Remotely Radiation Induced Absorption Dosimeter based on optical fibers

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Abstract:

To monitoring in the high-radiation environments it can use optical fiber sensors due to it contains many advantages compared with traditional electronic sensors. This paper proposed design consideration of remotely absorbed dosimeter based on radiation induced absorption based on optical fiber characteristics. The fundamental of absorbed dose calorimetry methods to dosimetry technique, which provide an absolute measure of the energy transfer to matter, was implemented in the present work. The irradiation effects on various optical fibers within 5 cm active lengths were determined. Results show that the relative sensitivity variation for 532nm wavelength source according to shift in such wave length and as a function to dose of radiation which related to temperature. The ratio of the power distribution between the core and clad of fiber selected to be a sensitive function of the refractive index difference, which depends on the temperature. Where the temperature changes cause changes in the transmission of the fiber when cladding is made lossy. The assessment of results illustrates the performance analysis in case of using optical fibers made from silica in radiation dosimetry and monitoring.The attenuation peak wavelengths will shift to shorter wavelengths

Keywords: Radiation dosimetry, alpha particles and beta, Gamma radiation, OFS.

الملخص: لمراقبة البيئات العالية الإشعاع ، يمكننا استخدام أجهزة استشعار الألياف الضوئية لاحتواءها على العديد من المزايا مقارنة بالمتحسسات الإلكترونية التقليدية .. يهدف البحث الى دراسة تصميم مقاييس الجرعات الممتصة من الأشعاع بتوظيف تقنية متحسسات الألياف البصرية لدراسة تأثيرالامتصاص المستحث بالإشعاع. تم تطبيق مبدأ طرق قياس المسعر للجرعة الممتصة لتقنية قياس الجرعات التي توفر مقياسًا مطلقًا لنقل الطاقة إلى المادة. تم تحديد آثار التشعيع على مختلف الألياف البصرية وبمدى طول فعال بحدود ٥ سم في ظل ظروف تشعيع مختلفة. تظهر النتائج الحساسية النسبية للطول الموجي 532 نانومتر كدالة لكثافة الضوء ومقدار الأنحراف في (الطور\ الطول الموجي) لمثل هذه الجرعات ألياف كداله للجرعة درجه حرارة النطاق الاختلاف. تكون نسبة توزيع الطاقة بين قلب الفايبر والألياف المختارة دالة التحسس لاختلاف معامل الانكسار، الذي يعتمد على درجة الحرارة. حيث تتسبب التغيرات في درجات الحرارة في حدوث تغييرات في الانتقال لليف عندما الغلاف الخارجي تكون فيه خسارة . يوضح تقييم النتائج وتحليل الفعالية في حالة استخدام الألياف البصرية المصنوعة من السيليكا في قياس الجرعات الإشعاعية ورصدها.

1. Introduction

Optical fiber sensor (OFS) are an attractive for monitoring in radiation environments for possessing number of advantages. The main advantages including high accuracy, self-calibration, absolute explosion safety, lightweight, small size, in addition to immunity to electromagnetic , mechanical flexibility and operation in extremely harsh environments[1]. Radiation is classified into non-ionized and ionized categories, according to its ability to either direct ionize matter such as protons, electrons, alpha particles, and heavy ions, which considered as (charged particles) or indirect ionize radiation (neutral particles) such as photons (gamma rays, X rays) and neutrons[2]. High energy radiation interaction with matter lead to either ionization of atoms or induce non-ionizing effects and energy losses . Radiation dosimetry is the fundamental of these radiation processes, which depend on the interaction types between the radiation and the sensor materials [3]. Material that directly exposures to the irradiation produce change in the optical properties of these materials. In gamma dosimeter, the materials must have a high sensitivity to dose ranges required of gamma radiation for the specific application. Different materials used to determine interaction effects of the ionizing radiation [4].

