CHARACTERISATION OF NEUTRON DETECTING SCINTILLATION GLASS FOR OIL WELL LOGGING APPLICATIONS

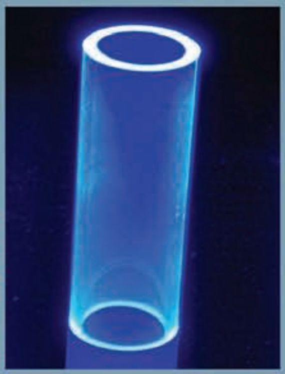

Figure 1: GS20 scintillation glass illuminated with UV.

Research Engineer: Martyn Staff

Supervisors: Glenn Tyrrell (Scintacor) & Annika Lohstroh (University of Surrey)

1. Introduction

A scintillator is a material which is used in radiation detectors to convert ionizing radiation into UV/visible light that can be detected in a photodetector.

The scintillator of interest for this research is GS20. GS20 is a lithium-6 based aluminosilicate glass which is doped with the rare earth, cerium (figure 1).

2. Physics of Neutron Scintillation (figure 2)

Fast neutrons (4 MeV - 14 MeV) are emitted from an Am-Be source and are moderated in the surrounding matter. The subsequent thermal neutrons (<0.025 eV) interact with lithium-6 which absorbs thermal neutrons and decays to produce triton and alpha particles. The triton and alpha decay products stimulate the cerium luminescent sites resulting in the release of a scintillation photon via radiative decay. Scintillation light is detected in a photodetector.

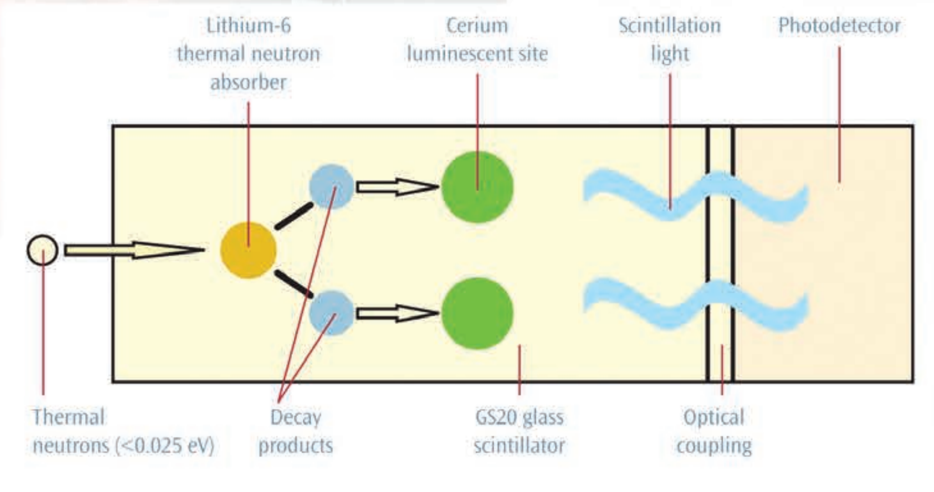

Figure 2: Physics of scintillation in GS20 glass.

3. Applications

GS20 is used in the oil well logging industry for neutron porosity measurements (figure 3).

Porosity measurements provide crucial information such as:
- identification of hydrocarbons
- locate zones between liquid and gas phases in hydrocarbon formations
- devise strategies to exploit the reservoirs

A neutron source, a scintillator and a photodetector are situated in a compact array above the drill head (figure 4). Neutrons are used to measure the hydrogen index to infer a porosity value. Hydrogen index is the ratio of the concentration of hydrogen atoms per cm^3 to that of pure water at 23°C. Hydrogen has the greatest effect of moderating neutrons via elastic 'billiard ball' collisions and hence there is an inverse relationship between count rate and porosity.

Figure 3: An oil rig where porosity measurements using GS20 are undertaken.

- Low count ratio between detectors = low hydrogen index = low porosity = lower hydrocarbon content
- High count ratio between detectors = high hydrogen index = high porosity = greater hydrocarbon content

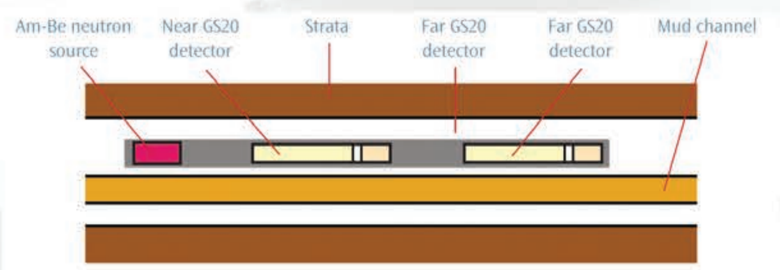

Figure 4: Neutron porosity unit which fits into an oil well logging assembly (edited from [1;2]).

