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Gamma ray dosimeter using Ag-Tragacanth gel

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Abstract. Silver nanoparticles can be synthesized through gamma ray irradiation and provide a localized surface plasmon resonance (LSPR) effect in the visible light so that it can be used as a dosimeter with the colorimetric principle. This article reports experimental results of radiosynthesis of silver nanoparticles in the medium of Tragacanth gum irradiated with gamma rays. The source of gamma rays is Cobalt-60 with varying doses between 1 - 40 kGy. The gel of $AgNO_3$-Tragacanth which was originally clear starts to turn yellow at an irradiation dose of 10 kGy and becomes darker yellow with increasing radiation dose. The absorbance spectrum of the gel was characterized by using UV-visible instruments and give a maximum absorbance value at a wavelength of 403 nm which is a characteristic of LSPR of the silver nanoparticles. This maximum absorbance value increases with increasing radiation dose. These results indicate that the Ag-Tragacanth gel can be used as a gamma ray dosimeter.

1. Introduction

Gamma irradiation plays important roles in the fields of medicine, food processing, and sterilization of medical equipment [1]. Related to the progress in these applications, in recent years, many researchers are developing dosimeter devices with the colorimetric principle because of simplicity in the principles of measurement, field operations and also have a low cost [2]. Radiochromic dosimeters have been developed using synthetic dyes [3-5] and natural dyes [6,7]. This radiochromic phenomenon occurs because the radiation from gamma rays makes decomposition or degradation of the functional material of the device.

However, with the rapid development of research and application of nanoparticles in all fields, it has encouraged researchers to use nanoparticles as dosimeter materials with radiochromic principles. Some metal nanoparticles have LSPR phenomena in the visible light region [8]. Gamma rays have a high energy which can be used to synthesize nanoparticles through the reduction of metal ion after going through the stages of radiolysis. Moreover, LSPR of metal nanoparticles is very sensitive to the size and shape of nanoparticles, the distance between nanoparticles and also the optical properties of their environment [9]. Therefore, dosimeters of nanoparticle material are very interesting for further research.

This paper reports the results of research on the preparation of Ag-Tragacanth gel for gamma radiation dosimeters. Silver nanoparticles were chosen because they have LSPR in visible light and can be synthesized with the help of gamma radiation. Tragacanth gel is used as a stabilizer to inhibit the reoxidation of nanoparticles that have formed.

2. Material and Method

2.1. Material

Tragacanth gum was purchased from CV. Rachmat Putra, a local pharmaceutical company in Indonesia. Silver Nitrate ($AgNO_3$) was obtained from Merck and used as received. Deionized water used as a solvent during the experiment was produced from the Direct-Pure® EDI tool (Direct-Q 5UV-R, Ultrapure type 1).

2.2. Gel Preparation

The gel dosimeter was prepared from 2.5 grams of tragacanth gum gel which was poured into a beaker filled with 50 ml of double distilled water as a solvent and then heated at 70°C. The tragacanth gum was left for 5 minutes until it swelled. The next process, the gel was stirred using a Ruptured Qiagen Tissue at 15000 rpm for 15 minutes. After settling for 2 minutes, 0.5 ml of $AgNO_3$ (50 mM) solution was mixed into the gel and then stirred for 10 minutes. This prepared Ag-Tragacanth gel dosimeter were then poured into 2 ml of microtubes and ready for further experiments. Before being tested in a gamma irradiator apparatus, the gel dosimeter were kept at room temperature and in a dark condition.

2.3. Irradiation Testing and Characterization of Gel

The response of the Ag-Tragacanth gel to gamma radiation was investigated by irradiating the gel which was placed in a 2.0 ml microtube using a gamma radiation source from Cobalt-60 at a dose rate of 5 kGy / hour. This experiment was carried out at the gamma irradiation facility of the National Nuclear Energy Agency (BATAN), Jakarta, Indonesia. The gel was irradiated at various doses of 1, 5, 10, 15, 20, 25, 30, 35 and 40 kGy. The color of the Ag-Tragacant gel that changes in response to the dose of gamma radiation were characterized by using a UV-Vis GENESYS 10S spectrophotometer from Thermo Scientific at wavelengths of 300 - 800 nm. The absorption spectrum were then analyzed to explain the dose response and radiochromic characteristics of the gel dosimeter.

3. Result and Discussion

Figure 1 shows visual observations of Ag-Tragacanth gel before (0 kGy) and after gamma irradiation. The effects of gamma irradiation make color changes in Ag-Tragacanth gel. Before being irradiated, the gel is clear and remains clear until it receives a dose of 5 kGy. After being irradiated at a dose of 10 kGy, the gel changes color from clear to bright yellow. The color of the gel becomes dark yellow as the radiation dose increases.

