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RESEARCH ARTICLE

Thermoluminescence (TL) response of silica nanoparticles subjected to 50 Gy gamma irradiation

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Abstract

Thermoluminescence (TL) response of silica nanoparticles synthesized by the sol-gel method is presented here. Transmission electron microscopy (TEM) was used to find out the size and morphology of the pure silica nanoparticles. By using an appropriate amount of tetraethylorthosilicate, ethanol, deionized water and ammonia solution, silica samples were synthesized. To determine the best TL response of silica, samples were irradiated with 50Gy gamma rays. The effect of size dependency towards TL yield indicates that decreasing the particles' size of silica, increases the TL yield.

***Keywords*:** Thermoluminescence, sol-gel, nanoparticles

INTRODUCTION

In their early research work about nanoparticle, Stober et al [1] discovered a method known as sol-gel technique for preparing silica monodisperse in micron size that lead to overwhelming further research work in silica nanosize area. They used aquose alcohol solutions of silicon alkoxides in the presence of ammonia as a catalyst. Nano-sized particles have one dimension that is less than 100 nano-meters in size. Because of their unique properties, they are useful as a catalyst, sensors, coating materials, tunable lasers, and memory devices. Nano-material is getting more interest and attention rather than bulk substance for research work in the area of nanotechnology [2]. In the sol-gel method, the prepared phosphors in the form of powders are mostly homogeneous and purer than the phosphor obtained via other conventional solid-state methods and have been widely applied to produce nanoscale materials. In order to synthesise the silica nanoparticle, many researchers have opted sol-gel as their method due to its advantages [3-5]. By taking the method into account, the size, shape and structure of the silica particle can be controlled due to the variable amount of materials used to produce the silica [6-8].

Thermoluminescence (TL) dosimeter is used to detect the amount of radiation exposure to workers of a radiation source. TL measurement is crucial for deciding the best TL dosimeter. Based on the TL mechanism where electrons escape from traps upon heating and return to the stable state, the sensitivity or the probability of electron escapes from the traps can be enhanced by giving temperature to them. So, different temperature will gives different TL sensitivity of the phosphor. In the previous research work on TL measurement, particular attention has been given to the sillica material in the form of optical fiber, thin film and bulk [9-12]. In this paper, nanosized TL particles are investigated to determine the effect of the size towards exposed doses.

EXPERIMENTAL

Synthesis of SiO_2 nanoparticles

The materials used to synthesize the SiO_2 are tetraethyl orthosilicate (TEOS) (96%) as precursor, ethanol (98%) acts as the solvent, deionized water, and ammonia (28%) acts as the catalyst agent. The set of 2 samples of SiO_2 were prepared by varying its amount of catalysis agent. SiO_2 sols were prepared by mixing 0.25 mol of ethanol and water for 10 minutes before TEOS (0.05 mol) was added to the mixture. While stirring for another 20 minutes by using magnetic stirrer (>150 rpm), 2 ml of ammonia solution were added dropwise into the mixture untill white turbid suspension was formed. The sample was stirred continuously for 24 hrs at room temperature. The suspension was then dried in an oven at 80 °C for 24 hrs before undergoing calcination process at 600°C for 2 hrs. The final product, SiO_2 powder, was then grinded in a porcelain mortar. The schematic diagram for synthesizing SiO_2 particles is shown in Fig. 1. The same processes were repeated by using 8 ml of ammonia.

Sample characterization and TL measurement

The X- ray diffraction pattern was obtained to see the nature of SiO_2 by using X-ray diffractometer (Siemens Diffractometer D5000). To identify the size of particles for both samples, Transmission Electron Microscope (TEM, JEM-2100, 200kV) was used. To verify the effect of particles size on the luminescence response, both samples were exposed to γ-ray for 50 Gy and by using Gamma cell 220E facility at Universiti Kebangsaan Malaysia with different annealing temperature from 100°C to 400°C for 1 h. The TL response was measured using HARSHAW 4500 TLD reader at a heating rate of 25°C s^{-1}.

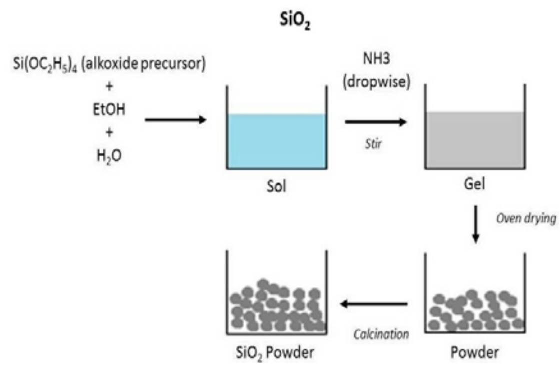

Fig. 1 Schematic diagram for the preparation of SiO_2.

RESULTS AND DISCUSSION

XRD analysis

The X-ray diffraction patterns confirmed the amorphous nature of the prepared SiO_2 samples as shown in Fig. 2. The broad peak shows a complete amorphous structure. There is no diffraction peak observed except for a broad band centered at 22° which is the characteristic peak for amorphous SiO_2. The results is also compared with the JCPDS file for SiO_2 and it reveals no impurities peak for SiO_2 [4, 13].

