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APPLICATION OF SURFACE PLASMON RESONANCE IN BIODIESEL CHARACTERIZATION

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ABSTRACT

Surface plasmon resonance is a versatile technique for characterizing biomaterials. In this work the optical parameter and Lorentz-Lorenz constant for biodiesel were determined. According to the experimental data for biodiesels base on palm oil and coconut oil mixture with methanol the accuracy and sensitivity of SPR for these materials is limited by the measurement resolution of 0.001.

INTRODUCTION

Surface plasmon resonance (SPR) is a powerful technique to retrieve information on optical properties of biomaterial. Essentially, SPR depends on the optical properties of metal layer[1] and dielectric so it is related to charge density oscillation at the interface between them[2]. If the parameters of gold layer (n, k) are known, resonance angle and width of dip in SPR curve depend on optical parameter of the dielectric. One advantage of SPR is, the light beam never passes through the dielectric medium of interest and hence the effect of absorption of the light in the analyte isn't appeared. Hence the main potential of surface plasmon resonance is characterization of medium after the metal layer. In this work the authors focus on characterizing the medium that consist of biodiesel base palm oil and coconut oil mixture with methanol by using SPR.

THEORY

Surface plasmons are excited by TM mode polarized light. Surface plasmon waves (SPWs) are longitudinal waves that propagate at the interface between metal (gold layer) and a dielectric (analyte). The relationship between optical constant of gold layer and analyte[1] at resonance angle is

$$n_2 = \sqrt{\frac{n_1^2 n_0^2 \sin^2\theta_p}{n_1^2 - n_0^2 \sin^2\theta_p}} \qquad (1)$$

where n_0, n_1, n_2 are the refractive index of prism, metal layer and analyte respectively

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and θ_p is the angle of resonance. At the given excitation wavelength the change in SPR angle is proportional to the change in the refractive index of analyte i.e.

$$\Delta\theta \propto \Delta n \qquad (2)$$

Moreover Lorentz–Lorentz constant relates refractive index and density as,

$$\frac{n^2 - 1}{n^2 + 2} = Q\rho \qquad (3)$$

where n, ρ and Q is the refractive index, density and Lorentz–Lorentz constant[3] respectively. This formula expresses the effect of change in refractive index with density that consequently results in the change in SPR angle proportional to density i.e.

$$\Delta\theta \propto \Delta\rho \qquad (4)$$

EXPERIMENTAL

4.1 Sample preparation

A following procedure was followed in mixing the palm oil and coconut oil respectively with methanol (Merck). At first NaOH (3.5g) was added into 1 litre of methanol. Then the oil is heated at $45\,^{\circ}\mathrm{C}$ before mixing with the methanol in a closed flask to be shaken for one hour. After eight hours lapsed the glycerol will be deposited at the bottom of flask to be removed. The final product was a clear liquid of biodiesel ready for use in the experiment.

The above procedure was repeated by increasing the percentage of oil in the mixture from 10% up to 90%.

Experimental Setup

The setup in Fig.1 consists of precision rotation stage, prism (SF52 FocTek), silicon photo-detector, polarizer (Thorlabs), chopper (SR540 Stanford Research system), lock-in amplifier and He-Ne 632.8 nm light source. The gold layer was deposited on prism ($n_p = 1.85$) by sputtering method. For the data acquisition, rotation stage and photo-detector were controlled with a program that was written with Matlab. In this set up rotation stage was connected to stepper motor where the minimum angle of rotation was 0.001 degree. The prism was first adjusted to its start point before being rotated up to 20° with incremental 0.01° step size. At each step the rotation stage momentarily stopped for light intensity to be registered by silicon photo-detector which was connected to the lock-in amplifier.

