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FIBER OPTIC SENSORS FOR CORROSION DETECTION

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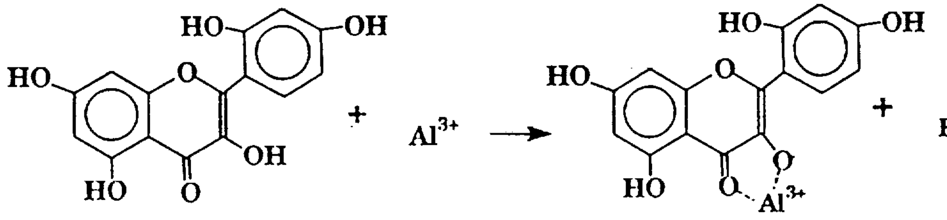
ABSTRACT

The development of fiber optic sensors[1-8] for the detection of a variety of material parameters has grown tremendously over the pass several years. Additionally, the potential for analytical applications of fiber optic sensors have become more and more widely used. pH sensors have also been developed using fiber optic techniques to detect fluorescence characteristics from immobilized fluorogenic reagent chemicals.

The primary purpose of this research was to investigate the feasibility of using fiber optic sensors to detect the presence of Al^{3+} ions made in the process of environmental corrosion of aluminum materials. The Al^{3+} ions plus a variety of other type of metal ions can be detected using analytical techniques along with fiber optic sensors

In order to acquire some background data on the use of fiber optic sensors that could be used for corrosion detection, experiments were conducted in the laboratory using morin as a fluorogenic reagent. Morin is a chemical that is widely used for fluorimetric analysis of aluminum and other metals. It is only weakly fluorimetric by itself but forms highly fluorometric complexes in the presence of Al^{3+} ions. The morin molecule has been extensively studied[8-10] and is used for analytical work, involving fluorimetric analysis of aluminum and other metals. It is also used for the spectrometric analysis of metals that do not form fluorescent complexes. This molecule comes under the flavonoids family. Hydroxylflavones belong to a vast class of flavonoid compounds - aromatic phenols of the general structure C_6 - C_3 - C_6. The flavonoids themselves can be identified through the characteristic color or fluorescence reaction with metals under suitable conditions. The fluorescence and color of the metal complexes formed depend on the number and position of the hydroxyl groups in the flavone molecule. The hydroxyl groups at the 3, 5, 2' - positions show the greatest effect on the fluorescence. Thus, morin (3, 5, 7, 2', 4'-pentahydroxyflavone) and datiscetin (3, 5, 7, 2'- tetrahydroxyflavone) have been used the most and these compounds have been found to be the most reactive and sensitive reagents among the flavones. These molecules contain a highly conjugated aromatic system, and consequently exhibit intense and characteristic absorption spectra. Flavones and flavonols generally exhibits two regions of intense absorption which fall in the ranges of 320-380 nm (Band I) and (240-270 nm (Band II). The addition of certain reagents to solutions of the flavones shifts the position of the absorption band maximum. Complex-formation by flavonoids with aluminum has long been used for the detection of certain hydroxy groups in these compounds. The flavonols form complexes with aluminum which are stable even in dilute hydrochloric acid. The complexation of the 3-hydroxyl group with metal ions, results in a structure as shown below which produces fluorescence that is detectable using fiber optic sensoring techniques.



For this experiment morin was used in solution with aluminum nitrate to form a complexation process with Al^{3+} ions. A sample solution of morin and aluminum nitrate as shown in Figure 1 was excited with a UV light source, using separate monochromators for the excitation and emission radiation. For a selected excitation wave length of 416 nm a 12 inch length of sodium lime glass was used as a sensor. The sensor was immersed in a glass container enclosing the solution of morin and aluminum nitrate. The solution was excited with the UV source in a direction perpendicular to the axis of the glass sensor. Figure 2 shows the emission spectra centered at approximately 520 nm The emission spectra data was obtained for the detected fluorescence light focused through the monochromator used for emission detection and into the photomultiplier tube(PMT). The multimeter as shown in Figure 1 was used to measure the relative intensity of the light output from the photomultiplier tube as a function of wave length.

