Торайғыров университетінің хабаршысы
ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ
Вестник Торайгыров университета

Торайғыров университетінің ХАБАРШЫСЫ

Физика, математика және компьютерлік ғылымдар сериясы

1997 жылдан бастап шығады

ВЕСТНИК Торайгыров университета

Серия: Физика, математика и компьютерные науки

Издается с 1997 года

ISSN 2959-068X

№ 1 (2024)

ПАВЛОДАР

НАУЧНЫЙ ЖУРНАЛ
Вестник Торайгыров университета

Серия: Физика, математика и компьютерные науки
выходит 4 раза в год

СВИДЕТЕЛЬСТВО
о постановке на переучет периодического печатного издания,
информационного агентства и сетевого издания
№ KZ91VPY00046988
выдано
Министерством информации и общественного развития
Республики Казахстан

Тематическая направленность
публикация материалов в области физики, математики,
механики и информатики

Подписной индекс – 76208

https://doi.org/10.48081/NLWQ4802

SRSTI 29.19.31, 29.31.26

https://doi.org/ 10.48081/GBDQ1313

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INVESTIGATION OF THE ABSORPTION PROPERTIES OF AN ULTRAVIOLET DETECTOR BASED ON GRAPHENE PLATELETS AND TITANIUM DIOXIDE

In this paper, the properties of a nanocomposite based on graphene plates and TiO_2 obtained by hydrothermal synthesis are investigated. The formation of the nanocomposite is confirmed by SEM imaging and Raman spectroscopy data. The SEM-e shows graphene sheets that are superimposed on the surface of TiO_2 nanoparticles. The Raman spectra of the nanocomposite show peaks characteristic of TiO_2 and graphene. It is assumed that the functional groups characteristic of graphene oxide partially disappear, which indicates its partial reduction during synthesis. The absorption spectra of the nanocomposite are shifted to the long-wavelength region of light, which may indicate a change in the band gap of the material.The absorption capacity also affects the increase in the photocurrent of the nanocomposite material. The absorption spectra show a shift to the long-wavelength region of light due to the transparency of graphene oxide in the visible region. The concentration of graphene oxide plays an important role in increasing the efficiency of the nanocomposite material. In this work, the concentration of the plates is equal to 1 wt% relative to titanium dioxide.

Keywords: nanocomposite material, photodetector, graphene plates, Raman spectrum, absorption properties.

Introduction

Currently, most electronic devices are directly or indirectly related to light interaction in various devices and applications. Photodetectors that can effectively detect and measure incident light have attracted considerable attention. Scientists have adopted various experimental methods to create new materials, for example, they include nanowires, quantum dots, nanowires and thin films, etc. A variety of methods are used for their manufacture, such as magnetron sputtering, electron beam evaporation, chemical vapor deposition (CVD), electrochemical and mechanical peeling, chemical etching, pulsed laser deposition (PLD) and pyrolysis by spraying, due to the potentially high surface-to-volume ratio and stability with fewer defects [1].

Photodetection in the ultraviolet region has become widespread due to its capabilities in various fields of application, such as flame and radiation detection, astronomical research and secure space communications, environmental and biological research, chemical analysis for shielding and optical communications, detection of a rocket plume, etc.

Currently, significant research is focused on the manufacture of portable and highly sensitive ultraviolet (UV) detectors due to their rapid use in microelectronic devices. Due to its significant ability to absorb ultraviolet radiation, several silicon-based materials are widely used in various fields. However, silicon has a band gap of 1.1 eV, which allows it to absorb visible radiation. To avoid this, several layers of high-frequency optical filters were introduced, which implies an expensive manufacturing process of the device [2;3].

In particular, the installation of filters has a relatively high noise generation. In this regard, transition metal oxides, SiC and AlGaN alloys are particularly attractive for UV photodetection due to their chemical and thermal stability. It is known that the band gap above all materials is exposed to ultraviolet radiation, which suggests that we can avoid using high-frequency optical filters. In another direction, metal oxide-based semiconductors such as ZnO, SnO_2, Fe_2o_3, WO_3 and TiO_2 have proven themselves to be an excellent UV photoactive material in optoelectronic devices [4]. It should be noted that if composite materials are integrated with various nanostructures, the sensitivity of the device can be significantly improved. Therefore, it is necessary to develop and investigate the suitability of a selective/hybrid material to improve the characteristics of photodetectors.

Methods and materials

The preparation of nanocomposite materials was synthesized by the hydrothermal method according to the method of work [5, 6]. The preparation was carried out on the basis of graphene plates (GNP, Cheaptubes), TiO_2 (d>21 nm, anatase, 99.7 %, Sigma Aldrich), deionized water (Drawel water purification system), ethanol (anhydrous). The concentration of graphene plates in the resulting nanocomposite material is 1 %.