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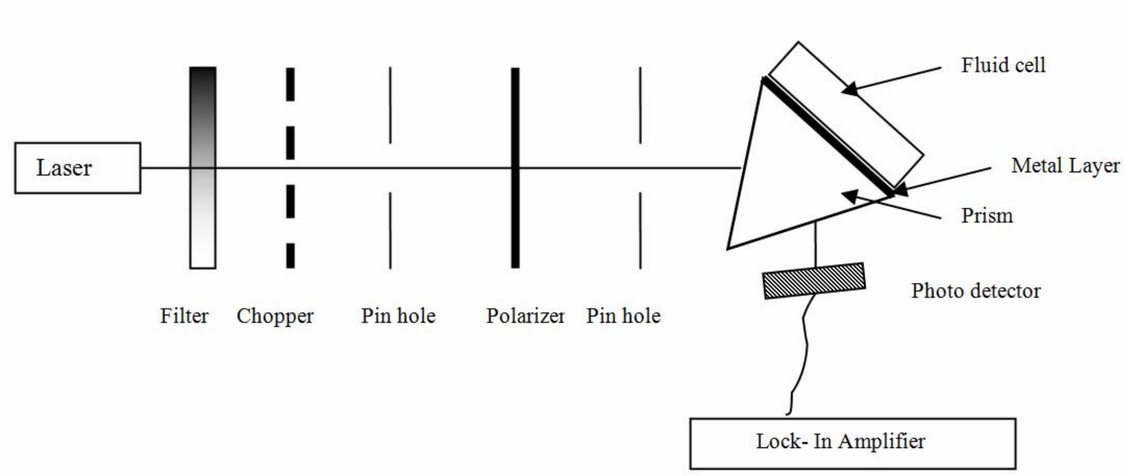

Figure 1: Experimental set up

RESULT AND DISCUSION

5.1 Palm oil mixture with methanol

Fig.2 shows the SPR signals fitted with the theory (solid line) for mixture of palm oil with methanol. With the increasing percentage of palm oil in the range of 10-90 %, the resonance angle increased from 54.323° to 61.404° while the refractive index increased from 1.349 to 1.439 as summarize in Table 1.

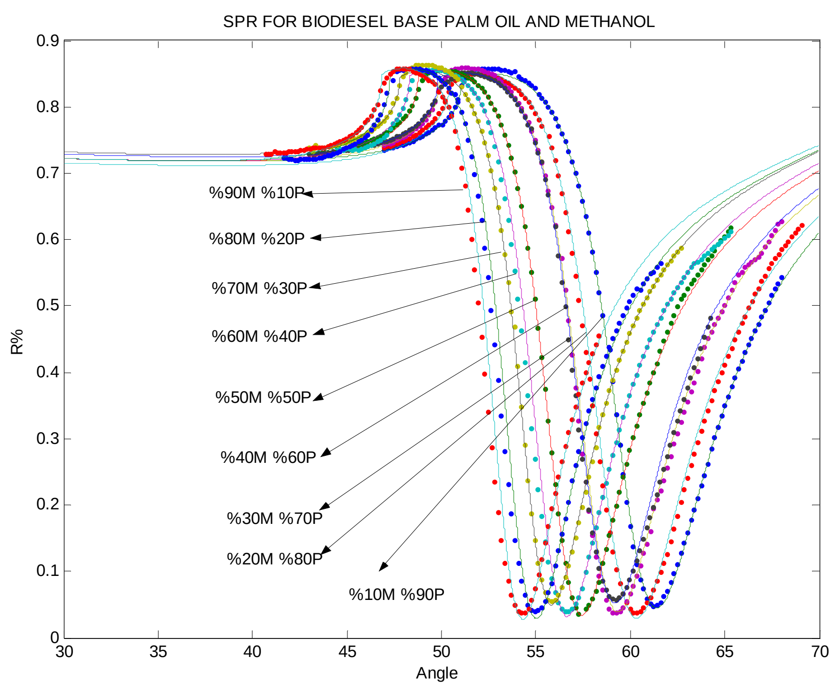

Figure 2: SPR signal for Palm biodiesel

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Table 1: Resonance angle and refractive index of palm oil base bio-diesel

Percentage of Palm Oil	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %
Resonance Angle (^{o})	54.323	55.041	55.851	56.669	57.438	59.208	59.358	60.343	61.404
Refractive Index	1.349	1.359	1.370	1.381	1.391	1.413	1.415	1.427	1.439

In Fig.3 the variation of refractive index with volume percentage of palm oil is shown whereby the slope of this curve is proportional to the Lorentz–Lorentz constant which is $0.202\,cm^3/g$.