In this experiment it was determined that fiber optic sensoring of fluorescence is rather easy to detect in a laboratory environment, using a solution of fluorescein reagent with a chemical to produce an abundance of Al^{3+} ions to complex with the reagent. Further studies will have to conducted to determine the detectability limits, and the practicality of this application to structures where corrosion is activated in an environmental condition where the chemistry of active surfaces could change with time. Furthermore, several metal ions forms luminescent metals - chelate complexes. However, the relative non-specificity of many chelates and the similarity of fluorescence spectra of metal chelates of a given chelating agent, could hamper the selectivity of some experimental methods. This would be especially true in an uncontrolled environment that would exist in most practical applications of fiber optic sensing. As an example some chelating molecules forms fluorescent chelates with different metal ions. Therefore one would have to be sure that a separation procedure could be performed in order to determine the presence of one metal ion in the presence of another. Because of the rather large differences between the fluorescence lifetimes(several nanoseconds) any interference in signal detection could be resolved by using phase-resolved fluorescence spectroscopy(PRFS). This technique would, help to enhance the signal to noise ratio due to background interferences and thus collectively help improve the measurement techniques.

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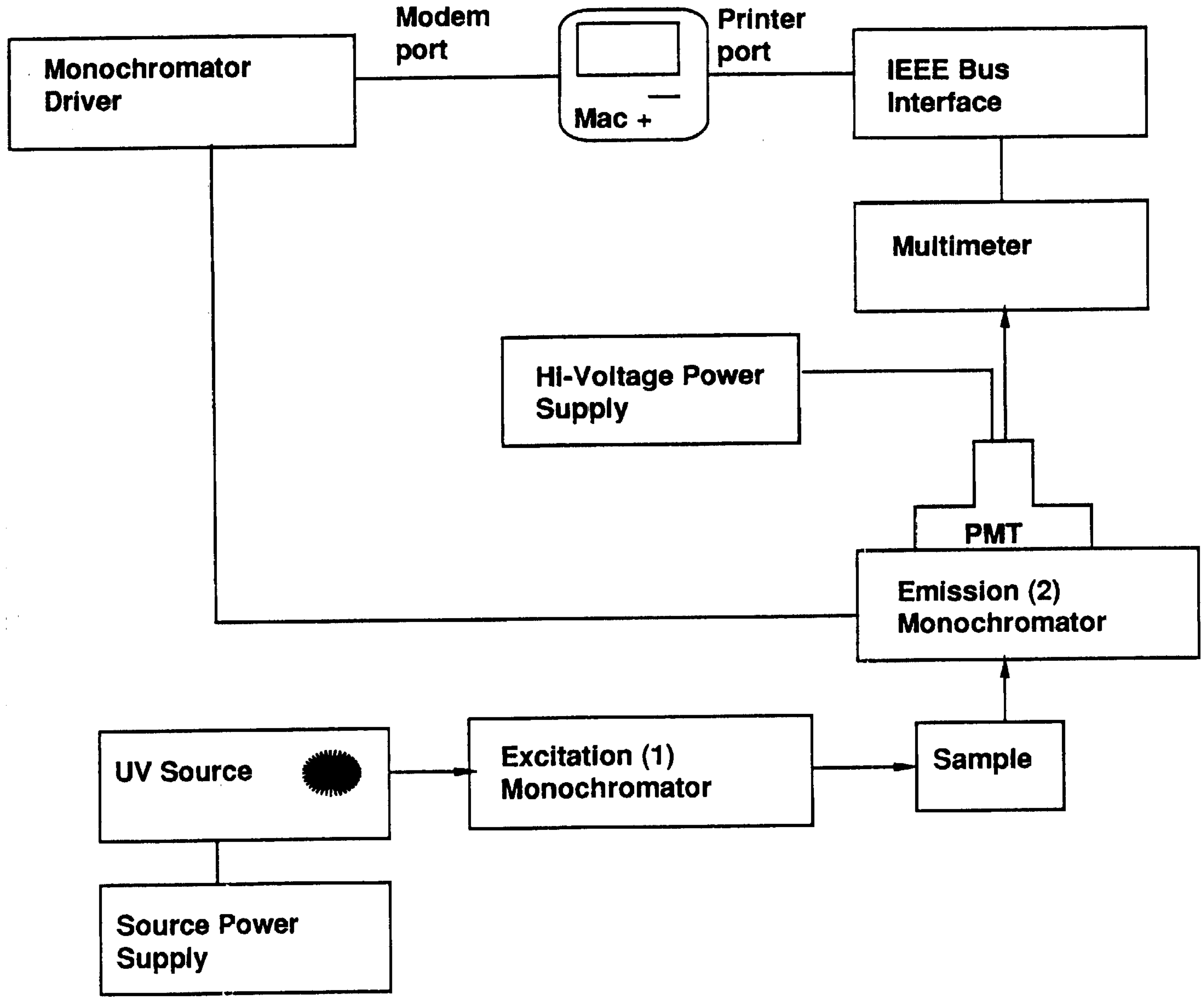

