CHARACTERIZATION OF FIBER OPTIC SENSOR FOR CORROSION MONITORING

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Special dedication for my beloved family, mak, abah, boloy, engkis, embo, along, kakak, ipan, doshi, eman, nomey, and uzair. May Allah shower his blessings to all of us forever.

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ABSTRACT

This research was conducted to characterize the parameter that can be associated with corrosion activity of metals using fiber optics as sensor. Three samples of metal rods were selected namely iron, copper and aluminium. Unclad multimode fiber optics were strapped onto the metal and soaked in corrosive solution. The corrosion process was monitored by a spectrometer linked to a computer. Two measurement techniques were used in this research namely transmission and reflection. For transmission technique, the changes in the intensity spectrum of light from a white LED source after passing through the unclad region (corrosion activity region) at different exposure period were monitored. For reflection technique, a Y-probe fiber bundle was used to observe the reflected intensity from the corroded region. The changes in colour of the corrosion product had an effect on the reflected component from the light source. The changes in the intensity spectrum for both techniques were monitored at certain time intervals. Generally the result showed a reduction in the intensity level with exposure duration for both techniques but fluctuations also occurred at some exposures. This is thought to be due to the nature of the corrosion process itself. When the ratios of the intensities peaks were plotted with exposure, a very distinct drop in the value for iron occurred for both the reflection and transmission spectra from around days 37 to 44. This was the period where corrosion activity actually started. After that period, the value began to level off for reflection measurement but slowly increased for transmission measurement. For copper and aluminium, the intensity ratios from the reflected spectrum indicated a more gradual drop. These proved that they were more resistant to corrosion compared to iron. It seemed that the ratio of the peaks from the intensity spectrum was the parameter suitable to be associated with the onset of the corrosion activity of iron.

ABSTRAK

Penyelidikan ini telah dijalankan untuk mencirikan parameter yang boleh dikaitkan dengan aktiviti kakisan logam yang menggunakan gentian optik sebagai pengesan. Tiga sampel rod logam telah dipilih iaitu besi, kuprum dan aluminium. Gentian optik jenis mod berbilang tidak berlapis diikat ke atas logam dan direndam di dalam larutan menghakis. Proses kakisan telah dipantau oleh spektrometer yang disambungkan dengan komputer. Dua teknik pengukuran yang digunakan dalam penyelidikan ini ialah penghantaran dan pantulan. Bagi teknik penghantaran, perubahan dalam spektrum keamatan cahaya dari sumber LED putih selepas melalui kawasan tidak berlapis (kawasan aktiviti kakisan) dipantau dalam tempoh pendedahan yang berbeza. Bagi teknik pantulan, gentian optik berbentuk-Y telah digunakan untuk memantau keamatan pantulan dari kawasan kakisan. Perubahan warna hasil kakisan mempunyai kesan ke atas komponen pantulan oleh sumber cahaya. Perubahan spektrum keamatan bagi kedua-dua teknik dipantau pada sela masa yang tertentu. Umumnya, hasil menunjukkan penurunan tahap keamatan dengan tempoh pendedahan untuk kedua-dua teknik tetapi fluktuasi juga boleh berlaku di beberapa waktu tertentu. Ini adalah kerana sifat proses kakisan itu sendiri. Apabila nisbah puncak keamatan diplotkan dengan waktu dedahan, penurunan nilai yang sangat berbeza untuk besi berlaku bagi kedua-dua pantulan dan spektra penghantaran sekitar hari 37 hingga 44. Ini adalah tempoh di mana aktiviti kakisan telah bermula. Selepas tempoh itu, nilai tersebut mula menurun ke tahap rendah bagi pengukuran pantulan tetapi menunjukkan peningkatan perlahan bagi pengukuran penghantaran. Bagi kuprum dan aluminium, nisbah keamatan daripada spektra pantulan menunjukkan penurunan secara beransur-ansur. Ini membuktikan bahawa mereka lebih tahan kakisan berbanding besi. Hal ini menunjukkan bahawa nisbah puncak dari spektrum keamatan adalah parameter yang sesuai untuk dikaitkan dengan bermulanya aktiviti kakisan bagi besi.

