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Fiber Optic Displacement Sensor for Medal Detection using Fiber Bundled Probe

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Abstract: A simple fiber optic displacement sensor (FODS) based on intensity modulation technique is investigated using a bundle multimode plastic fiber as a probe for various medals detection. The sensor consists of a light source, a probe, and photodiode detector. The sensor is capable of measuring displacements of flat medals ranging from 0.05 to 4.2 mm using a red light source of wavelength 630 nm. The highest sensitivity of the sensor is found to be 0.0048 mV/µm over 50-650 µm for the gold medal. The sensor is highly sensitive at the front slope and very useful for close distance target. The simplicity of the design, high sensitivity, long dynamic range and the low cost of the fabrication make it suitable for wider applications in industries as position control and micro displacement measurement in the hazardous region.

Keywords: fiber optic, fiber displacement sensor, medal detection, reflection based.

INTRODUCTION:

Fiber optic displacement sensor (FODS) has wide application, because its work based on variable range of parameters such as, temperature, compression, pressure and strain [1,2]. FODS offer several advantages over conventional sensor systems. Specifically due to its non-contact and non-electric, compact, lightweight, sensitivity, immune to electromagnetic interference, and distributed sensing over the lengths of fiber optic. Inherently it is a versatile sensor which allows operating in dangerous environment such as in chemical reaction or explosive region [3,4], but less attention is focused to use optical technology to test the purity of metal especially noble metal like gold.

The medals (gold, silver and bronze) are a valuable metal because they are chemically inert, which used in many devices as coating, gold nanoparticle for commercially as jewelry. All these applications normally required high purity of gold. Thus determination purity of gold (medal) is important to ensure the functionality of the device, the successful of the treatment or satisfaction of the consumer. Currently several methods to determine the medals purity or karats are available. In conventional method, analysis of a metal-bearing material, especially medals and silver was carried out using fire assay that is heated the sample with a suitable flux and weighing the resulting metal beads. This is the common practices in all jewellery shop. They are time consuming, cumbersome as well as destructive.

Chemical analysis normally involves acid solution to verify the purity of medals with a degree of certainty. However safety handling of acid is required [5]. Other method by using sophisticated machine like x-ray fluorescent (XRF) and specific gravity based measurement device to detect the purity of medals. Although XRF testing is the most accurate medals purity testing technique, and also non–destructive testing, but it is high cost testing and time consuming making it less compatible for testing in small scale samples [6-8]. In this research, we proposed a novel method of measuring purity of medals based on fiber optic displacement sensor using intensity modulation

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technique. The proposed system consist of a fiber probe, a red laser (630 nm), photodetector and translation stage to provide highly accurate with 10 μm of resolution.

EXPERIMENTAL SETUP

Figure 1 shows the schematic diagram of the fiber optic displacement sensor by using fiber probe with 1000 RF. The experimental setup consists of a light source, a bundled fiber optic probe, flat medals (e.g. gold, silver and bronze), a silicon photo-detector and a digital multimeter. A bundled fiber optic probe was used, the glass fiber probe with 1000 TF (= 0.05 mm) and 1000 RF (= 0.05 mm). The light source used is a He-Ne laser with a peak wavelength of 630 nm. Silicon photo-detector was employed as it provides precission detection with an wavelength response of 400-1100 nm, making it compatible with a wide range of visible light including the 630 nm visible He-Ne laser used in this experiment.

The displacement of the fiber optic probe from the flat medals, is varied by mounting it on a micrometer translation stage, which was rigidly attached to a vibration free table. The light from He-Ne laser enters the transmitting fiber (TF) and then radiates to the flat medal, and the light reflected from the medal is transmitted through the receiving fiber (RF) bundle to silicon photo-detector. The amount of light detected by the photodetector can be determined from the output signal from the detector which has been preliminary connected to a digital multimeter. The voltage is measured against the corresponding change in displacement of micrometer translation stage. All samples used were obtained from commercial medals. The sensor utilizes the linear parameters from each pattern of output signal against displacement recorded for each target as the linear calibration slope.

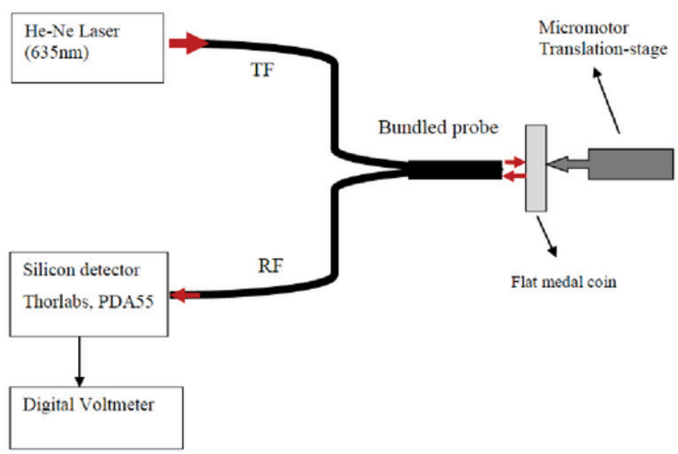


Figure 1: Experimental setup of fiber optic displacement for flat medal plate detection

RESULTS AND DISCUSSIONS:

Figure 2 shows the variation of the output voltage of the sensor with the displacement of the flat medals from the fiber optic probe. The curve exhibits a maximum with a steep front slope and back slope which obeys an almost inverse square law relationship for the reflected light intensity versus distance of the flat medals from fiber optic probe. The signal is very low at zero distance because the light cone does not reach the receiving cores. When the displacement is increased, the size of the reflected cone of light at the plane of fiber increases and starts overlapping with the receiving cores leading to a small output voltage. Further increase in the displacement leads to large overlapping which results in increase in output voltage. However, after reaching maximum, the output voltage starts decreasing for larger displacements. This is because of large increase in the size of the light cone and the power density decreases with increase in the size of the cone of light. The maximum output voltage obtained is 3.3 mV for a distance of 1.0 mm between the flat medals and the fiber optic probe.