0 1 5 10 15 20 25 30 35 40
Doses (kGy)

Figure 1. The color of the Ag-Tragacanth gel before and after gamma irradiation doses.

Figure 2 shows the UV-visible spectrum at a wavelength of 300-800 nm from the Ag-Tragacanth gel before and after gamma irradiating up to a dose of 40 kGy. The spectrum of the Ag-Tragacanth gel does not provide absorption in the wavelength region near 400 nm, nor does gamma irradiation up to a dose of 5 kGy. On the other hand, after the gel received radiation with a dose of 10 kGy, an absorption peak appeared at a wavelength of 403 nm. The absorption spectrum at this wavelength is a characteristic of LSPR of silver nanoparticles [10].

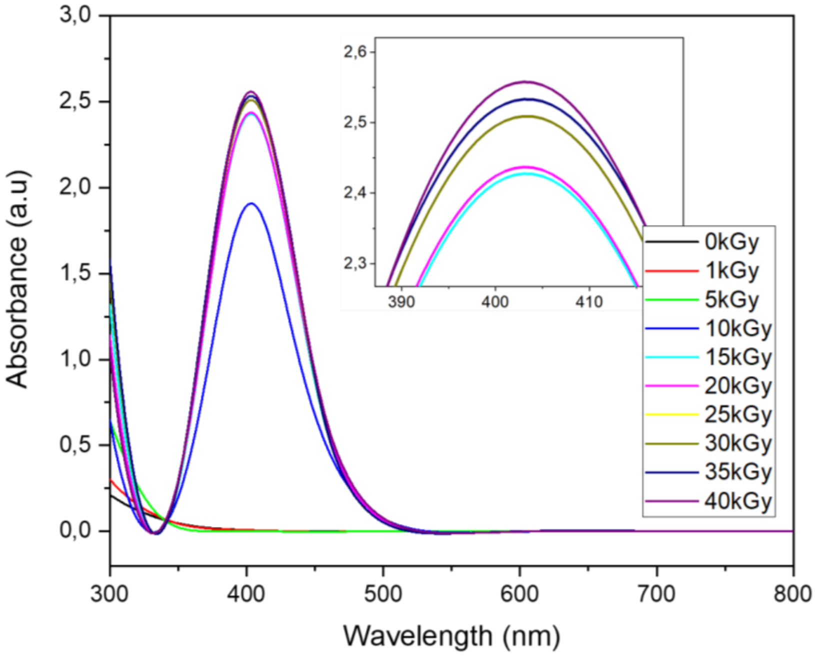

Figure 2. Absorption spectra of the Ag-Tragacanth gel with different irradiation doses.

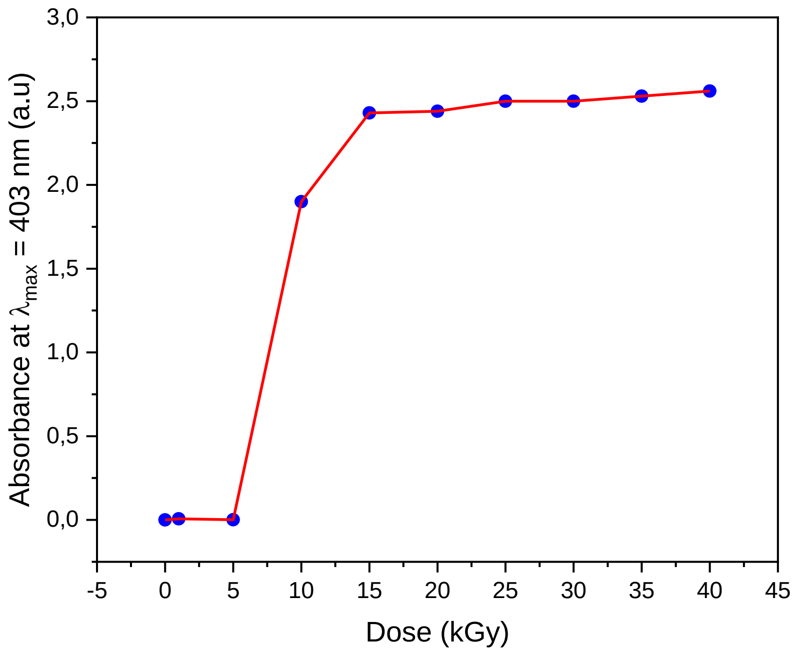

Figure 3. Response of the Ag-Tragacanth gel as a function of irradiation doses.