Fig. 1 Schematic Diagram of Automated Fluoremeter Experimental Setup

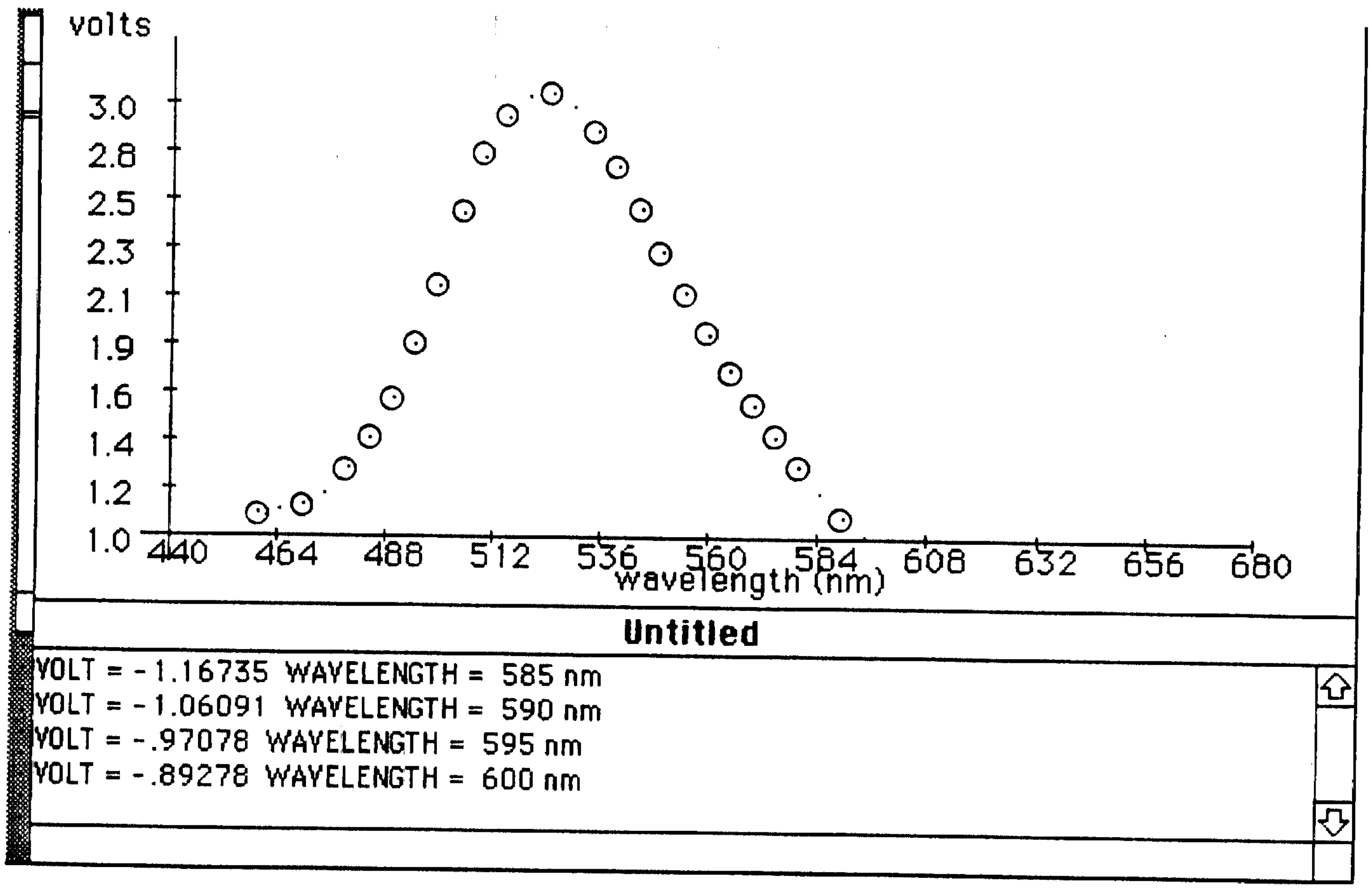

Fig. 2 Experimental Data