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Dosimetric Characteristics of Agate Stones for High Dose Dosimeters

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Abstract

1. INTRODUCTION

Indonesia is a country having abundant potential natural resources including precious stones. One of the precious stones is agate, which is often used as jewelry. Like any other precious stones, such as jasper, amethyst, topaz, jade and onyx, agate mainly consists of SiO_2 chemical compound. The formerly mentioned stones have been reported as high dose dosimeter [1,2], however experiment using agate stone as a material for dosimeter was rarely reported. Therefore in this research different colored agate stones from Borneo mines were powdered and mixed with polytetrafluoroethylene (PTFE/teflon) to be applied as a high dose dosimeter. The purpose of this research is to analyze the influence of the composition of the agate stone in Indonesia towards the thermoluminescent dosimetry (TLD) properties and to verify the potency of their use as high dose dosimeters for irradiation accident in industrial areas.

2. METHODS

2.1 Chemicals

the first of all the whole material as Brown agate, dark yellow agate, grey agate, and dark grey agate were crushed until 100 mesh. Agate become a powder after crushed, then continued with sieving to get powders which size 100 micron. materials which have size 100 mesh it should be cleaned up to lost an impurity substance. experiment to remove impurities used a chemical techniques. The purpose of this cleaning was to remove a variety of organic and carbonate material, this substance is not expected on the phenomenon of thermoluminescence. each 5 grams material agate in one crucible, and then added the solution (99% H_2O + 1% HCl) into crucibles. after that the crucible given heat treatment (135°C ; 2 hours) in muffle furnace.

2.2 Procedures

experiments begins with the process of making pellets with a mixture of agate stone and teflon (Polytetrafluoroethylene) in comparison (1 : 2). agate to be formed pellets have previously performed impurity removal. there are four agate stone for this experiment (Brown Agate, Dark Yellow Agate, Grey Agate, Dark Grey Agate.). each pellets has diameter 4 mm and height (1-0,8 mm). There are four material pellets with different compositions based on the type of agate stone. each kind of pellet material given a annealed variation of 200°C, 300°C, and 400°C. The samples were packed in plastic and paperfor irradiation, at a Gamma Cell-IRPASENA system of ^{60}Co (dose rate of 4 kGy/h), For doses 0,1 kGy, 1 kGy, and 10 kGy. The response towards the radiations were analyzed by thermoluminescent dosimeter-reader (TLD-reader). The structure, morphology and chemical composition of the materials were characterized using X-Ray Diffractometer (XRD), Scanning Electron Microscope (SEM), Energy Dispersive X-Ray Spectrometer (EDXS) and Neutron-Activation Analysis (NAA). The correlations between material structures and dosimetric characteristics were then analyzed based on the resulted data. The effect of sensitivity was very important, because sensitivity will effect toward dosimetric characteristic. Sensitivity TL dosimeter toward radiation (S) define as comparasion between TL intensity (I_{TL}) and radiation dose (D), formulated as :

$$S = \frac{I_{TL}}{D} \qquad (1)$$

3. RESULTS AND DISCUSSION

Result of SEM Test, observations micrograph with Scanner Electron Microscope (SEM) using FEI S-50 tools aimed as observers morphology of the agate stone powder.

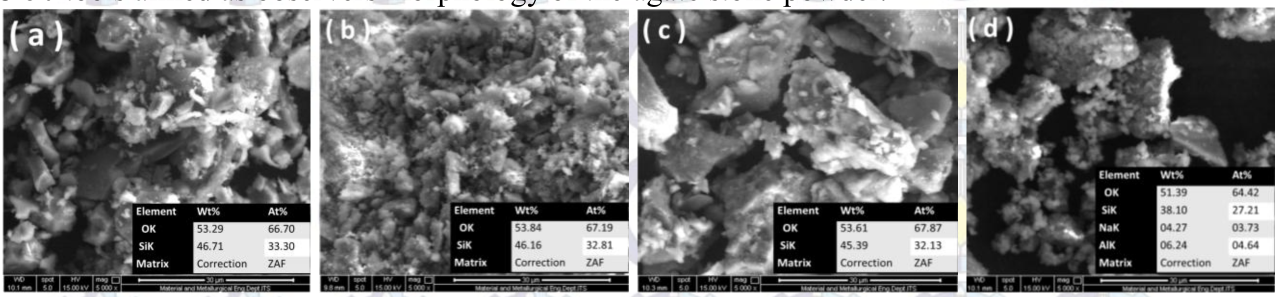
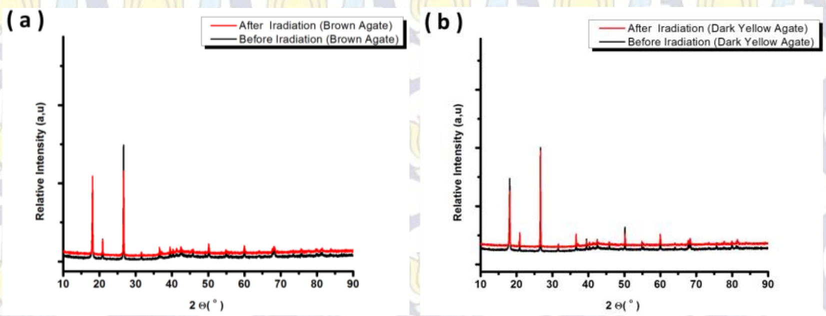


Figure 1 (Results test of variety agate stone SEM with magnification 5000X (a) Brown Agate, (b) Dark Yellow Agate, (c) Grey Agate, (d) Dark Grey Agate.)