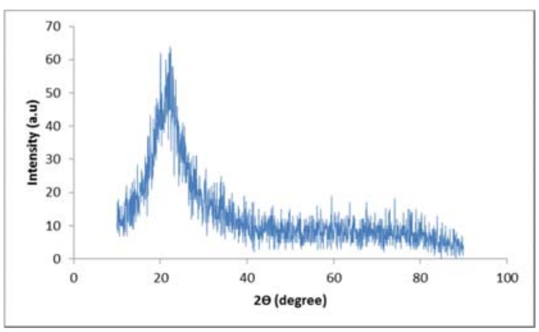

Fig. 2 XRD analysis of SiO_2 nanoparticles.

TEM analysis

To investigate the morphology and size of particles in nano scale, high-resolution Transmission Electron Microscope (TEM) is used to punctual electron diffraction analysis of the SiO_2 nanoparticles. By changing the concentration of ammonia solution in SiO_2 synthesis, the effect of particle's size can be varied. From Fig. 3(a), the image shows the average particles's in the range of <400nm for the sample of 2ML ammonia whereas, a sample with 8ML ammonia solution, its size is up to 934nm Post analysis is done by Digital Micrograph (GATAN) version 3, year 2015. The particles are not well dispersed due to agglomeration. It can be overcome by increasing the sonication time.

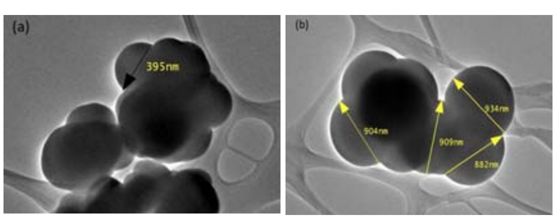

Fig. 3 TEM image of silica nanoparticles with (a)2ML and (b) 8ML of ammonia solution.

Effect of catalyst on size particles

One of the processes involved in the sol-gel method is hydrolysis reaction where acids or bases are used as catalysts. Catalyst will increase the rate of hydrolysis and condensation process in a sol-gel process that leads to a faster kinetics. The particle size strongly depends on hydrolysis kinetics. According to Singh L.P et al [14], the size of silica particle size increases with decreasing the amount of ammonia but reverse effect is obtained by Rao et al [2]. In this work, we discovered that the SiO_2 particle size was increasing with the increasing of ammonia concentration, in agreement with Rao et al [2].

Thermoluminescence measurement

In early stage for TL identification, annealing procedure should be carried out to remove any previous exposure. Different annealing temperature from 100°C to 400°C were done for 1 hr each by using oven annealing (Harshaw) connected to readout system to identify the suitable temperature for the dosimeter material. The samples were then exposed to 50 Gy of γ-ray and was measured using the Harshaw 3500 TLD reader to see the best intensity. Based on the TLD reader, a sample with 100°C annealing temperature as shown in Fig. 4 and 5 exhibits a higher TL intensity for samples from both 2 and 8 ml of ammonia. The same time temperature profile was used for TLD measurement on both samples(13.3s reading cyle and 25°Cs^{-1}). However, the response for 2 ml ammonia is higher than 8 ml ammonia.

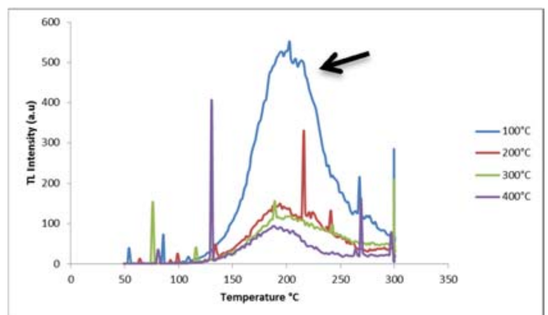

Fig. 4 TL intensity of SiO_2 with 2 ml ammonia under different annealing temperature indicates higher intensity for 100°C.

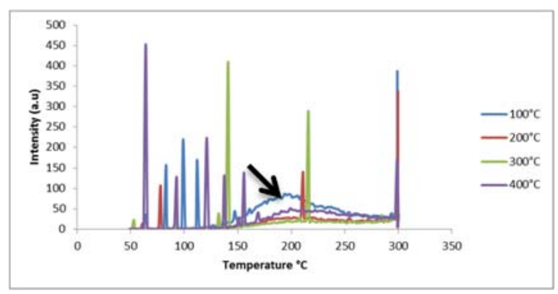

Fig. 5 TL intensity of SiO_2 with 8 ml ammonia under different annealing temperature indicates higher intensity for 100°C.

CONCLUSION

The SiO_2 particles size was measured by TEM. The results shows that the size of SiO_2 particles with a lower concentration of ammonia is smaller than higher concentration used in synthesizing of SiO_2 powder. Based on the XRD analysis, amorphous nature of samples is confirmed since there is no crystalline phase occure. For TL indentification, 100°C annealing temperature was chosen to be the best annealing temperature for SiO_2 nanoparticle because of the high TL intensity. Based on the TL intensity, it also shows that smaller particles give high TL yield than a larger particle. The present result also supports that the particles's size affects the TL yield but taking ethanol (solubality agent) to be varied in the silica synthesis [15].

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