All reagents were analytically pure and used without additional purification.

The surface morphology of the obtained composite materials was studied using a TescanMira3 scanning electron microscope (SEM). A Confotec MR520 microscope (Sol Instruments) with laser excitation at a wavelength of 632.8 nm was used to register Raman spectra. Films made of TiO_2 or TiO_2-PTC nanocomposite were prepared from a paste obtained by continuous stirring of 50 mg of TiO_2 powder and TiO_2-Npc 1 ml of ethanol for 12 hours.

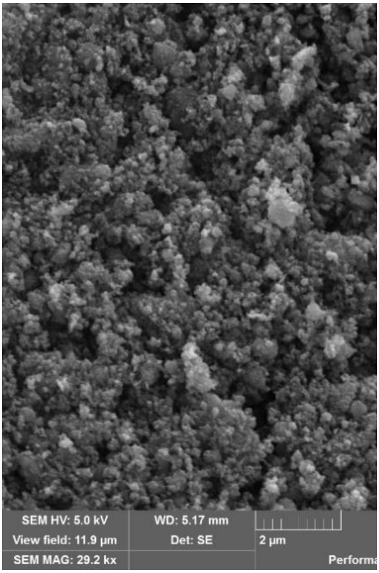
The finished paste was applied to the surface of the substrates by the "spin-coating" method at a rotation speed of 3000 rpm. After application, the film was annealed in an Ar atmosphere for 2 hours at a temperature of 450 °C.

The photodetector was assembled on glass with a conductive layer of fluorinated tin oxide (FTO, ~7Ω/sq, Sigma Aldrich). Counter-comb tracks were cut on the surface of the substrates using a Laser machine 1610 RD 150W (Bodor) laser scriber [7].

The absorption properties of the films were recorded using an ATP-2002 spectrophotometer (OptoSky). To measure the optical characteristics, the films were deposited on quartz substrates.

Results and discussions

Figure 1 shows the SEM images of the TiO_2-ZNO nanocomposite material. It can be seen from the figure that titanium dioxide nanoparticles are aggregated. At the same time, interparticle pores can be distinguished in the images. Graphene oxide and reduced graphene oxide in the samples have a layered structure, which is formed by separate sheets. Moreover, it is in these places that TiO_2 nanoparticles are preferably concentrated. At the same time, the presence of graphene oxide in the synthesized sample was confirmed by EDS analysis (Figure 1, c).



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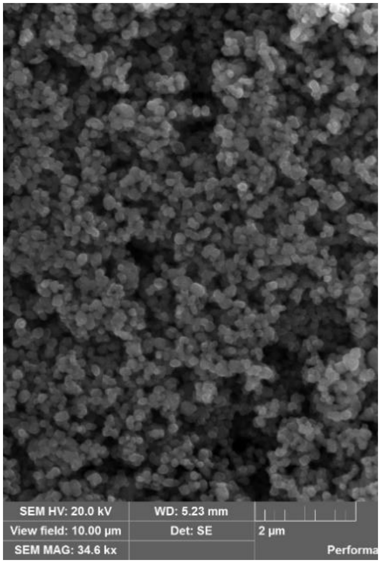

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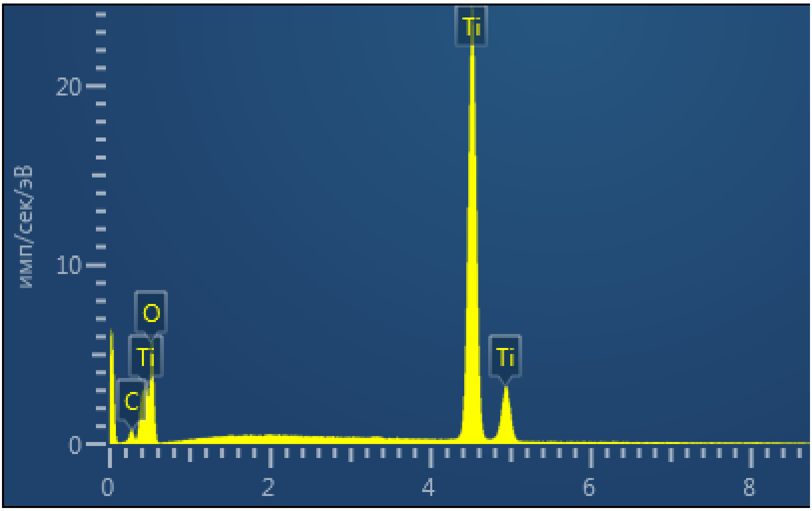

c)

Figure 1 – SEM images of PTS (a) and TiO_2-PTS (i) powders and EMF analysis of nanocomposite (c)

The TEM images (Figure 1) show rGO sheets and TiO_2 particles. This can contribute to the formation of a conductive network between TiO_2 particles and more efficient injection of photogenerated electrons into graphene sheets, ensuring their further transport to the FTO layer and registration.

