Synthesis, Characterization, and Optimization of Carbon Quantum Dots by Hot Injection Method

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INTRODUCTION

Quantum dots are semiconductor nanocrystals that can radiate well and can be used in many biological applications as imaging and/or therapeutic agents thanks to their high quantum efficiency and their narrow emission bands that enable them to get excited with different wavelengths. They are preferred as medical imaging agents since they are more stable than fluorophores and have high absorption coefficients. Carbon quantum dots have high potential as bioimaging agents in the diagnosis of certain diseases such as cancer and are more preferred in biological integrations due to their good and long-term luminescence properties and low cytotoxicity. The hot injection method is a rapid method to synthesize not just only carbon quantum dots but also any type of quantum dots. Here, we present carbon quantum dot synthesis by hot injection method and the characterization of quantum dots by Energy-Dispersive X-ray Spectroscopy (EDS), UV-Vis Spectrophotometry, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and fluorescence microscopy.

EXPERIMENTS & RESULTS

The synthesis of carbon quantum dots was done using 98% sulfuric acid (H_2SO_4) an oxygen-containing organic solvent and acetone by hot injection method. The mixture of 5 mL of 98% H_2SO_4 and 2.5 mL acetone (volume ratio 2:1) was heated to 170°C for approximately 1 minute and then neutralized with 5 M sodium hydroxide (NaOH) (**Fig. 1**). The synthesized carbon quantum dots were purified by centrifugation for 3 times at 6,000 rpm for 15 minutes. The purified carbon quantum dots' characterization was done with spectrum analysis with UV-Vis Spectrophotometer, Energy Dispersive X-Ray Spectroscopy (EDS), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), and fluorescent microscopy. The spectrum analysis with UV-Vis Spectrophotometer showed that carbon quantum dots with different concentrations have absorbance peak at 287-289 nm. In EDS analysis, only carbon and oxygen elements were observed which indicated that the carbon quantum dots were purified successfully by centrifugation. SEM indicated the presence of spherical nanoparticles (**Fig. 2**). Fluorescence imaging was done using 10x (x100 magnification), 20x (x200 magnification), and 40x (x400 magnification) objective lenses in Zeiss Axiovert inverted fluorescent microscope (**Fig. 3**). TEM images showed that the diameter of atoms was around 340.6 picometers (pm) indicating the presence of carbon atoms since a carbon atom's radius is approximately 170 pm. SEM and TEM results also showed that there was aggregation of the carbon quantum dots, therefore, the optimization of the synthesis should be performed.

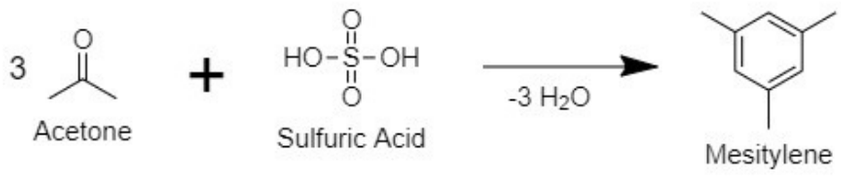

Figure 1: The reaction in hot injection method at 170°C.

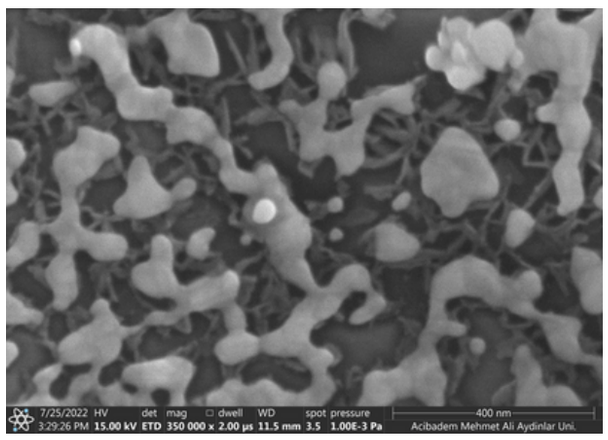

Figure 2: SEM image of synthesized and purified carbon quantum dots.

Figure 3: Fluorescence imaging of synthesized carbon quantum dots (x200 magnification).

CONCLUSION & PLANNED FURTHER APPLICATIONS

- In TEM, the quantum dot diameter was found to be around 340.6 pm, which is an indication of a carbon atom.
- The aggregation of quantum dots was observed in TEM, therefore, optimization of the method should be done to prevent aggregation and to increase the synthesis efficiency.
- Synthesized carbon quantum dots' ligand exchange studies with surface modification are planned.
- Cytotoxicity and cell localization studies of the synthesized carbon quantum dots are planned to predict their potential in biological applications.
- The synthesized carbon quantum dots are planned to be used in cancer cell and tumor imaging.

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