2. Remotely Optical Fiber Dosimeters

The optical fiber dosimeter feature is that the information related to dose transmitted as optical signals, and according to the type of interaction between the incident radiation and the sensor, radiation dosimeters are primarily characterized. Different types of radiation dosimeters vary according to type of interaction [5]. Optical fiber sensors multiplexing benefit lead to that a single controller can monitor a number of sensors [6].
Optical fiber sensors can classified into two types intrinsic and extrinsic sensors.

3. Design consideration of Radiation induced attenuation (RIA) Dosimeters.

Optical fibers are became more important for radiation dosimetry, where extrinsic sensors have high ratio of the optical fiber dosimeters while there are also a number of intrinsic dosimeters act on the same fundament as RIA dosimeters monitored by spectrophotometry [7].

The operating principle of the Radiation induced attanuation (RIA) dosimeter based on fiber optic is showing in Figure 1.

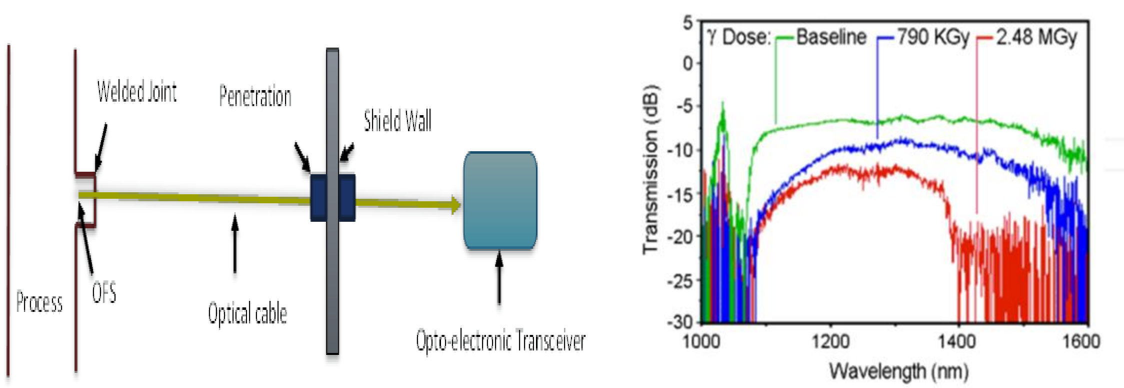


Figure 1: The operating principle of (RIA) dosimeter based on fiber optics [11].

Another sensor configuration is also based on evanescent penetration of the light beyond the core. If the thickness of the cladding is sufficiently small the light extends beyond the cladding wall and may penetrate a nearby fiber where it propagates as a guided mode. The source light is transmitted through the sample, while the intensity of the received light which changed as a function of absorbance measured by the photometer device. The radiation dose absorbed can be determined using Beer-Lambert law. The absorption coefficient (α) is given by equation (1) [8]:

$$\boldsymbol{\alpha = -\frac{1}{L_0}\log\left\{\frac{P(\lambda)}{P^0(\lambda)}\right\}} \text{ ---------- } \mathbf{(1)}$$

where: $\left\{\frac{P(\lambda)}{P^0(\lambda)}\right\}$ is the ratio between radiant powers values of transmitted light through dosimeter to that in the absence of the dosimeter, the radiation-induced attenuation is given by equation (2) :

$$\boldsymbol{RIA(dB) = -\frac{10}{L_0}\log\left\{\frac{P_T(\lambda,t)}{P_T^0(\lambda)}\right\}} \text{ ---------- } \mathbf{(2)}$$

where: L_0 is fiber length , $P_T(\lambda, t)$ is the transmitted power (measured optical power), while $P_T^0(\lambda)$ is the optical incident power for reference fiber. The relation between fiber temperatures (T) as a function to dose of radiation exposed (D) is given by (3) [9].

$$\boldsymbol{T = \left(\frac{C}{2} - \frac{D}{3}\right)D^2} \quad \text{--------} (\mathbf{3})$$

where: C=2D.

4. Experimental Part

In this work, the type of single-mode fiber was used, and the determined length for sensitive area of fiber was 5 cm^2.To increase the sensitive area of fiber, the part of clad area of fiber are etching. After the etching the part of clad area of fiber, the width of area (core and clad) was measured using microscope. The procedures of work is determined by apply the external effect on the fiber (the external effect is the change in temperature). We drowned the optical fiber into the pan of water and carefully heat the water. Connected one end of the fiber into the coupler, and the other into a reference. The measurement were taken for outer intensity from the fiber as a function of the change of temperature.