Raman spectra were recorded to identify the materials. According to the Raman spectra, TiO_2 and rGO peaks are present in the nanocomposite material. Titanium dioxide of anatase structure has six combinationally active peaks in the vibrational spectrum [8]. There are two characteristic bands in the spectrum of reduced graphene oxide: D- and G-bands.

A decrease in the ID/IG intensity ratio in the nanocomposite material indicates the process of further reduction of graphene oxide during synthesis, where the formation of sp2 carbon domains and a decrease in the number of oxygen-containing groups can occur [9].

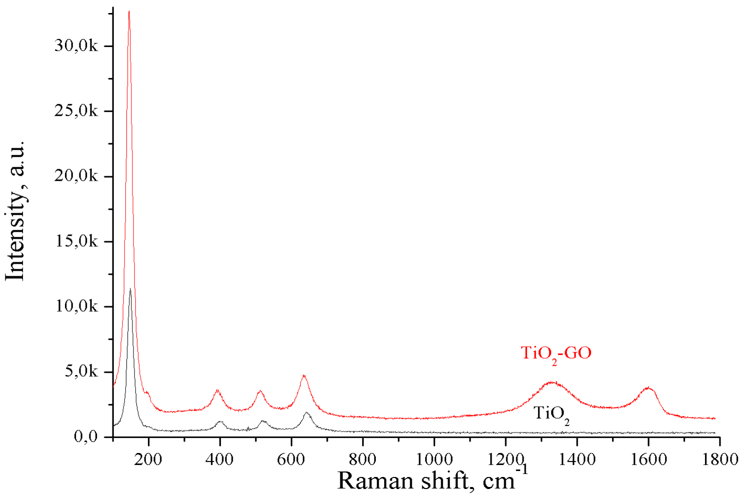

Figure 2 – Raman spectra of samples

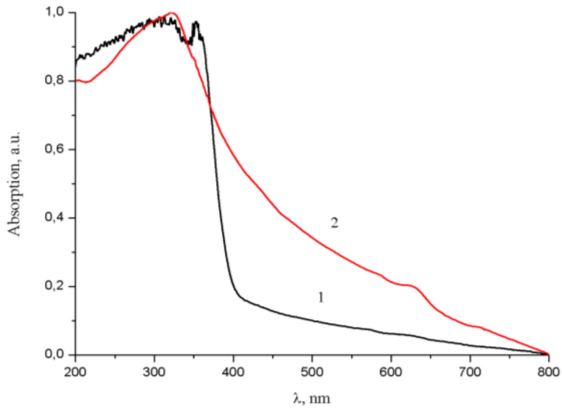

Figure 3 – Absorption spectra of 1 – TiO_2, 2 – TiO_2-GNP samples

When studying the absorption spectra of the nanocomposite, the data shown in Figure 6 were obtained. The edge of the TiO_2 absorption band appears in the UV region of the spectrum about 400 nm. Graphene oxide also absorbs in the UV region, the maximum of its absorption spectrum is at 230 nm. Reduced graphene oxide in the absorption spectra of rGO films also exhibits a wide absorption band with a maximum at 230 nm and an implicit shoulder at 270 nm. At the same time, GO and rGO films are practically transparent in the wavelength range from 400 to 800 nm [10;11]. TiO_2-GO and TiO_2-GNP nanocomposites also actively absorb light in the UV region of the spectrum. Along with this, there is a broadening of the absorption band into the visible range of the spectrum. As it was shown in [12], this is due to the fact that in nanocomposite materials there is a change in the band gap of the semiconductor. A decrease in the band gap and improved absorption in the visible region as a result of the modification should contribute to a higher photocatalytic activity of nanocomposite materials [13;14;15;16].

Conclusions

In this way, a nanocomposite material based on reduced graphene oxide and TiO2 was obtained by hydrothermal synthesis. The morphology of the nanocomposite surface is shown and GNP sheets and TiO_2 nanoparticles are clearly visible. The Raman spectrum also confirms the presence of the initial components in the nanocomposite material. The intensity ratio shows that further GNP recovery occurs in the nanocomposite material. Measurements of the optical characteristics of the synthesized material have shown that the absorption spectra of TiO_2-GNP nanocomposites are shifted to the long-wavelength region relative to the absorption spectra of the initial components, which may be the result of a change in the band gap of the semiconductor.