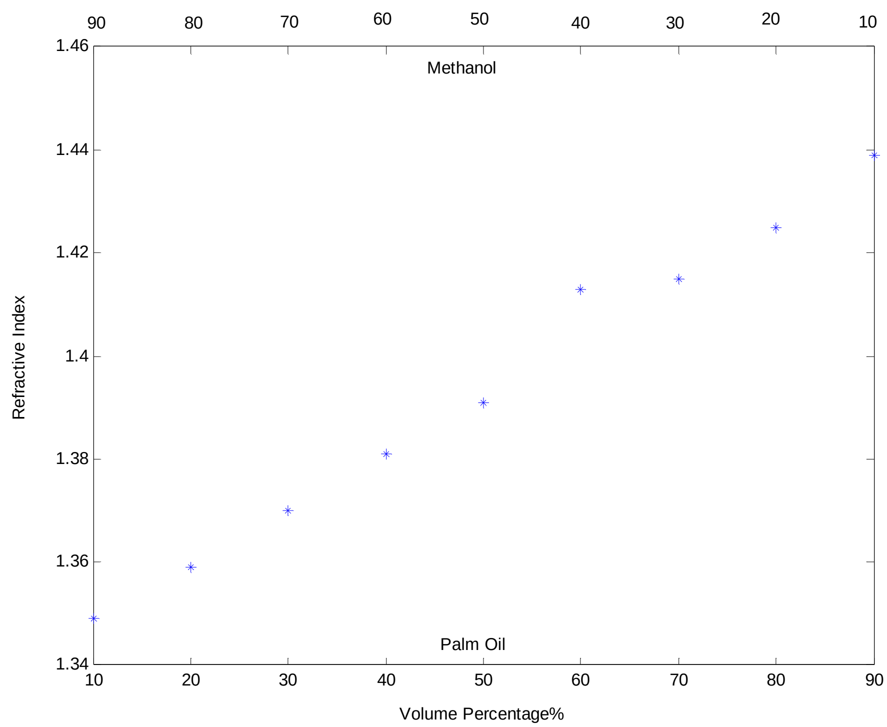

Figure 3: Refractive index with respect to percentage of Palm oil and Methanol

Coconut oil mixture with methanol

Fig.4 shows the SPR signals fitted with the theory (solid line) for the mixture of coconut oil with methanol where the resonance angles shifted from 53.947° to 60.218° while the refractive index increased from 1.342 to 1.424 as summarize in Table 2.

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Table 2: Resonance angle and refractive index of Coconut oil base bio-diesel

Percentage of Coconut Oil	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %
Resonance Angle (^{o})	53.947	54.657	55.442	56.360	57.087	58.740	58.957	59.734	60.218
Refractive Index	1.342	1.352	1.363	1.376	1.385	1.406	1.409	1.418	1.424

