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THE EFFECT OF THE MOLECULAR WEIGHT ON THE ELECTROOPTIC KERR PHENOMENON OF METYL SILICON OIL

The Kerr constant and quadratic electrooptic coefficient in methyl silicon oils were measured. The dependence of their magnitude on molecular mass was determined. On the base of obtained results one cannot define the character of the dependence between determined quantities and molecular mass of examined oils.

Keywords: Kerr effect, quadratic electro-optic effect, organosilicon polymers, methyl silicon oils.

1. INTRODUCTION

The aim of our research is to investigate the Kerr constant and quadratic electro-optic effect in selected methyl silicone oils. Methyl silicon oils are used in many optical experiments, for example during the measurements of electro-optic effects in crystals. Hygroscopic materials may significantly change their properties since they are absorbing water from the air during the experiment. To prevent this, methyl silicon oil is used to create the protective layer around the examined crystal. What is more, the layer of oil prevents the examined crystal from mechanical destructions which may be caused by applied electric field. Such approach is essential during studies of the electro-optic effects in hygroscopic crystals.

2. METHYL SILICON OILS

Silicones are synthetic organosilicon polymers with structure of siloxanes where atoms of silicone are substituted by alkyl or aryl groups. They are obtained in the form of oils, elastomers or silicone resins [1]. The basic component constituting the polymer chain consists of silicon oxygen couple. Then, two methyl groups are attached to each silicon molecule [2]. The structural formula of methyl silicon oil molecule is shown in Fig. 1.

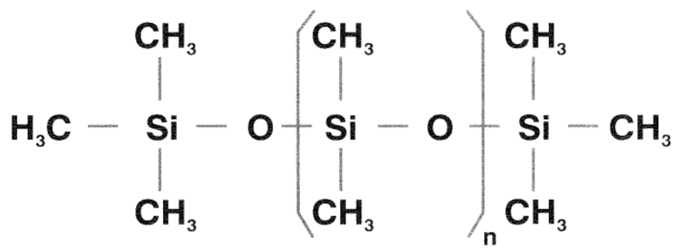

Fig. 1. The structural formula of oil molecule (*n* denotes the number of dimethyl silicone segments) [2]

In this study, methyl silicon oils produced by Organika Sarzyna SA were used. In further considerations we will use abbreviation OM and magnitude of viscosity in centistokes to denote methyl silicon oil of given viscosity. For example, the methyl silicone oil of viscosity 100 cSt will be denoted by OM 100.

3. THE DEPENDENCE BETWEEN VISCOSITY AND MOLECULAR MASS

The viscosity of methyl silicon oils depends on its molecular mass. The detailed data concerning molecular mass and viscosity are given by the producer [2]. They are shown in Table 1. The values for OM 300 and OM 3000 were determined in Ref. [3].

Table 1

Viscosity and molecular mass of methyl silicon oils [2,3]

η [cSt]	10	50	100	300	500	1000	3000	5000	10000
M [Da]	1200	3800	6000	17000	17000	28000	40000	49000	62000

4. MEASUREMENT OF KERR CONSTANT

The Kerr effect consists in appearing of birefringence in medium under influence of electric field. The effect can be observed in various media with various symmetry. For substances in which the effect is observed, the difference between ordinary and extraordinary refraction coefficients, Δn, is proportional to square of intensity of applied electric field [4].

The experimental setup consists of He-Ne laser emitting the red light beam of wavelength equal to 632.8 nm, polarizer, two quarter-wave plates and Kerr cell placed between them, analyzer, photodiode, voltmeter that uses the lock-in technique and computer to control measurements and saving measured data.

In order to compute the Kerr constant, the dependence between modulation depth and square of RMS value of modulating voltage applied to the Kerr cell, U_m, must be determined. Modulation depth $m_{2\omega}$ is defined by Eq. (1) with use of voltages proportional to light intensity obtained from photodiode. It is equal to the ratio of effective voltage of second harmonic $U_{2\omega}$ to voltage U_{dc} measured by DC voltmeter:

$$m_{2\omega} = \frac{U_{2\omega}}{U_{dc}} . \quad (1)$$

The plot presented in Fig. 2 shows the exemplary dependence of the modulation depth $m_{2\omega}$ on square of modulating voltage U_m for OM 10000.
As it can be seen, this dependence is linear, therefore it can be described by simple linear function:

$$m_{2\omega} = aU_m^2 + b . \quad (2)$$

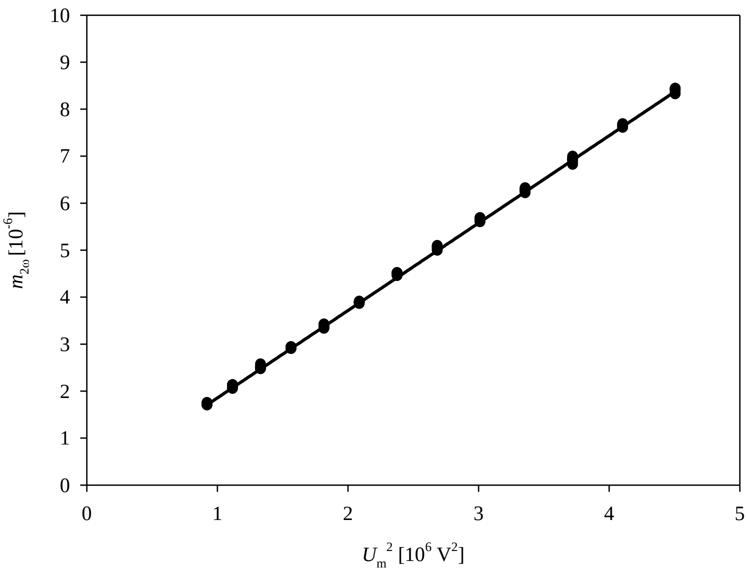

Fig. 2. Modulation depth $m_{2\omega}$ as a function of square of modulating voltage U_m

The slope of the function, *a*, can be easily determined using least square method. Its magnitude can be also expressed by the function:

$$a = \frac{Kd^2}{\sqrt{2}\pi L} \quad , \tag{3}$$

where *d* is the distance between electrodes, equal to 4 mm and *L* is the length of optical path, equal to 99 mm. Thus, the Kerr constant can be calculated from the formula:

$$K = \frac{ad^2}{\sqrt{2}\pi L} \quad . \tag{4}$$

The obtained values are shown in Fig. 3 as a function of molecular mass of oils.

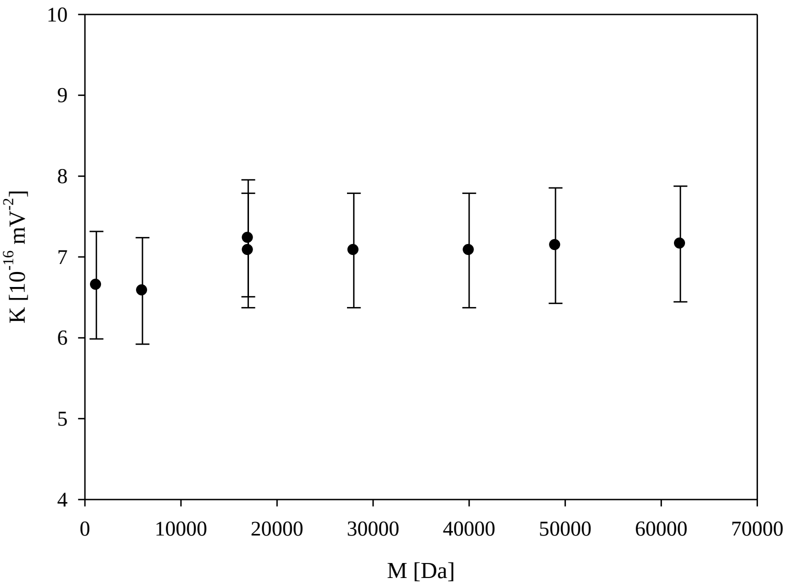

Fig. 3. Dependence between molecular mass of oils on Kerr constant

Having this results, one cannot deduce the character of dependence between Kerr constant and molecular mass of examined oils. The average Kerr constant of methyl silicon oil is equal to $(7.0 \pm 0.7)\cdot 10^{-16}\,\mathrm{mV}^{-2}$.

5. DETERMINATION OF QUADRATIC ELECTROOPTIC COEFFICIENT

Quadratic electro-optic coefficient depends on refractive index [5]. Refractive index of methyl silicon oils was measured by Abbe refractometer. Measurements were performed for oils of different viscosity at temperatures between 280 K and 370 K. Results are presented in Fig. 4 and Fig. 5. They show that viscosity does not have any influence on refractive index. The relationship between refractive index and temperature can be approximated by decreasing linear function.