The results obtained can be used in the development of new photosensitive devices for optoelectronic and photocatalytic applications.

Acknowledgements

This research is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP19576361).

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Received 09.03.24.
Received in revised form 09.02.24
Accepted for publication 07.03.24.

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09.02.24 ж. баспаға түсті.
09.02.24 ж. түзетулерімен түсті.
07.03.24 ж. басып шығаруға қабылданды.

ГРАФЕН ПЛАСТИНАЛАРЫ МЕН ТИТАН ДИОКСИДІ НЕГІЗІНДЕГІ УЛЬТРАКҮЛГІН ДЕТЕКТОРДЫҢ ЖҰТУ ҚАСИЕТТЕРІН ЗЕРТТЕУ

Бұл жұмыс гидротермиялық синтез әдісімен алынған графен пластиналары мен TiO_2 негізіндегі нанокомпозиттің қасиеттерін зерттеді. Нанокомпозиттің қалыптасуы Сэм-сурет және Раман-спектроскопия деректерімен расталады. SAM-е-де TiO_2 нанобөлшектерінің бетіне қолданылатын графен парақтары көрсетілген. Раман нанокомпозит спектрлері TiO_2 және графенге тән шыңдарды көрсетеді. Графен оксидіне тән функционалды топтар ішінара жоғалады деп болжануда, бұл оның синтез кезінде ішінара тотықсыздануын көрсетеді. Нанокомпозиттің сіңіру спектрлері жарықтың ұзын толқындық аймағына ауысады, бұл материалдың жолақ енінің өзгеруін көрсетуі мүмкін.Нанокомпозиттік материалдың Фото ағынының жоғарылауына сіңіру қабілеті де әсер етеді. Жұтылу спектрлері көрінетін аймақтағы графен оксидінің мөлдірлігі арқылы жарықтың ұзын толқындық аймағына ауысуын көрсетеді. Графен оксидінің концентрациясы нанокомпозиттік материалдың тиімділігін арттыруда үлкен рөл атқарады. Бұл жұмыста пластиналардың концентрациясы титан диоксидіне қатысты 1 % массасын құрайды.

Кілтті сөздер: нанокомпозиттік материал, фотодетектор, графен пластиналары, Раман спектрі, сіңіру қасиеттері.

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Поступило в редакцию 09.02.24.
Поступило с исправлениями 09.02.24.
Принято в печать 07.03.24.

ИССЛЕДОВАНИЕ АБСОРБЦИОННЫХ СВОЙСТВ УЛЬТРАФИОЛЕТОВОГО ДЕТЕКТОРА НА ОСНОВЕ ГРАФЕНОВЫХ ПЛАСТИН И ДИОКСИДА ТИТАНА

В настоящей работе исследованы свойства нанокомпозита на основе графеновых пластин и TiO_2, полученного методом гидротермального синтеза. Формирование нанокомпозита подтверждено данными СЭМ-изображения и Раман-спектроскопии. На СЭМ-е показаны листы графена, которые накладываются на поверхность наночастиц TiO_2. Раман спектры нанокомпозита показывают пики, характерные для TiO_2 и графена. Предполагается, что частично исчезают функциональные группы, характерные для оксида графена, что свидетельствует о его частичном восстановлении в ходе синтеза. Спектры поглощения нанокомпозита сдвинуты в длинноволновую область света, это может говорить об изменении ширины запрещенной зоны материала. На увеличение фототока нанокомпозитного материала также влияет абсорбционная способность. Спектры поглощения показывают сдвиг в длинноволновую область света за счет прозрачности оксида графена в видимой области. Большую роль в повышении эффективности нанокомпозитного материала играет концентрация оксида графена. В данной работе концентрация пластинок равна 1 % массе по отношению к диоксиду титана.

Ключевые слова: нанокомпозитный материал, фотодетектор, графеновые пластинки, Раман спектр, абсорбционные свойства.

Теруге 11.03.2024 ж. жіберілді. Басуға 29.03.2024 ж. қол қойылды.
Электрондық баспа
7,50 Mb RAM
Шартты баспа табағы 10,01. Таралымы 300 дана. Бағасы келісім бойынша.
Компьютерде беттеген: Е. Е. Калихан
Корректор: А. Р. Омарова
Тапсырыс № 4206

Сдано в набор 11.03.2024 г. Подписано в печать 29.03.2024 г.
Электронное издание
7,50 Mb RAM
Усл.печ.л. 10,01. Тираж 300 экз. Цена договорная.
Компьютерная верстка Е. Е. Калихан
Корректор: А. Р. Омарова
Заказ № 4206

«Toraighyrov University» баспасынан басылып шығарылған
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