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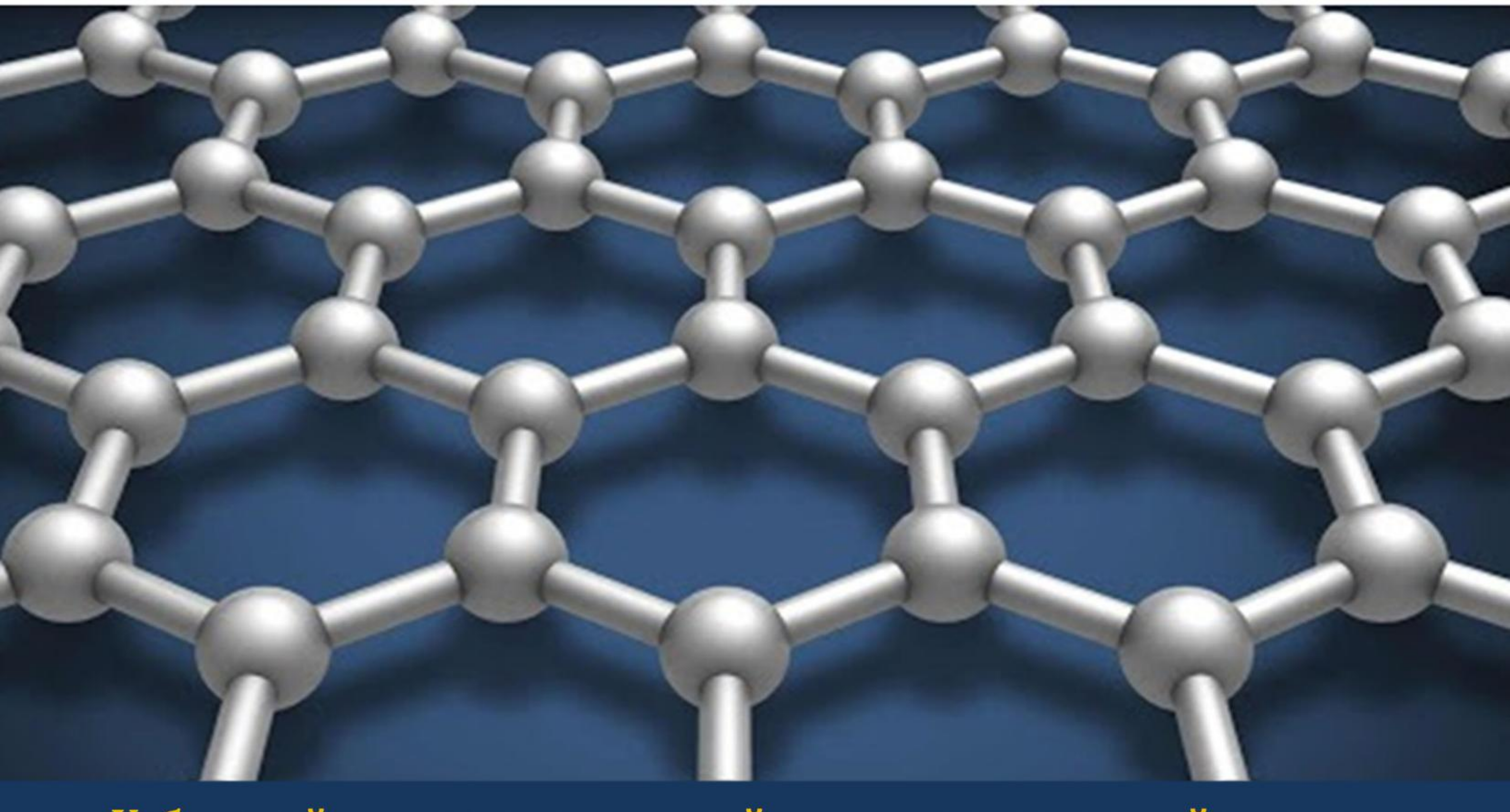

