Neutron Radiography using isotopic neutron sources: Preliminary results

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INTRODUCTION

Neutron Radiography (NR) is an imaging method based on the neutron attenuation properties of the imaged object. To produce an image a source of neutrons, a collimator to shape the emitted neutrons to a mono-directional beam, an object and a method of detecting neutrons are required. The present work is a preliminary study aiming to investigate the potential of Neutron Radiography using (a, n)-type isotopic neutron sources. As an application, NR images of a portable NaI scintillation detector and common computer components (CC) were acquired. The parameters that should be taken into account for the design of NR system based on (α, n) type sources are discussed. In addition, the NaI detector was examined with X-ray Computed Tomography (CT) to compare the two imaging techniques on their efficiency as diagnostic tools for such instruments.

EXPERIMENTAL SETUP & METHODOLOGY

Source

^{239}Pu/Be neutron source

(Activity: 185 GBq, Emission Rate: 9.46*10^6 n/s)

Collimator

A modified collimator of a Prompt Gamma Neutron Activation Analysis (PGNAA) system comprising of a graphite within a composite shield of borated-lead-polyethylene

Moderator

Polyethylene slabs inserted between the source and object.

- 13 x 24 x 0.8 cm^3
- ρ = 0.98 g /cm^3
- Total thickness: 6 x 0.8 cm = 4.8 cm

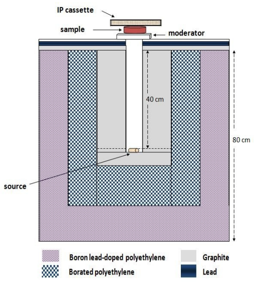

Figure 1: Schematic diagram of the PGNAA experimental facility

Imaging Plate (IP)

The IP is a film-like image sensor comprising specifically designed phosphors that trap radiation and keep it stored until scanned with a laser beam. A Bio-imaging Analyzer releases the energy as luminescence.

The IP Detector system (Fig. 2) consists of:

- Bio – Imaging Analyzer BAS1500 (reader/eraser)
- BAS – IP Cassette Fuji
- Imaging Plate (IP / film) BASND2040 Fuji (20x40 cm^2)
- with a Gd_2O_3 surface layer

Figure 2: i) IP reader
ii) IP eraser
iii) IP cassette

IP reader conditions:

- Gradation: 12 bits (4096 grayscale)
- Resolution: 100 μm
- Sensitivity: 1 : 10^4

Samples (Fig. 3)

- Portable NaI detector, 3" x 3", total length including PMT 22.5 cm
- Floppy drive: (15 cm) x (10 cm) x (2.4 cm)
- PC graphics card: (17.3 cm) x (10 cm) x (0.1 cm)

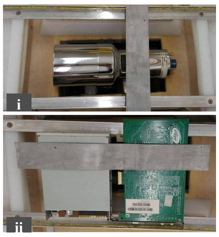

Figure 3: Neutron Irradiation setup with samples
i) NaI detector
Ii) Floppy drive (left), PC graphics card (right)

Neutron Irradiations

Sample	Cadmium	Moderator	Δt (min)	Figure
Floppy drive / Graphics card	+	-	60	5 i
	+	+	60	5 ii
NaI	-	+	38	6 i
	+	-	60	-
	+	+	60	6 ii
	-	+	120	6 iii
	+	-	210	7 ii
	+	+	210	6 iv / 7 i

Table 1 : Neutron Irradiations using (+) / not using (-) a reference (1st column) and a moderator (2nd column), the exposure time (Δt) and the respective figure.

Computed Tomography Scanner

A medical CT scanner operating at General Hospital of Nikaia "*Agios Panteleimon*" (Fig. 4) to obtain detailed sections of the NaI detector.