Distribution of particle from each material agate was different. Dark grey agate showed that powder is less sticky from the other agate stone. The purpose of Energy Dispersive X-Ray Spectrometer (EDXS) test was to define atomic percent from all agate stone. On that case all material agate was hidroscopis but only dark grey agate lesshidroscopis. Condition agate with dry powder, is more advantage then a less dry. Brown agate have a proportional compotition between silicon and oxygen followed dark yellow agate and grey agate as showed **figure 1**. Only the dark grey agate has a different comparasion composition between silicon and oxygen which showed over oxygen.

XRD testing done by using a Phillips Analytical. Pellet sampel (Agate stone + Teflon) with diameter of 4 mm and a thickness of 1-0.8 mm. Tests are performed with X-rays to use a relatively long range of angles, ie, 10^o-90^o and using a wavelength of 1.54056 Å.



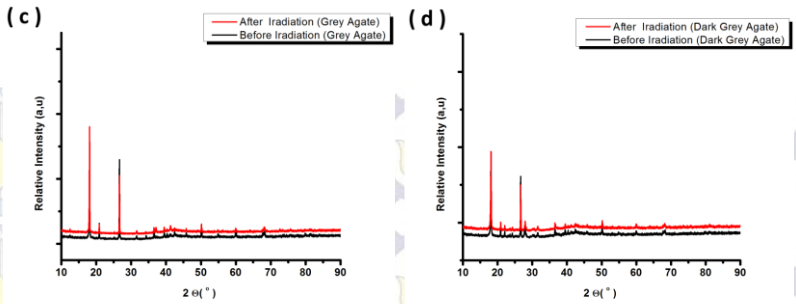


Figure 2 (Comparasion of the agate XRD test results of the agate variety before irradiation and after (a) Brown Agate, (b) Dark Yellow Agate, (c) Grey Agate, (d) Dark Grey Agate.)

Based of JCPDF card no. 85-1108 for SiO2 and no. 47-2217 for Polytetrafluoroethylene. The XRD pattern shows the crystal orientation brown agate, dark yellow agate, grey agate, and dark grey agate (011;SiO2) at 2θ 26.7518, at 2θ 26.8032, at 2θ 26.87003, at 2θ 26.75305. Polytetrafluoroethylene at 2θ 18.079, at 2θ 18.079, at 2θ 18.0699, at 2θ 18.079. After three times irradiation, which several highest peak had intensity decrease and increase. This is caused by that heat treatment after respon reading.

Tabel 1 (Results of neutron activation analysis of agate stone samples)

No	Sampel	Parameter	Hasil Uji (mg/kg)
1	Brown Agate	Cs	0.51 ± 0.04
		Hf	2.16 ± 0.08
		Sb	0.37 ± 0.03
		U	0.09
2	Dark Yellow Agate	Cs	0.31
		Hf	0.21 ± 0.02
		Sb	2.95 ± 0.08
		U	1.97 ± 0.06
3	Grey Agate	Cs	0.86 ± 0.03
		Hf	1.10 ± 0.07
		Sb	0.28 ± 0.01
		U	0.84 ± 0.07
4	Dark Grey Agate	Cs	0.31
		Hf	4.29 ± 0.39
		Sb	0.66 ± 0.05
		U	1.37 ± 0.09

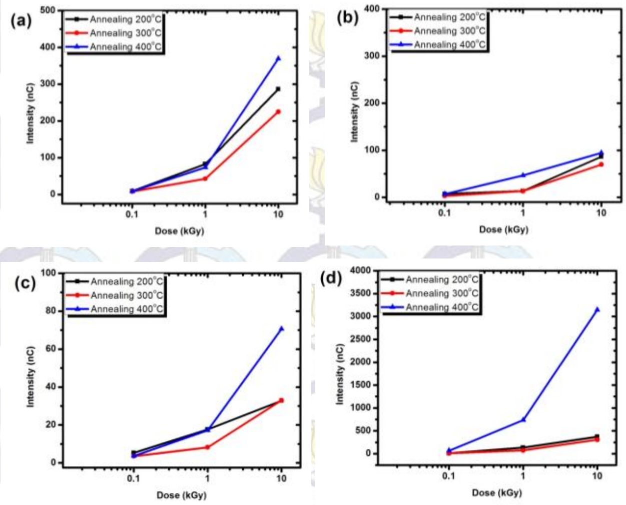


Figure 3 (The effect of annealing temperature toward varaitions in radiation dose (a) Brown Agate, (b) Dark Yellow Agate, (c) Grey Agate, (d) dark Grey Agate.)