Attempts have been made to develop methods of radiation induced temperature measurement in water through implementation of fiber optics sensor, which investigated have included the measurement of the variation in refractive index of water as a function of temperature induced from radiation. Fiber optic sensor designs of adequate sensitivity, as the temperature sensor in absorbed dose calorimetry has a number of advantages ;(physically small; not self-heating and has low thermal conductivity which minimizes heat losses and isolated absorber). Figure (2) shows photography of the Proposed Mach-Zehnder interferometer (MZI) interferometric sensor prototype based on an extrinsic sensor design where since the same physical path is used for the reference and sensing beams; will have good noise rejection characteristics. Spectrophotometry technique used to monitor the optical signal attenuation of the fiber sensor based on radiation-induced attenuation (RIA). The light source passed through the fiber sensor and all changes as the light absorbed by the sample temperature changes measured by the optical spectrum analyzer (OSA), through the variation in the intensity of the received light.

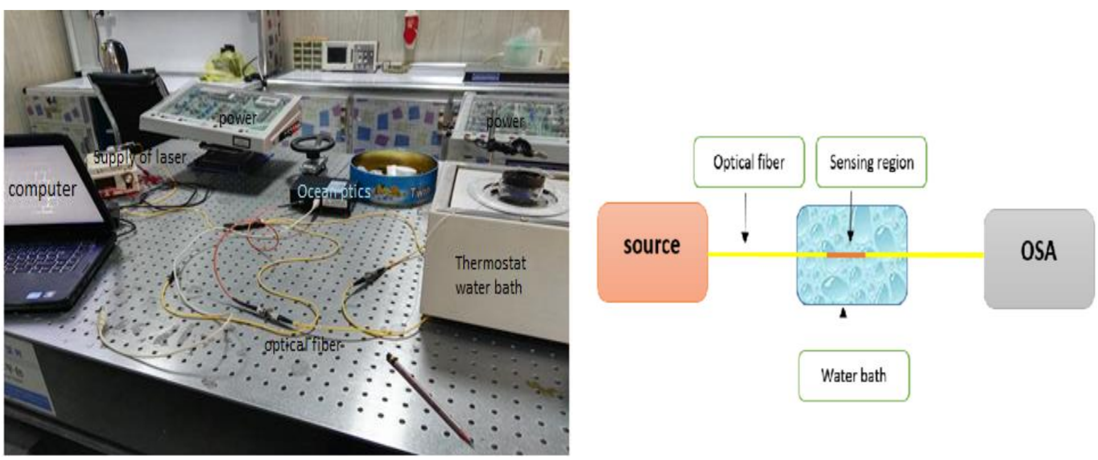
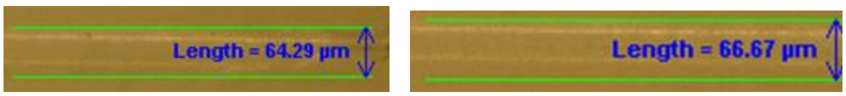


Figure (2): Photographic of the Proposed MZI interferometric sensor prototype based on an extrinsic sensor.

4.1 Samples Preparation

In this research, several sensor samples were prepared from a single- mode fiber, one of these fibers; its plastic coating (shield) was removing within 5cm sensitive length. Others samples were chemically etched through emerging the sensitive length in fluoric acid with controlled concentration and time of the etching process to remove a specific portion of the clad glass. While the fiber core was kept for all prepared samples as shown in Figure 3



Figure(3): Samples preparation by etching

4.2. Measurements and Results

For dose range between (0.6-2) Gray acalibrated curve which estimated from the relation illustrated in equation 3 is shown in Figure 4.

