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Research Article

Diagnostics of Motor Oil Quality by Using the Device Based on Surface Plasmon Resonance Phenomenon

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Abstract: We demonstrate the possibility to examine quality of motor oil by using the method of surface plasmon resonance (SPR) for comparing values of refractive indexes inherent to initial and used oil. It was experimentally shown that the SPR method can be applied for examining quality of motor oils for controlling their quality and wear factor of machinery and mechanisms.
Keywords: Lubricants; Motor Oil; Quality Control; Surface Plasmon Resonance

INTRODUCTION

It is known that optical sensors are the most promising for assessing the quality of oils [1, 2].The task of simultaneous determining both the condition of motor oil and degree of car engine wear, with high sensitivity and productivity.

This task can be solved using highly precise fast examining lubricants, which can be provided by the measurement of optical properties inherent to motor oils with application of devices based on surface plasmon resonance (SPR) phenomenon [3]. The respective diagnostically facilities possess high sensitivity to very low concentrations (0.01 – 2 pg/ml) of studied substances and high precision of measurements [4]. It enables to apply them as precise analytical devices in lab investigations for food, chemical and pharmaceutical industries, in agriculture, medicine and ecology [5, 6].

MATERIALS AND METHODS

We performed measurements of optical parameters inherent to the samples of motor oil Mobil Super 3000 fe sw-30 before using it in a car engine as well as after 3,000 km running-in. There were prepared three samples of this oil for measurements: i) initial oil; ii) the used one..

Measurements of the refractive index were performed using the SPR refractometer "PLASMON-6" in the Kretschman geometry [7], which was designed in the V. Lashkaryov Institute of Semiconductor Physics NAS of Ukraine, Kyiv (Fig. 1). In this device, the range of such measurements lies between 1.0 and 1.43 with the accuracy $\pm 2 \cdot 10^{-5}$, which enables to determine the substance concentration in a sample from 100 µg/ml in colloidal solution and from 15 pg/mm^2 on the surface of a sensitive element. The method implies measurements of angular dependences of the intensity of light after total internal reflection. Used in experiments were glass (sort Ф1) substrates with the refractive index n = 1.61 and a glass prism with the same index. Using thermal deposition in vacuum, these substrates were covered with a gold film of the thickness 50±2 nm, where SPR was excited. The optical contact between the glass substrate and prism was reached using immersive liquid with the same refractive index as inherent to the prism. The used laser wavelength was λ = 650 nm.

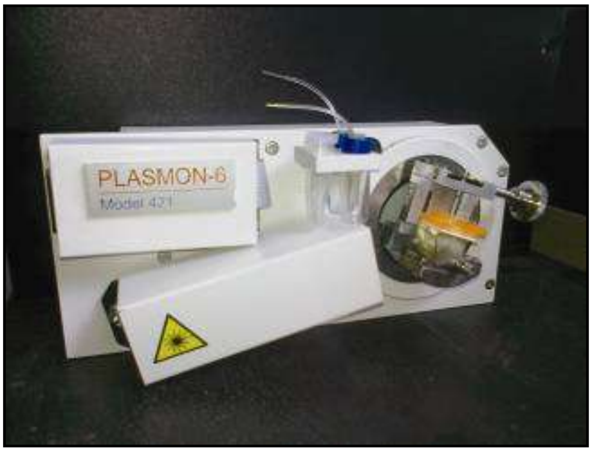

Fig-1: Front view of SPR refractometer "PLASMON-6".

The SPR refractometer and cells with the studied oil samples were placed into thermostat capable to keep the constant temperature 25±0.50C. This way enables to minimize the temperature error in results of experiments and, in addition, to lower the temperature load on measuring equipment, which allows increasing its operation life [8, 9].

One of the ways for measuring the refraction index was as follows. We used a two-channel measuring cells, one channel of which was filled with the used motor oil, while the other – with initial motor oil. Thus, measurements of both samples were carried out under the same conditions, which lowered the methodical error in the obtained results. The volume of every channel in the cell was 70 µl.

RESULTS AND DISCUSSION

The dependence of the reflection coefficient at the boundary motor oil – gold on the laser beam angle of incidence is shown in Figure 2. It is clearly seen a distinction between resonance angles and shapes of SPR curves for two samples of the motor oil.

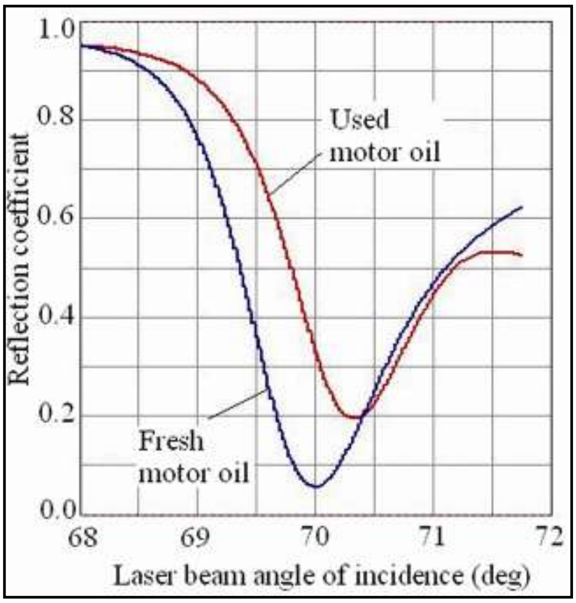

Fig-2: Resonance curves for two studied samples of the motor oil Super 3000 se 5w-30 measured using the SPR spectrometer "PLASMON-6".

