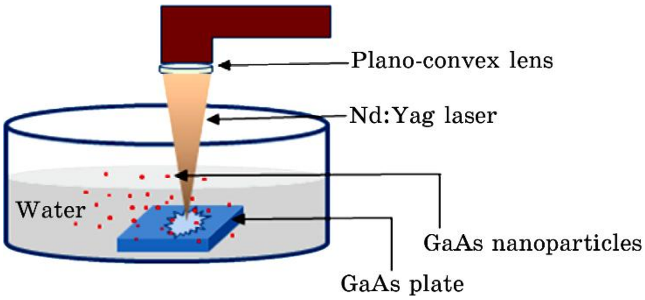

Fig. 2. Laser ablation method.

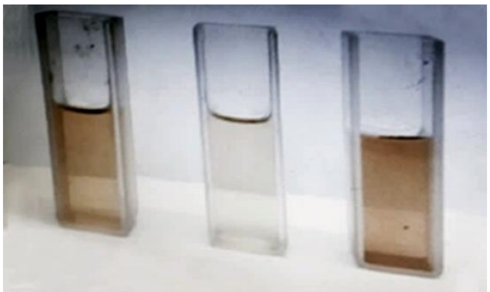

Fig. 3. Light brown colloidal solution of GaAs nanoparticles.

3. RESULTS AND DISCUSSION

The transmittance of GaAs has been examined using UV-visible spectroscopy.

The transmittance of the particles increases with wavelength and stabilizes approximately between 60% and 75% over the wavelength range 800–1000 nm (Fig. 4). The absorbance and reflectance spectrums are determined using Ref. [8] as follow:

$$A = \ln(1/T), \quad (1)$$

$$R + A + T = 1. \quad (2)$$

The absorbance show several peaks within the range 200–300 nm, which belong to the GaAs nanoparticles [9]. The reflectance also varied with wavelength as shown in Fig. 4, *c*.

The optical constants *n*, *k*, and absorption coefficient have been deduced from the optical properties using Eqs. (3), (4) and (5), respectively, and showed a clear variation with wavelength as shown in Fig. 5 [10–12]:

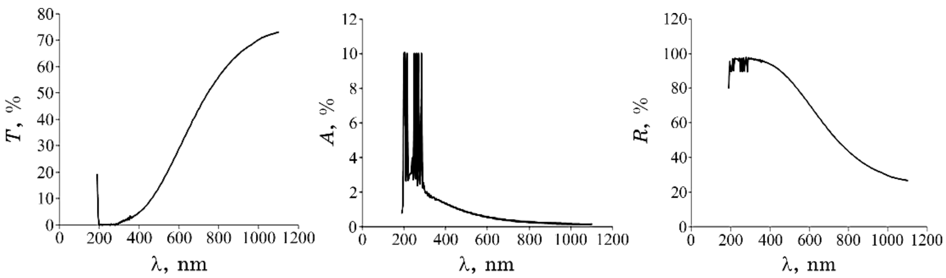

Fig. 4. Transmittance, absorbance, and reflectance of GaAs nanoparticles *versus* wavelength.

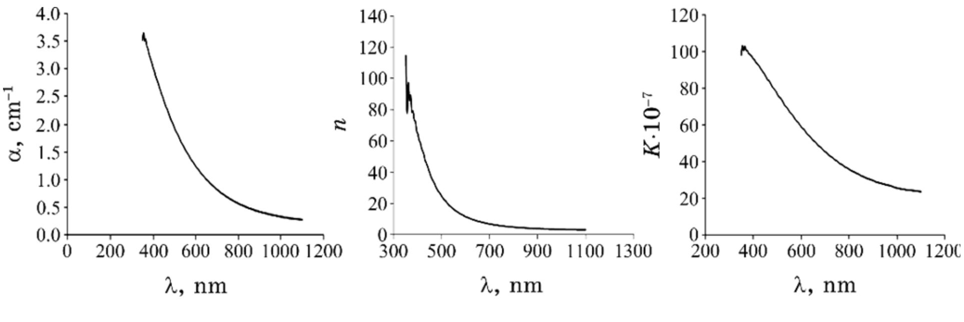

Fig. 5. Absorption coefficient, refractive index, and extinction coefficient of GaAs nanoparticles *versus* wavelength.

$$n_0 = (1 + R)/(1 - R) + \sqrt{4R/(1 - R)^2 - k_0^2}\,, \tag{3}$$

$$k_0 = \alpha\lambda/(4\pi)\,, \tag{4}$$

$$\alpha = 2.303A/t. \tag{5}$$

where α is the absorption coefficient, A is the absorbance and t is the film thickness.

The energy gap of GaAs nanoparticles was also investigated by drawing the relation between the square of the absorption coefficient multiplied by the energy $(\alpha h\nu)^2$ [(eV/cm)^2] and the photon energy E [eV], where the tangent to the curve showed that the energy gap of the GaAs nanoparticles of about 1.86 eV (Fig. 6).

One of the most important properties of colloidal solutions is stability, and this property is measured by examining the zeta potential. The stability of the colloidal solutions increases with the increases in the zeta potential. Figure 7 shows that the zeta potential value is of around −22.01 mV that reflects acceptable stability for

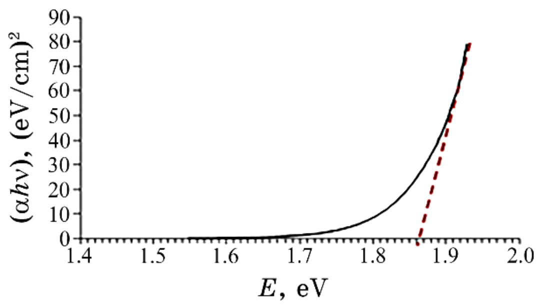

Fig. 6. The energy gap of GaAs nanoparticles *versus* wavelength.

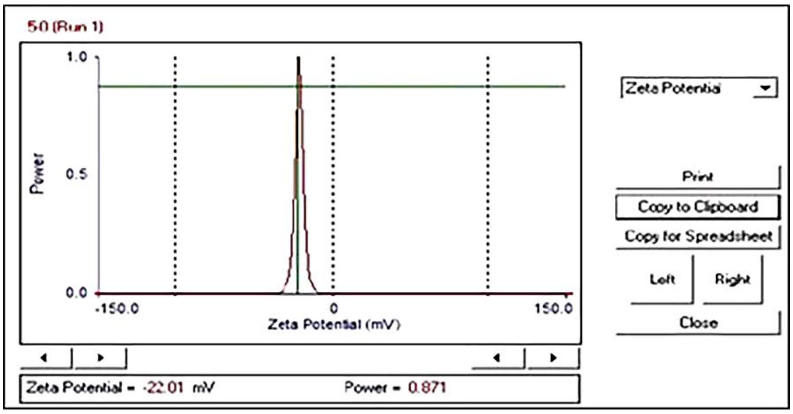

Fig. 7. Zeta potential of GaAs nanoparticles.

the colloidal solution of GaAs nanoparticles [13].

4. CONCLUSION

Gallium arsenide GaAs nanoparticles have been prepared in water using Laser ablation method, the transmittance of the particles show good transmittance of about 60–75% over the wavelength range 800–1000 nm. The absorbance, reflectance, refractive index and extinction coefficient were varied with wavelength. The energy gap was calculated of about 1.86 eV; finally, the zeta potential value was of −22.18 mV.

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