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SYNTHESIS OF CARBON DOT FROM POMEGRANATE PEEL WASTE AND ITS MODIFICATION WITH FE_3O_4 MAGNETIC NANOPARTICLE

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Abstract. In recent years, the development of environmentally friendly materials in line with green chemistry principles has become a global scientific priority. Among these efforts, the recycling of organic waste particularly from agricultural and food sources into high value nanomaterials stands out as a promising strategy. Carbon dots (CDs), have gained significant attention and an incredible interest in the field of nanotechnology and biomedical science; including their enhanced electron transferability, fluorescence property, excellent biocompatibility, high photoluminescent quantum yield, good aqueous solubility, minimal toxicity, low-cost and acquaintance of large effective surface area-to-volume ratio. When modified with magnetic Fe_3O_4 nanoparticles, these composites can enhance the removal of heavy metals and dyes from aqueous systems, offering multifunctionality in water purification and biomedical fields. In this study, the synthesized nanocomposites were characterized using dynamic light scattering (DLS) and light reflection techniques, employing a 365 nm wavelength mirror coupled to a xenon lamp source (PLS-SXE300E).

Keywords: hydrothermal method, carbon dot, pomegranate peel, Fe_3O_4, dynamic light scattering.

Introduction: Submicron molecules made of inorganic or organic materials are called nanoparticles and have many new properties compared to micron-sized materials, such as small particles (1-100 nm). Among nanomaterials, magnetic nanoparticles (MNPs) not only have special magnetic properties such as superparamagnetism, high sensitivity, etc., but also have unique physical properties, biocompatibility, stability, and many other related properties. Fe_3O_4 nanoparticles (NPs) are widely used in separation technology, protein immobilization, catalysis, medical science, and the environment. The applications of Fe_3O_4 nanoparticles in medical science are mainly targeted drug delivery, biosensors, magnetic resonance imaging (MRI), contrast enhancement and hyperthermia, biophotonics, cancer cell detection, diagnostics, magnetic field-assisted radiotherapy, and tissue engineering. Considering the different applications, various methods have been developed to prepare Fe_3O_4 nanoparticles, such as co-precipitation, hydrothermal, pyrolysis, sol-gel, microemulsion, sonochemical, polyelectrodeposition, etc.[1, 2].

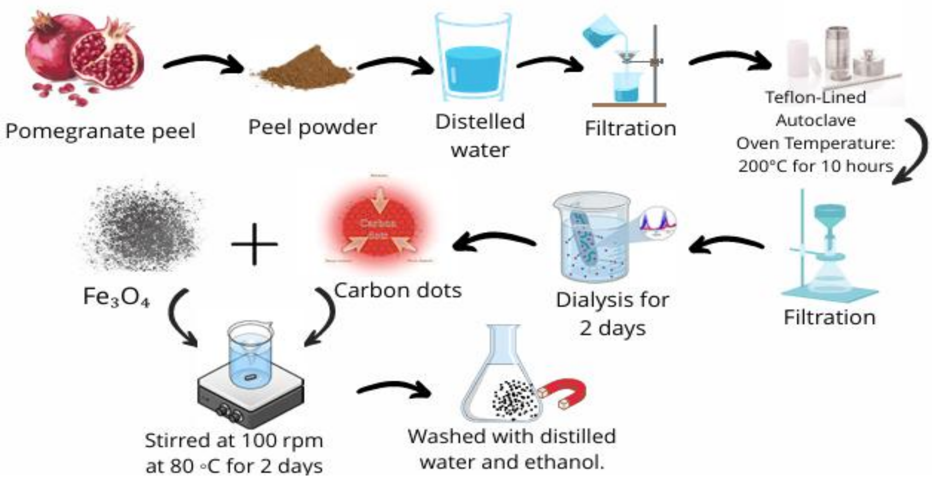
The control of the particle size of nanoparticles has always been a major problem in their application, and a suitable preparation method can be selected according to the required size. It is very easy to agglomerate magnetic iron oxide nanoparticles to reduce their surface energy. However, bare Fe_3O_4 nanoparticles usually have high chemical activity and are particularly prone to oxidation, which often leads to a decrease in magnetic properties. Therefore, improving the stability of magnetic nanoparticles is an important step in their application, and their surface functionalization is one of the main methods. The surface functionalization strategy is roughly divided into surface modification of organic materials and surface modification of inorganic materials. As shown in practical applications, in most cases, the protective shell can be used for further functionalization while improving the stability and dispersion of Fe_3O_4 nanoparticles. However, with the development of magnetic nanocomposites, their application areas are still expanding rapidly, and the classification of these materials is not strict. Therefore, there is still no clear classification [3-5].