Shown in Fig-3 is the time dependence (kinetics) of the resonance angle for both samples of motor oil: initial (a) and used (b). During the measurement time (25 min), we observed deviation of the resonance angle inherent to initial oil relatively to the initial position of the curve minimum 69.996 deg, which is related with inertness of heat transfer processes and gradual heating the oil from external heat radiation sources. One of the main sources is the spectrometer itself. In the case of used oil, we observed a permanent shift of the minimum position from 70.335 up to 70.422 deg for the time of measurements. It corresponds to the increment of refractive index by the value $1.05 \cdot 10^{-3}$, which is related with deposition of fine-dispersed wear debris particles on the surface of sensitive element.

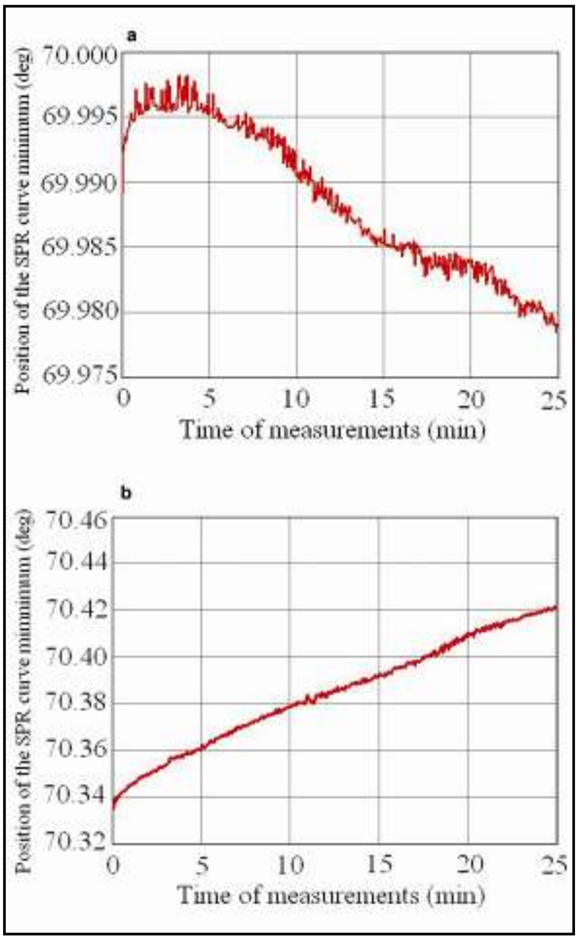

Fig-3: Kinetics of the shift inherent to minima of resonance curves characterizing both samples of motor oils, measured using the SPR refractometer "PLASMON-6". (a) Initial motor oil. (b) Used motor oil.

The software designed for the SPR refractometer "PLASMON-6" provides re-calculation of the angular position of the resonance curve minimum into the value of refractive index. In these measurements, we obtained the following results: during measurements of kinetics, the refractive index of initial oil decreased from the value 1.46912 down to the value 1.46891, which was caused by heating the sample. It is explained by the negative value of thermal coefficient for volume expansion of motor oil 0.0006 K^{-1}. In the case of used oil, for the same time the refractive index almost linearly grew from the value 1.47318 up to 1.47423. The kinetics of refractive index for the sample of used motor oil demonstrate the velocity of linear growth 4×10^{5} min^{-1}, while the sample of initial oil shows only temperature drift of the refractive index with the velocity -8×10^{-6} min^{-1} (i.e., lowering the refractive index).

Also, we used samples of engine oils dissolved by buffer solvent. As solvent it was chosen purified kerosene. For each concentration was obtained PPR minimum value.

We determined the optimal concentration (dilution of 50%.) of engine oil (Figure 4).

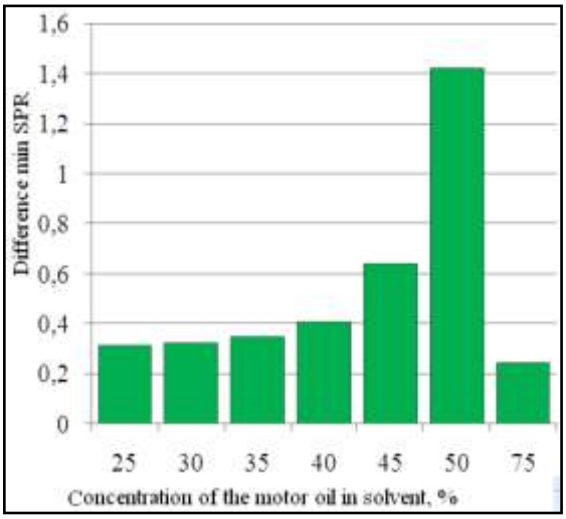

Fig-4: Influence of concentration of the motor oil in solvent on a difference minimum SPR of initial and used motor oil

For a given concentration observed the largest difference mines CPD provision of initial and contaminated motor oils , which is associated with a decrease in viscosity and increase of wear products on the sensing element.

CONCLUSIONS

Investigated in this work were the following three samples of motor oil Mobil Super 3000 fe sw-30: i) initial oiland ii) used oil. When measuring the kinetics for the used motor oil, we observed its linear growth with the velocity 4×10^{-5} min^{-1}, while the initial oil demonstrated only the low-temperature drift of the refractive index with the velocity -8×10^{-6} min^{-1}.

Using the results of comparative investigations of such optical characteristic of oils as the refractive index, one can draw the following conclusions:

- Used oil has a higher refractive index than that of initial oil of the same sort;
- Used oil contains wear debris that settle onto the bottom of oil tank, which results in increasing the oil refractive index near the bottom. It can be found using the SPR method.

Thus, the SPR method can be applied to examine quality of motor oils and lubricants in combination with other methods for estimation of their quality and wear degree of parts and mechanisms.

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