Moh's hardness Scale and micro vicker’s hardness study of bgo and lyso inorganic scintillators

Wuttichai Chaiphaksa1,2*, Pruittipol Limkitjaroenporn1,2, Hong Joo Kim3 and Jakrapong Kaewkhao1,2
1Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand
2Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand
3Department of Physics, Kyungpook National University, Daegu 702-701, Korea
wuttichai.chaiphaksa@gmail.com

Abstract - BGO and LYSO inorganic scintillation crystals were chosen in this paper for density and hardness properties investigation. Moh’s hardness scale was determined by scratching test which of the standard minerals. The micro vicker’s hardness was measured with a diamond indenter and the test load was used at 0.1 kgf. The results show that, the moh’s hardness scale of LYSO crystal are higher than BGO crystal which correspond with micro vicker’s hardness values. The density of scintillation crystals were measured and found to be 7.1 g/cm³ for BGO crystal and 7.15 g/cm³ for LYSO crystal.

1. Introduction
Inorganic scintillator are widely used in many application for engineering, high energy physics, oil exploration and nuclear medicine, i.e., positron emission tomography (PET) and single photon emission computed tomography (SPECT) [1-2]. Bismuth germinate (Bi4Ge3O12) and lutetium yttrium oxyorthosilicate (LYSO) are a good choice used in commercial PET technology [3-4]. The choice of the detector is based on several characteristics such as scintillation decay time, light output, energy resolution of the detector, stopping power and also including hardness test [5]. The hardness test is a mechanical test for material properties which are used in engineering design, analysis of structures and materials development. The principal purpose of the hardness test is to determine the suitability of a material for a given application and including with the relationship between hardness and other properties of material [5]. In this paper present the micro vicker’s hardness test and moh's hardness scale of BGO and LYSO inorganic scintillation crystals. Moh's hardness scale was determined by scratching test which of the standard minerals. The micro vicker’s hardness was measured with a diamond indenter and the test load was used at 0.1 kgf. The density of scintillation crystals were also measured.

2. Experiment
The BGO and LYSO crystals with size of 10×10 cm² and 10×10×10 cm³ respectively, were used in this experiment. The micro vicker’s hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load not exceeding 1 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal
of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation follow as [5]:

\[
HV = \frac{2F \sin 136^\circ}{d^2}
\]

(1)

\[
HV = 1.854 \frac{F}{d^2}
\]

(2)

where \( F \) is load in kgf, \( d \) is arithmetic mean of the two diagonals, \( d_1 \) and \( d_2 \) in mm, \( HV \) is micro vicker’s hardness. The Moh's hardness scale, it simply consists of 10 minerals arranged in order from 1 to 10. Diamond is rated as the hardest and is indexed as 10 and talc as the softest with index number 1. The hardness is determined by finding which of the standard minerals the test material will scratch or not scratch. The hardness will lie between two points on the scale, the first point being the mineral which is scratched and the next point being the mineral which is not scratched. In this study, focus on density and hardness properties investigation of BGO and LYSO crystals. The density was measured by Archimedes principle, the weights of the prepared samples were measured in air and in mineral oil (\( \rho_b = 0.825 \text{ g/cm}^3 \)) using a 4-digit sensitive microbalance (AND, HR200). The micro vicker’s hardness test method using digital display micro hardness tester (HVS-1000) was measure 6 side per sample and from each side were measured 5 point per side then average. The Moh's hardness scale was used 10 minerals arranged in order from 1 to 10 for measurement.

3. Results and discussion

Density and hardness properties

The density of BGO and LYSO crystals by Archimedes principle are shown in Figure 1. It was found that LYSO crystal is slightly higher value than BGO crystal. The value corresponds to 7.15 g/cm\(^3\) for LYSO crystal and 7.1 g/cm\(^3\) for BGO crystal.

![Figure 1: Density of BGO and LYSO crystals](image)

Figure 2 shows the micro vicker’s hardness of BGO and LYSO crystals, measured using digital display micro hardness tester and the test load was used at 0.1 kgf. It is seen that the micro vicker’s hardness of LYSO crystal are higher than BGO crystal. Figure 3 shows that the moh’s hardness scale of BGO and LYSO crystals, measured by the standard minerals. It was found that the moh's hardness scale of LYSO crystal are higher than BGO crystal which correspond with micro vicker’s hardness values.
Figure 2: Micro vicker’s hardness of BGO and LYSO crystals

Figure 3: Moh’s hardness scale of BGO and LYSO crystals

4. Conclusion
The density and hardness properties of BGO and LYSO inorganic scintillation crystals have been studied. Moh's hardness scale was determined by scratching test which of the standard minerals. The micro vicker’s hardness was measured with a diamond indenter and the test load was used at 0.1 kgf. The results show that, the moh's hardness scale of LYSO crystal are higher than BGO crystal which correspond with micro vicker’s hardness values. The density of scintillation crystals were measured and found to be 7.1 g/cm$^3$ for BGO crystal and 7.15 g/cm$^3$ for LYSO crystal.

Acknowledgments
The authors gratefully acknowledge the National Research Council of Thailand (NRCT) for supporting this research and Nakhon Pathom Rajabhat University (NPRU) for facilities.

References
[1] Van Eijk, C.W.E., “New inorganic scintillators aspects of energy resolution,” Nuclear Instruments and Methods in Physics Research A, vol. 471, pp. 244-248, 2001.
[2] Van Eijk, C.W.E., “Inorganic-scintillator development,” Nuclear Instruments and Methods in Physics Research A, vol. 460, pp. 1-14, 2001.
[3] Gopal, B. S., Basics of PET Imaging: Physics, Chemistry and regulations, 2nd ed., Springer, pp. 18-20, 2010.
[4] M. Moszynski, “Energy resolution and non-proportionality of scintillation detectors new observations,” Radiation Measurements,” vol. 45, pp. 372-376, 2010.
[5] M. J. Weber, “Inorganic scintillators: today and tomorrow,” Journal of Luminescence, vol. 100 pp. 35-45, 2002.
[6] J. Newby, Metals Handbook, Mechanical Testing, 9th ed., Vol. 8, 1990.