The unique properties of carbon nanomaterials such as nanodiamonds, fullerenes, carbon nanotubes, graphene sheets, and luminescent carbon nanoparticles or carbon dots (CDs) have inspired extensive research on them due to their great potential for various technical applications. Among the electronic and physicochemical characteristics of carbon dots, their optical properties, and especially their fluorescence emission, have attracted increasing interest in recent years. For many years, semiconductor quantum dots have been extensively studied for their strong and tunable fluorescence emission properties, which allow them to be used in biosensing and bioimaging. However, semiconductor quantum dots have certain limitations, such as high toxicity due to the use of heavy metals in their production. It is known that heavy metals are very toxic even at relatively low levels, which can be prohibitive for any clinical studies [6, 7].

In addition to having similar fluorescent properties, carbon dots have been proposed as a replacement for semiconductor quantum dots due to their low toxicity, biocompatibility, low cost, and chemical inertness. The accidental discovery of carbon dots during the separation and purification of single-walled carbon nanotubes (SWCNTs) by Xu et al. in 2004 initiated further research to exploit the fluorescent properties of carbon dots and create a new class of viable fluorescent nanomaterials. Fluorescent carbon nanoparticles were named "carbon quantum dots" by Sun et al. in 2006. Carbon dots are synthesized in two ways, namely top-down and bottom-up. Carbon dots are typically composed of amorphous to nanocrystalline cores, mainly composed of graphene and graphene oxide sheets bonded together by graphite or turbostratic carbon (sp^2 carbon) or diamond-like sp^3 carbon hybridizations. The carbon dots have a large number of carboxyl moieties on their surface, which give the carbon dots excellent water solubility and suitable chemically reactive groups for subsequent functionalization and surface passivation with various organic, polymeric, inorganic, or biological materials. After surface passivation, the fluorescence properties of the carbon dots are enhanced. Surface functionalization also changes their physical properties, such as solubility in aqueous and non-aqueous solvents [8-10].