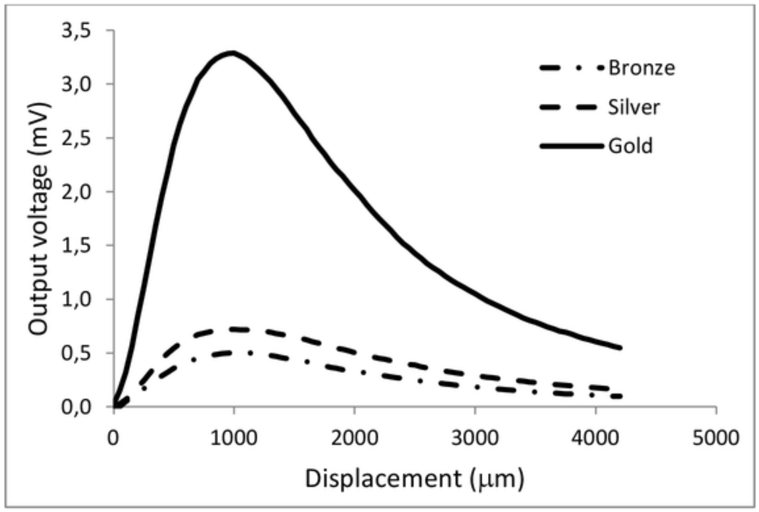
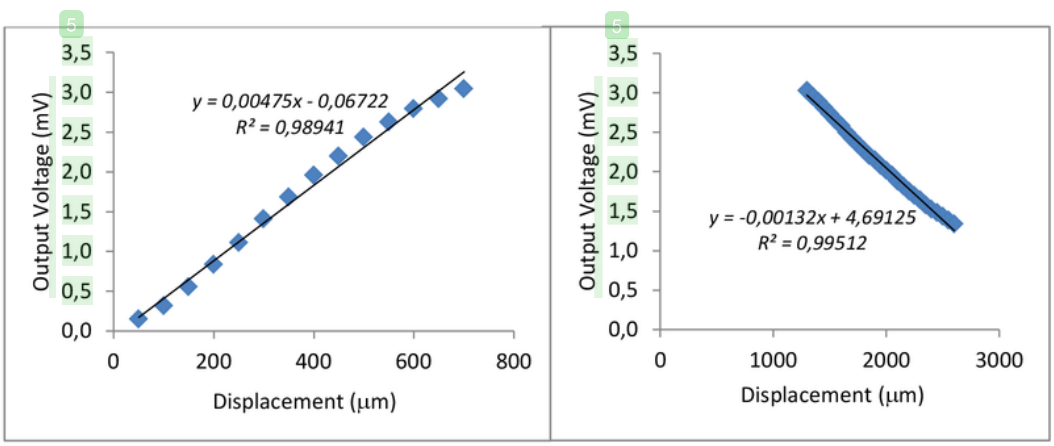


Figure 2: Output voltage of the sensor versus displacement for various medals.

Figure 3 shows the linear range of the sensor for gold medal for front and back slope. The slope is used to determine sensitivity of the sensor. As shown in the figure, the sensor achieves the highest sensitivity of 0.005 mV/μm over the range of 0.05– 0.65 mm. Sensitivity of -0.00132 mV/μm is also achieved over a range 1.3-2.6mm. The sensor shows a very good linearity for the gold medal in both ranges as shown in Figure 3. However, the graph exhibits the nonlinear properties over a range of 0.80–1.20 mm. In our displacement sensor, the front slope is highly sensitive and useful for close distance target and the back slope is less sensitive and useful for long distance. The performance of the sensor is summarized in Table 1. The sensor has many potential applications such as in industries as monitoring automated control, position control, and micro-displacement sensor in the hazardous regions. New, robust, low cost yet very sensitive gold sensor is proposed utilizing fiber optic displacement sensor. Based on the standard provide by the optical sensor, any unknown purity of medals plate can be determined. This optical sensor is very beneficial for quality control in mass production of solid medals such as in the form of foil, coin, and bar.



(a) (b)

Figure 3: The linear range of gold medal for (a) front slope and (b) back slope.

Table 1: Performance of FODS for medals detection.

Medals	Front slope		Back slope	
	Linear range (μm)	**Sensitivity (mV/μm)**	**Linear range (μm)**	**Sensitivity (mV/μm)**
Gold	600 (50-650)	0.0048	1300 (1300-2600)	0.00132
Silver	650 (50-700)	0.0011	1550 (1330-2850)	0.00025
Bronze	500 (50-650)	0.0007	1350 (1250-2600)	0.00019

CONCLUSION:

A simple fiber optic displacement sensor is proposed based on intensity modulation technique to detect the purity of various flat medals. The sensor uses a bundled fiber probe (1000 RF) and the red laser of peak wavelength 630 nm as a light source. The sensor shows a very good linearity (more than 99%) with the highest sensitivity of 0.0048 mV/μm over a range of 0.05– 0.65 mm for the gold medal. Instead of using high cost instrument such as XRF, this sensor offers an equivalent replacement with its simplicity and low cost. In future, further improvement can be done on this system to provide detection of the purity of medals in the form of nanoparticles that is used widely for medical purposes.

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