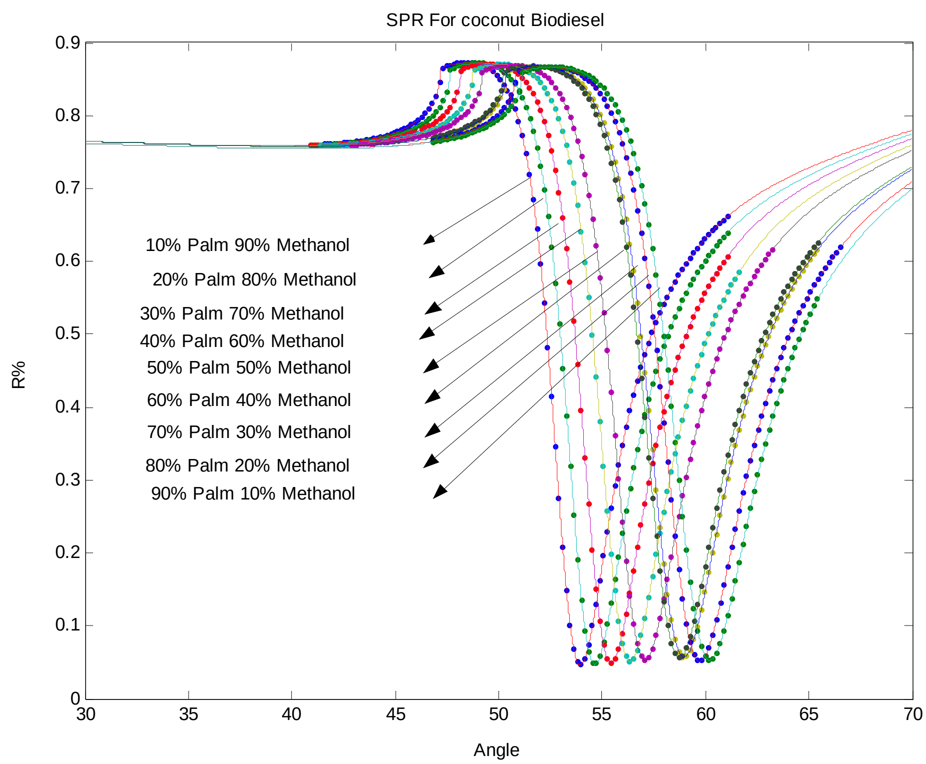

Figure 4: SPR for Coconut biodiesel

In Fig.5 the variation of refractive index with volume percentage of coconut oil is shown whereby the slope of this curve is proportional to the Lorentz–Lorentz constant which is $0.193\,\mathrm{cm^3/g}$.

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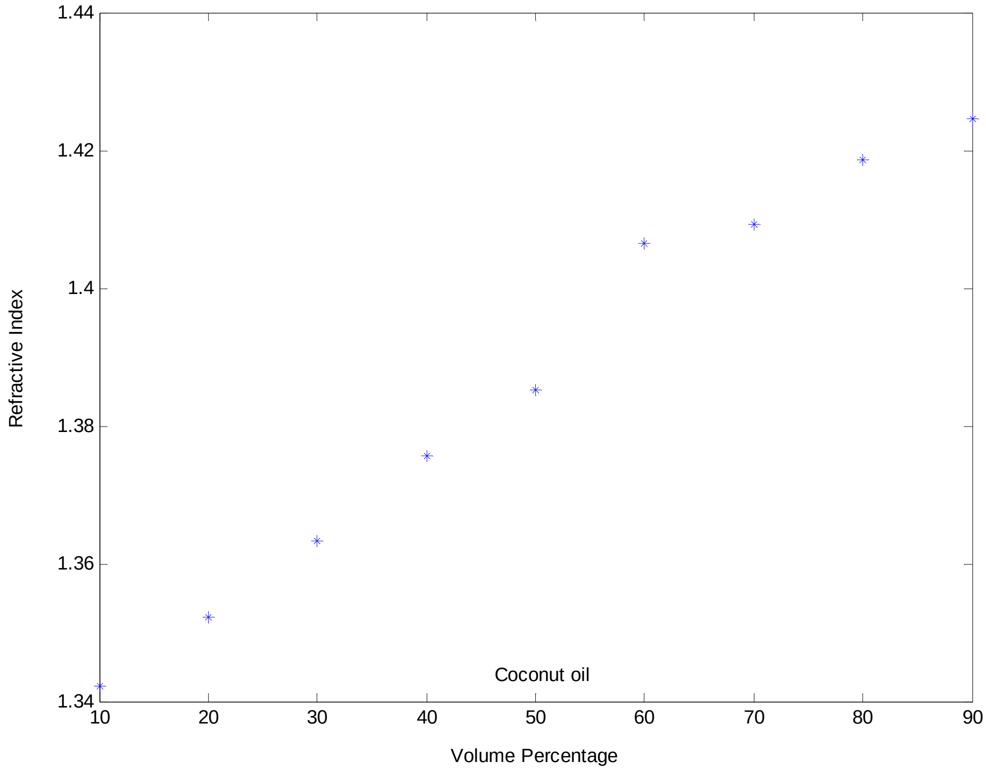

Figure 5: Refractive index with respect to percentage of Coconut oil and Methanol

CONCLUSION

Surface plasmon resonance is found to be a suitable method for determining the refractive index of biodiesel in linear range and is sensitive to change in the percentage of oil. As compare to another method such as minimum deviation, the light beam has to pass through the whole volume of the liquid and hence determine the averaged refractive index. While in the present work measured the refractive index of the liquid layer adjacent to the gold layer and hence works equally well for nontransparent liquids.

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