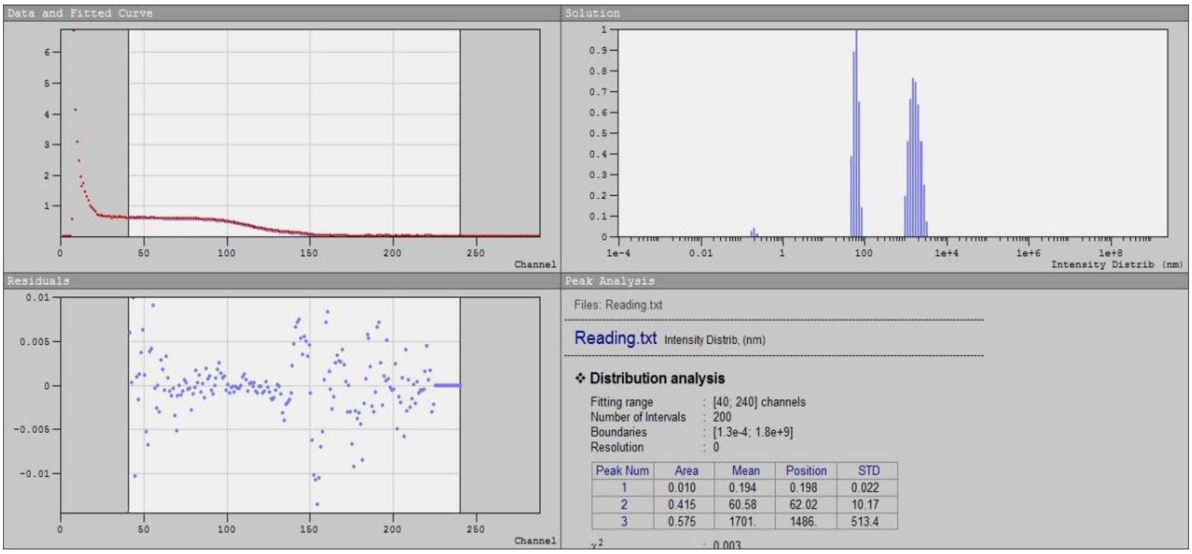
Required Reagents: Fe_3O_4 magnetic nanoparticles, ethanol (96%), H_2O, pomegranate peel.

Synthesis: To synthesize carbon dots from pomegranate peel, first the pomegranate peel is dried at room temperature and dissolved in distelled water at 50°C for 48 hours. The obtained extract is filtered. The filtered extract solution is placed in a Teflon container (100 ml) and hydrothermally reacted at 200°C for 4 hours. After the reaction is completed, it is cooled to room temperature, and a solution of carbon dots is obtained. The obtained carbon dots are purified in several steps, centrifuged, filtered, and dialyzed for 48 hours. The obtained carbon dots solution in a pure state is modified by adding Fe_3O_4 magnetic nanoparticles. The reaction process is carried out at a speed of 200 r/min at a temperature of 80°C for 2 days, and magnetic nanoparticles based on Fe_3O_4/carbon dots are obtained. The solution is evaporated at 25°C for 6 hours to obtain dry Fe_3O_4/carbon dot-based magnetic nanoparticles (picture 1).



Picture 1. Synthesis stages

Analysis of results: We used the dynamic light refraction method to study the size of the synthesized carbon dots.



Picture 2. Dynamic refraction of light of carbon dot.

According to the analysis of the dynamic refraction of light results of carbon dots, we can see that 41.5% of the particles with a size of 60.58 nm and an additional 57.5% of the particles with a size of 1701 were formed. It can be seen that our 60.58 nm particles are carbon dots and the other larger particles formed solvates (picture 2).

We also studied the optical properties of the obtained quantum dots by using a xenon lamp light source (PLS-SXE300E) with a wavelength of 365 nm to study their light reflection.

(A)

(B)

Picture 3. (A) Carbon dot taken in the visible region, (B) carbon dot under 365 nm monochromatic light

As can be seen from the images above, the color of the synthesized carbon dots solution is brown, and it reflects red light when absorbing light at 365nm wavelength, indicating that fine particles have been synthesized. (picture 3). Alcohol was also used as a solvent to obtain carbon dots. Carbon dots were synthesized by hydrothermal method from the extract obtained from pomegranate peel and alcohol in the ratio of 1:15, and it was found that the carbon dots obtained in this way have hygroscopic properties. Also, it is known from the literature that the pH of the solution is important for increasing the stability of carbon dots, and the particles retain their stability in an alkaline environment. To increase the stability of the synthesized carbon dots, a 0.1 M NaOH solution was used.

Conclusion: This study demonstrates a green and sustainable method for synthesizing carbon dot-magnetic nanocomposite from plant-derived waste. The use of pomegranate peel as a carbon source not only reduces organic waste but also adds value through the generation of functional nanomaterials. The Fe_3O_4-modified carbon dots show great promise for future applications in wastewater treatment and environmental safety technologies.

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