- 16 detector Somatom Emotion CT scanner , Siemens 2007
- I = 25 mA
- V = 130 kV

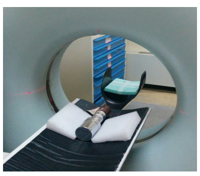

Figure 4: CT scanner

RESULTS

Computer Components NR

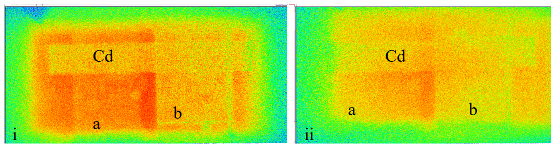

Figure 5: i) NR with fast neutrons, Δt = 60 min ii) NR with slow neutrons, Δt = 60 min
a) Floppy drive b) Graphics card. The Cadmium reference sheet is marked in the picture.

Fast vs. Slow neutrons

For the same exposure time, the NR image obtained with fast neutrons (no moderator) is of higher quality in comparison to the one obtained with slower neutrons (5 cm moderator) in the case of the computer components. CC consist mainly of metal parts.

NaI Detector NR

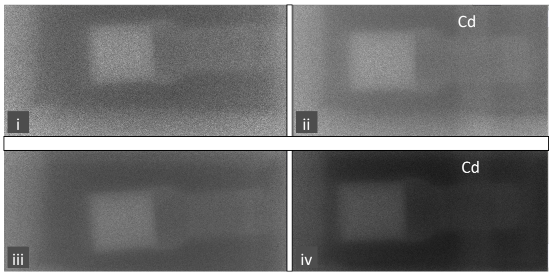

Figure 6: NR with slow neutrons i) Δt = 38 min ii) Δt = 60 min iii) Δt = 120 min iv) Δt = 210 min
The Cadmium reference sheet is marked in the picture.

The effect of exposure time on NR

The resolution of the NR images obtained with slow neutrons is proportional to the exposure time.
The detector consists of sodium iodide and metal parts (e.g. PMT).

NaI Detector NR - CT

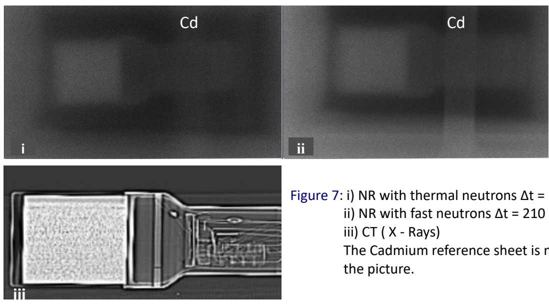

Figure 7: i) NR with thermal neutrons Δt = 210 min
ii) NR with fast neutrons Δt = 210 min
iii) CT (X - Rays)
The Cadmium reference sheet is marked in the picture.

NR vs. CT in the case of NaI detector

The initial aim of the irradiation of the portable NaI detector was to detect any defects or cracks in the crystal. The NR image with thermal neutrons (Fig. 7i) is of higher resolution in comparison to the one with fast neutrons (Fig. 7ii), whereas Fig. 7ii has a better image quality. No significant structural defects were detected with NR. The CT image (Fig. 7iii) offers the greatest resolution and image quality in the minimum exposure time. No defects were detected either. Dimensions of the NaI crystal (known) agree with the measurements taken from Fig. 7i and Fig. 7iii.

CONCLUSIONS

- The results of the study suggest that neutron imaging can be performed using an isotopic (α, n) type neutron source and an IP (imaging plate) with Gd_2O_3 surface layer .
- Requirement for a successful image is a well collimated and moderated neutron beam.
- The thermal-neutron fluencies that can be achieved from isotopic source assemblies are low and can only be used for applications in which high resolution and short exposure times are not required.
- Nevertheless, a significant advantage of this approach is the overall simplicity and cost effectiveness due to the long half-life of (α, n) type neutron sources.
- Future work will be directed towards a trade-off study between source intensity, neutron collimation and moderation, as well as radiation shielding requirements, in order to achieve a given image resolution.

REFERENCES

- **Neutron Imaging: A Non - Destructive Tool for Material Testing, IAEA - TECDOC - 1604, ISBN 978 - 92 - 0 - 110308 - 6**
- **Practical Neutron Radiography , J. C. Domanus, ISBN 0 - 7923 - 1860 - 9**
- **Bio-Imaging Analyzer BAS1500 IP Reader (Fujifilm) Operation Manual**
- **N. Chankow et al., *Applied Radiation and Isotopes*, 68, 662 - 664, (2010)**