The best results were obtained with the dark grey agate, which have Dark grey agate has 4,29±0,39. The main dosimetric properties studied of the agate stone samples in this work were thermal treatments, reutilization, lower and high detection limits, residue signal, and sensitivity.

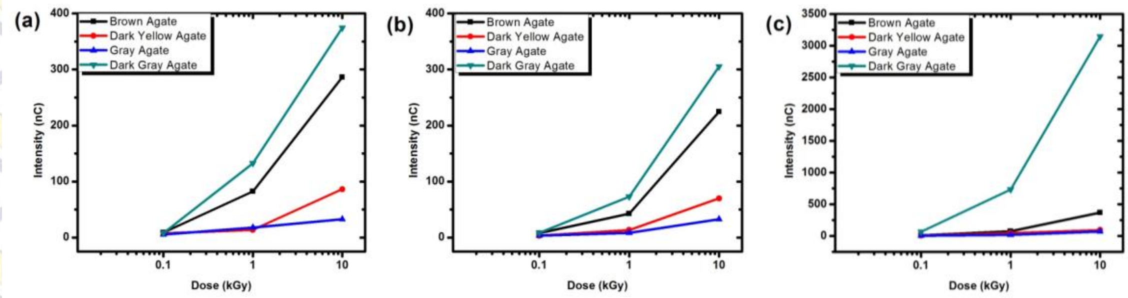


Figure 4 (Variations Agate Stone toward Variation in radiation dose (a) annealing 200°C, (b) annealing 300°C, (c) annealing 400°C.

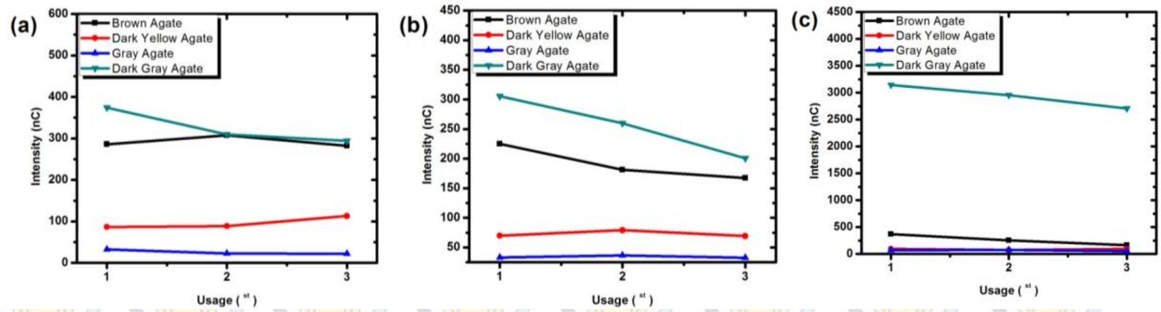


Figure 5 (reutilization of agate stone (a) annealing 200°C, (b) annealing 300°C, (c) annealing 400°C.

variations TL response of the dosimeter determined the value of CV.TL response reproducibility effected toward variety agate stone

Tabel 2 (TL response reproducibility as CV(%) of Agate)

Annealing	Sampel	Rata-rata CV (%) Respon
400°C	Brown Agate	0.41
	Dark Yellow Agate	0.29
	Grey Agate	0.31
	Dark Grey Agate	0.10

Tabel 3 (The results of the Fourth residue signal sample of Post-Irradiation Reading)

No	Bahan Dosimetri	Background (nC)	I_{max} (nA)	Total (nC)	Persentase Residu (%)
1	Brown Agate	14.05	3.01	690.2	2.03
2	Dark Yellow Agate	3.24	0.72	124.9	2.59
3	Grey Agate	4.83	0.83	89.51	5.39
4	Dark Grey Agate	16.11	43.88	3588	0,45

Tabel 3 (sensitivity annealing temperature of 400 ° C)

Temperatur Annealing	Material	Berat (mg)	Sensitivitas	Rata - rata Sensitivitas
400'C	Brown Agate	11.7	1.67	2.31
	Brown Agate	13	1.71	
	Brown Agate	19.5	3.54	
	Dark Yellow Agate	13	0.96	0.73
	Dark Yellow Agate	16.4	0.62	
	Dark Yellow Agate	9.4	0.61	
	Grey Agate	26.3	0.23	0.43
	Grey Agate	11.8	0.75	
	Grey Agate	20.9	0.29	
	Dark Grey Agate	20.5	15.30	13.95
	Dark Grey Agate	22.5	15.94	
	Dark Grey Agate	25.5	10.60	

4. CONCLUSIONS

Density of thermoluminescence dosimeters affected to the value of TL response. Dark grey agate had the highest radioactive contents among the four samples. Therefore, it showed the highest sensitivity and response towards radiation. Besides dark grey agate also showed the smallest coefficient variation (CV) and residual value making it suitable for thermoluminescent dosimeter (TLD). To determine the ability of the dosimeter was measured with repeated use. All materials dosimeter were decrease of response until three times used.

5. REFERENCES

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