Optic Sensor for radon monitoring: proof of concept

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Introduction

The radioactive gas Rn-222 is a decay product ofRa-226, which is present in the earth’s rocks, soil and water [1]. Radon can diffuse through the soil and enter indoors or even be transported in water and is the leading contributor (50% of total) to background natural dose levels. It is identified has a main source of lung cancer (second only to smoking). The inhalation of Rn can result in deposition of its short lived progeny into the respiratory tract, leading to the emission of highly energetic alpha-particles (from Po-214 and Po-218) that can result into biological damage [2]. Therefore, the measurement of radon and its monitoring is of uttermost importance. In this work a compact fiber optical sensor, consisting of encased scintillating fibers coupled to a photomultiplier was developed.

Detection using Optical Fibers

The compactness and the possibility of performing radiation real-time monitoring without electromagnetic interference makes optical fibers into an alternative to more conventional sensors.

Scintillating Optical Fiber

Working principle

- Incident ionizing radiation passes through the fiber interacting with the fluorescent dopant.
- The fluorescent dopant is excited, emitting a visible photon (with no preferential direction) when returning to the ground state.
- The emitted photons are guided through the fiber.

Prototype optimization

Fiber response to ionizing radiation

BCF-60 response to different types of radiation (β,γ,α) was assessed using Sr-90 (β,γ) 662 keV, Cs-137 (β) @60 keV and Am-241 (β,γ) 5.486 MeV radioactive sources placed on top of the fibers. The encased fibers were directly coupled to a photomultiplier (PMT, R647-01) Hamamatsu and then to a preamplifier, a NIM amplifier and a multichannel analyser (MCA) for energy discrimination.

The fibers responded to all ionizing types of radiation with a higher response to the beta particles. However, a more robust study should be done using sources with closer activity. Because the fiber manufacturer claims that the fibers sensitivity is not affected up to 5 MeV, another alpha particle source with energy < 5 MeV should also be tested.

Number, length and fiber tip finishing

The influence of the number of fibers, its length and the fiber tip finishing was also studied taking into account the limitation of the photomultiplier window size. The study was carried out using an UV light source as an excitation mechanism. The fibers were directly coupled to a photomultiplier (H7468 Hamamatsu) that was connected to a Raspberry Pi for datalogging.

For the setup, the optimum configuration is 3 fibers with 10 cm length. A higher signal output was achieved when using a reflective surface at the tip of the optically grade polished fiber. This finishing resulted in an output signal 2x higher than achieved without mirror.

Remote access, Temperature and Humidity monitoring

To monitor the temperature and humidity inside of the sensor case a Raspberry Pi with a Sense HAT board was implemented. The microcomputer was also used as data storage and as wireless interface to the photomultiplier for remote access.

Radon Measurements

After light collection optimization, the sensor response to radon rich gas was studied. An air tight box containing rocks with natural uranium for gas accumulation was connected to the sensor container through a gas hose. The hose, that connects the two containers, carried the radioactive gas to the sensor. The system is schematized in the following figure.

Preliminary radon measurements were taken every 3h and are shown in the following figure. The measurements started with valve closed and then it was opened after 3 days. Radon built up inside the aluminum box for 5 days. The valve was then closed for 7 days and a decrease in the signal was verified, corresponding to a decrease in radon concentration.

Conclusions

A new radon measuring system made of scintillation polymeric fiber optics has been developed and optimized and maximum sensitivity was achieved using 3 fibers of 4-mm diameter and 10 cm length and having a mirror in the fiber-end. The fibers responded to all ionizing types of radiation, but further studies need to be done. The accumulation of radon was successfully monitored by the detector. This prototype system provides continuous measurements at high temporal rates [minute or less] and for long time periods autonomously.

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References


Multi-day radon signal from rocks rich in uranium obtained with the optical fibers.

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