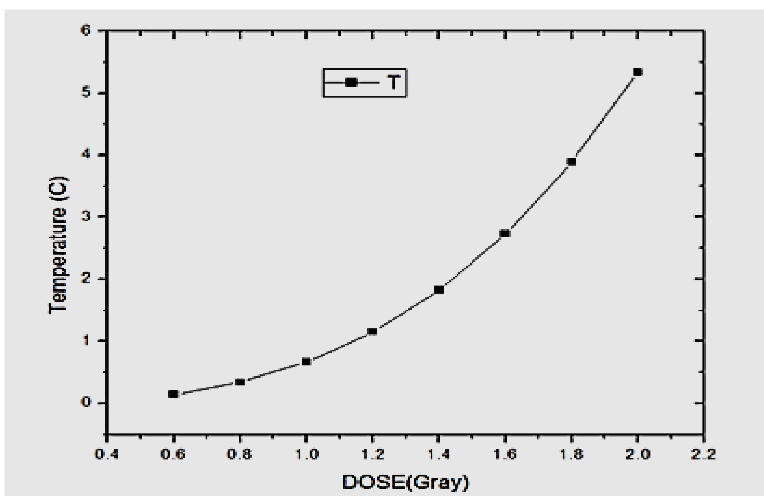


Figure (4): Variation of optical fiber Temprature with Radiation dose

Numerical measurements for modified glad silica single mode fiber (SMF) tested for a specific temperature ranges. Figure 5 shows the relative sensitivity according to 532nm wavelength transmitted light intensity and (phase \ wavelength) shift for such fiber dosimeter as a function to dose range temperature variation.

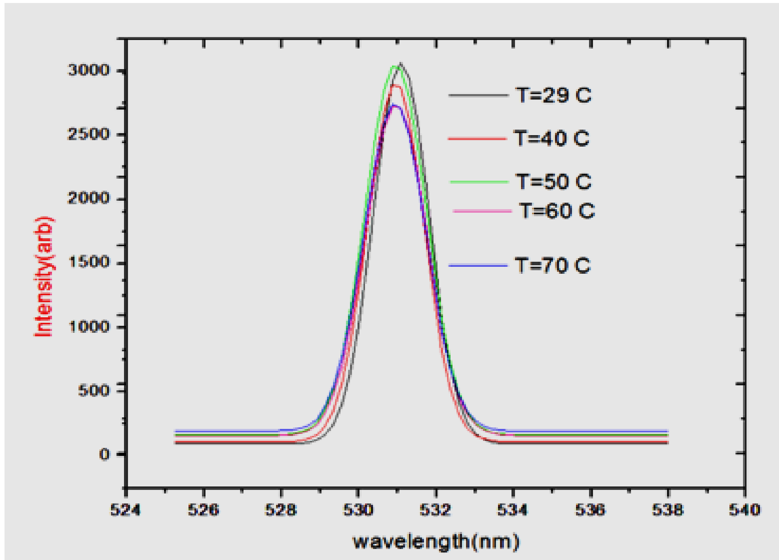


Figure (5): Intensity shift as a function of wavelength for different fiber Temprature

5. Conclusions

Optical fibers dosimetry system and due to a number of advantages are becoming more important and increasingly widely used industrial and clinical environments, when they possess over conventional sensors. The results shows that there is potential for ultrasensitive temperature sensors using optical fiber technology to be applicable to the measurement of absorbed dose. At tempratures (29,40,50,60, 70)^{o}c obtained shift in wave length to short wave length(531.08,530.95, 530.94, 530.96, 530.92)respectively and full width half maximum was (1.4469, 1.4681, 1.5960, 1.6014, 1.6132).

An interferometric phase sensor is potentially more sensitive than the electrical methods currently used for precision calorimetry. The relative sensitivity according to wavelength transmitted light intensity and (phase \ wavelength) shift for such fiber dosimeter as a function to dose range temperature variation, The attenuation peak wavelengths will shift to shorter wavelengths, In the case of heating, temperature increase of the water will cause this to the density and refractive index decreasing and cause changes and attenuation in the transmission of the light in [optical fiber and thus effect on the principle of total internal reflection which depends on it the light path in optical fiber.

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