The ratio between the two scintillators is used as a measure of porosity as opposed to using a single scintillator. Using two scintillators to acquire a relative measurement of porosity is less sensitive to environmental factors such as density, clay and gas. Drilling deeper for hydrocarbons exposes radiation detectors to increasingly hostile operating conditions such as high temperatures, vibrations and shocks.

4. Advantages of GS20

- Gamma discrimination possible
- High temperature stability
- Large volume
- Fast response (~70 ns)
- Low cost
- Easily machinable
- 386 nm emission closely matches PMT spectral response [3] (figure 5)

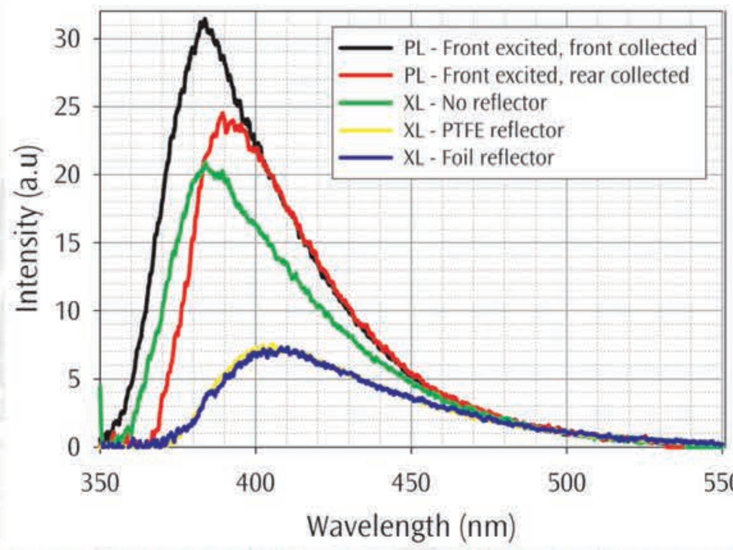

Figure 5: Photoluminescence and radioluminescence spectra of GS20. Two photoluminescence (PL) spectra are excited by a xenon source and three radioluminescence (RL) spectra are excited by a 38 kVp 90 μA Ag anode X-ray generator. The spectra vary due to different collection geometries. The path length of the scintillation light varies depending on collection geometry and results in differing amounts of self-absorption.

5. Disadvantages of GS20

- Internal defects
- Detect gamma rays
- Low light output (6000 photons.MeV^{-1}) [4]

6. Possible Solution

GS20 has some disadvantages which are of high importance for a radiation detector. These disadvantages can be addressed in a variety of ways to increase the efficiency of the scintillator:

- Incorporation of crystals introduces an ordered structure which would result in a higher light output.
- Doping glass with other rare earth elements to shift the spectrum to spectrally match other photodetectors.

7. Potential Pitfalls

Possible solutions will no doubt lead to additional problems. Problems which are likely to exist are:

- Controlling devitrification
- Machinability
- Self-absorption of scintillation light
- Optimise composition
- Economically viable

8. Conclusions

- GS20 glass is an industry leading scintillator for oil well logging.
- Improvements are possible to increase the light output which increases the efficiency.
- Attempts will be made to incorporate crystals and rare earth dopants into GS20.

References:

[1] Scneider, D. M. and Hubner, B. G., 1991, Neutron/gamma discrimination in a lithium-6 glass scintillator in an MWD tool, *Nuclear Science Symposium and Medical Imaging Conference: Conference Record of the 1991 IEEE*, **2**, 1113-1117

[2] Frederick, L. D. and Frederick Jr, L. D., 1998, Unitized scintillation detector assembly with axial and radial suspension systems, *United States Patent 5*,742,057

[3] Spowart, A. R., 1976, Neutron scintillating glasses: part 2 the effects of temperature on pulse height and conductivity, *Nuclear Instruments and Methods*, **140**(1), 19-28

[4] Knoll, G. F., 2010, *Radiation Detection and Measurement*, 4th Edition, John Wiley & Sons Inc, USA

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