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LIST OF SYMBOLS

Al	-	Aluminium
A	-	Absorbance
Cu	-	Copper
Cl^-	-	Chloride ion
D, d	-	Diameter
Fe	-	Iron
F	-	Force
g	-	Gravity = 9.81 m/s
H^+	-	Hydrogen ion
l	-	Length
MP	-	Megapixels
NaCl	-	Sodium Chloride
P	-	Power
PCS	-	Plastic clad silica
P_0	-	Output power
Q	-	Volumetric flow-rate
%	-	Percentage

%T	-	Transmission percentages
n	-	Refractive index
c	-	Speed of light
v	-	Velocity

ABBREVIATIONS

EDX -	Energy Dispersive X-ray
FBG -	Fiber Bragg Grating
FESEM -	Field Emission Scanning Electron Microscope
LED -	Light Emitting Diode
MMF-	Multimode Fiber
SMF -	Single Mode Fiber
SMA -	Subminiature Type A

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CHAPTER 1

INTRODUCTION

1.0 Background of Study

Corrosion occurs through the deterioration of a material or its properties because of the reaction with the environment. It influences the economic cost and also creates safety awareness from the damages such as in pipelines, building, bridges, wastewater system, and even our residence. A recent study in USA of industrial sectors, reported that 121 billion USD has been spent annually on corrosion control methods (Andres M. Cardenas-Valencia *et al.* 2007). The fundamental of corrosion must be well understood in order to avoid or to remedy the problem at an earlier stage. Earlier detection can be taken to identify the problem before it gets too late. Several methods for the diagnosis, detection and measurement of corrosion in structures are available, but there is no consensus regarding which method assesses corrosion levels of structures most accurately, that is why the technique for corrosion detection will remain as an issue and progressing no matter how corrosion inhibition is being carried out. The feasibility of an optical fiber as corrosion sensor depends on several advantages which might not be present in others sensor. Recently, the feasibility of fiber optic as corrosion sensor had been explored by many researchers from entire world and it became a very interesting field to study.

The revolutions in optoelectronic industries have enabled the development of fiber optic sensors that offer a series of advantages over conventional electronic sensors (Siaw, 2003). This development, in combination with advances in the composite material technology, has opened up the new field of fiber optic sensor in many field of application to the world. The optical fiber is a very versatile transmission medium and the advantages of the optical fiber explain why it has become such an attractive alternation to conventional transmission (Keigo Lizuka, 2009). By dealing with a simple monitoring system and the basic function, it can function as a good sensor. In recent years, optical fiber sensors have attracted substantial attention and shown to be capable of monitoring a wide range of physical measurement in non-destructive technique. The ability of the evanescent field to interact with the corrosion product on the fiber core has been investigated by numerous researchers.

1.1 Statement of Problem

The realization of how serious the corrosion impact on our environmental and economic issue and also the rapid growth of fiber optic sensor technology is the reason why this works is carried out. At present, several non-destructive methods of monitoring corrosion activity using fiber optics are available. Most of them proved to be sensitive for their environments involved but in terms of the sensor preparation or fiber modification, they could get rather tedious and complicated. In this work, another approach is being looked into to see the viability of producing a simple and direct-measurement fiber sensor for measuring corrosion activity of metals. Certain parameter need to be characterized in this work. In terms of sensor preparation, the sensor is just the unclad portion of an optical fiber which will be exposed together with the metals undergoing corrosion. This region must be sensitive enough to detect any changes in the metals surface due to corrosion activity through its transmitted and reflected intensities.

1.2 Objectives of Research

The main objectives are to develop:

i. To develop a simple and direct-measurement fiber sensor for corrosion of metals.
   - Characterize the transmitted and reflected intensity spectrum
   - Find the other intensity related parameter that can be associated with corrosion activity
   - To relate the intensity to the degree of corrosion of metals in seawater environment.

1.3 Scope of Study

The scope of this work is to use an unclad optical fiber to characterize the fiber optic sensor for corrosion studies. A similar environment is also created in a corrosion chamber in the laboratory. Corrosion of the three metal samples which are iron, copper and aluminium will also be conducted in this environment to see the changes if any in the two environments (seawater and laboratory).

Corrosion activity is monitored using spectrometer and the spectrum is displayed on the computer. The parameter observed in this work is the intensity from a broad band source in the form of a white phosphor-based Light Emitting Diode (LED). The characteristic intensity spectrum of the light source featuring two intensity peaks is monitored for any changes throughout the corrosion activity. In this work, both the transmitted intensity and the reflected intensity spectrum from the corrosion region are monitored. Changes in the intensity levels, peak intensity ratios and wavelength shift are monitored to see if these phenomena could be related to the stages of corrosion activity of the metals.

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