This phenomenon can be explained that the gamma irradiation at a dose of 10 kGy has caused the formation of silver nanoparticles through the process of radiosynthesis. High energy from gamma rays has caused a radiolysis of water molecules that produce radicals e^-_{aq}, HO·, H·, HO_2·, H_3O^+, OH^-, H_2O_2, H_2 [11]. Hydrated electrons (e^-_{aq}) and hydrogen atoms (H·) are strong reducing agents so they can actively reduce silver ions and produce Ag^0 which then undergoes a chain reaction to grow to form silver nanoparticles. On the other hand, there are hydroxyl radicals (HO·) which are strong oxidative species that can reoxidize silver atoms. The reduction and oxidation reactions of these silver atoms compete with each other so they can inhibit the growth of silver nanoparticles. But the presence of the Tragacanth gel inhibits the reoxidation of the silver atoms formed, so that it can continue its growth to form silver nanoparticles.

An increased irradiation dose makes the absorbance value of the gel large but the absorbance peak does not shift, remains at a wavelength of 403 nm. This indicates that the number of silver nanoparticles that are formed is increasing or also increasing in size, although not too much. The sharp absorbance spectrum and good symmetry indicate that silver nanoparticles are monodispers in size and are round in shape.

The response of the Ag-Tragacanth gel to gamma irradiation with varying doses is shown in Figure 3. These data were analyzed from the peak absorbance value at a wavelength of 403 nm. The gel dosimeter has high sensitivity at a dose of 5 to 15 kGy. For larger doses the sensitivity decreases. In the dose area of 5-15 kGy the rate of formation of silver nanoparticles is strongly influenced by the dose of gamma radiation resulting in dramatic changes in the color of the gel. At high doses the formation of silver nanoparticles begins to slow down which indicates almost all silver ions have been reduced but agglomeration of silver nanoparticles does not occur because it is inhibited by Tragacanth molecules.

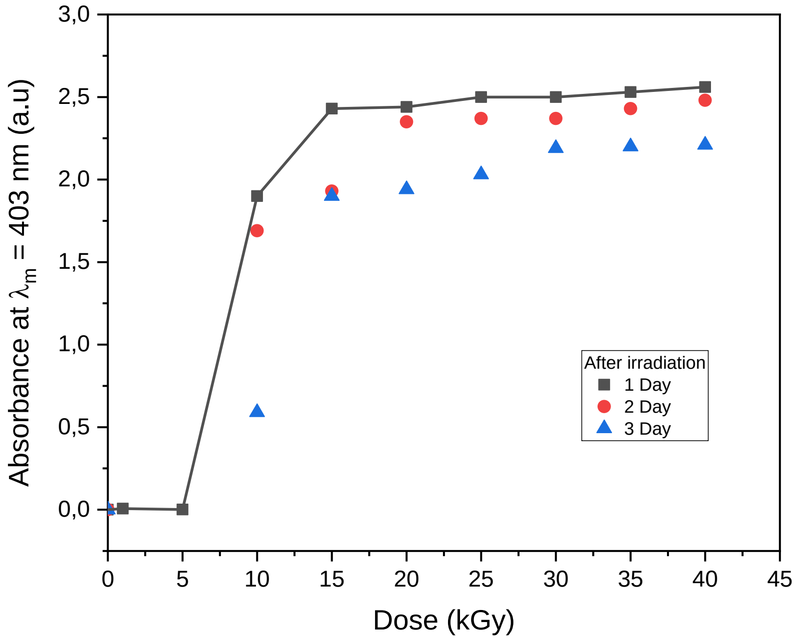

Figure 4. Stability of the Ag-Tragacanth after irradiation for 3 days.

The color stability of the gel dosimeter before and after gamma irradiation was observed. Before being irradiated, the samples of Ag-Tragacanth gel were stored at room temperature and dark conditions. The observations showed that the dosimeter gel remained clear and did not change color. This shows that there was no spontaneous reduction of silver ions. Investigation of the stability of the dosimeter gel after irradiation was carried out for three days by measuring its absorption properties with a UV-visible spectrophotometer every day. The spectra have the same absorption characteristic which they have an absorption peak at a wavelength of 403 nm. The results of data analysis for the gel stability after irradiation are shown in Figure 4. Absorbance values appear to decrease with increasing shelf life. This phenomenon is likely due to the reoxidation of silver nanoparticles.

4. Conclusion

A dosimeter from Ag-Tragacanth gel was successfully prepared and can be used as gamma radiation dose detectors with simple colorimetric principles. The UV-visible absorption spectrum of the gel provides the maximum absorbance value at a wavelength of 403 nm which is the LSPR characteristic of silver nanoparticles. This maximum absorption value increases with increasing radiation dose and has very good sensitivity at a dose range of 5-15 kGy. Therefore, the Ag-Tragacanth gel has a good opportunity to be used as gamma radiation dosimeters in sterilization applications.

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