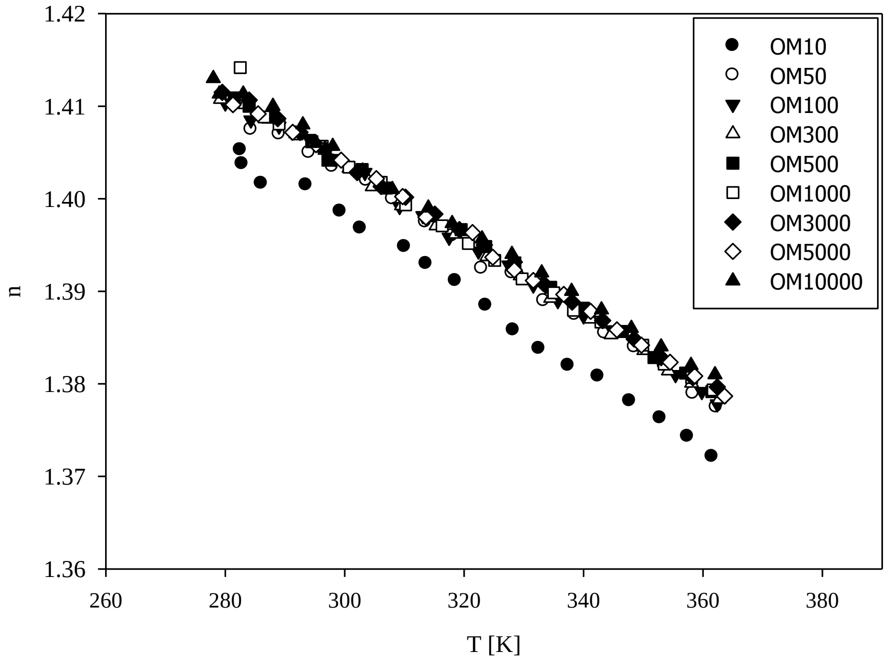

Fig. 4. Temperature dependence of the refractive index for methyl silicon oils for wavelength of light λ = 650 nm

Having the refractive index one can calculate quadratic electro-optic coefficient g_{eff} using the formula:

$$g_{eff} = \frac{2\lambda K}{n^3}. \tag{5}$$

The results for room temperature are shown in Fig. 6.

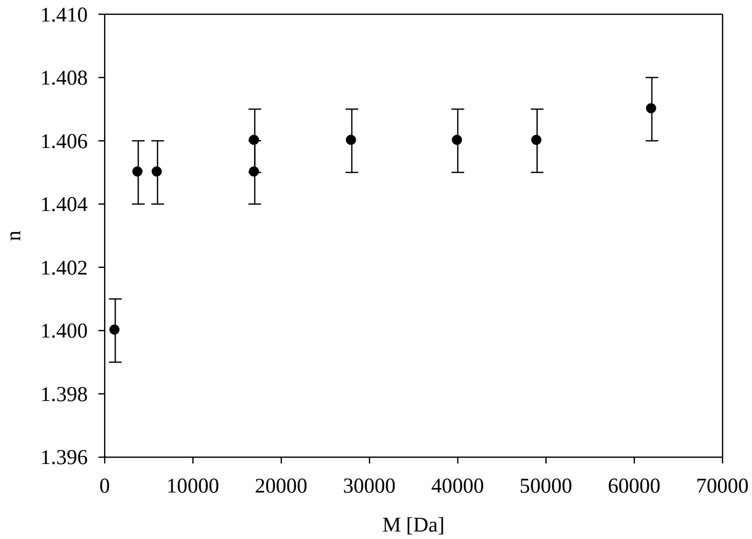

Fig. 5. Dependence of the refractive index on molecular weight for wavelength of light λ = 650 nm at temperature 295 K

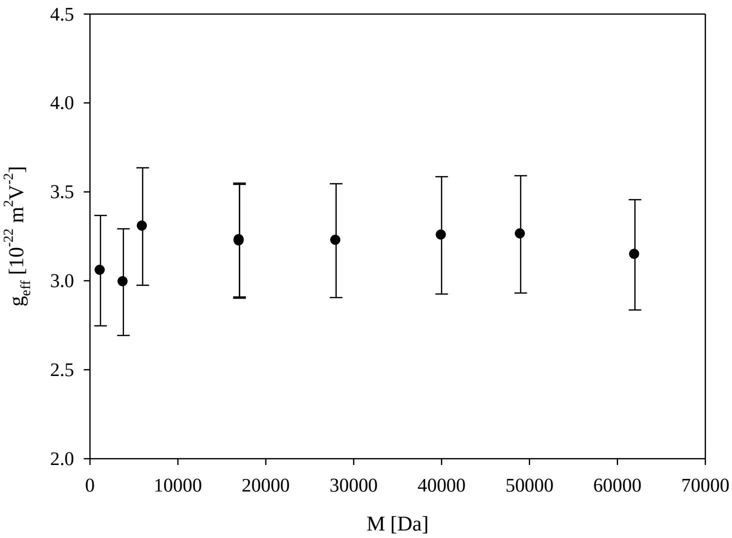

Fig. 6. Dependence of the quadratic electro-optic coefficient on molecular mass of oils

Table 2

Comparison of Kerr constant for different liquids and polymers

	K [10^{-16}mV^{-2}]	ΔK [10^{-16} mV^{-2}]
OM10	6.7	0.7
OM100	6.6	0.7
OM300	7.2	0.7
OM500	7.1	0.7
OM1000	7.1	0.7
OM3000	7.1	0.7
OM5000	7.1	0.7
OM10000	7.21	0.7
Nynas Nytro 10 GBN [6]	18	1
Castor oil – Fresh [7]	151.6	0.7
Castor oil – Aged [7]	141.1	0.6
Fomblin Z [5]	17	1

6. CONCLUSIONS

The obtained results do not let us define character of the dependence between Kerr constant and molecular mass. The Kerr constants have similar values for all tested oils. Similarly, one cannot define character of such dependence for quadratic electro-optic coefficient. Its values depend on Kerr constant and refraction index, which in the given temperature have similar values for all examined oils.

It can be observed that Kerr constant (Fig. 3) as well as quadratic electro-optic coefficient have slightly smaller values for oils of lower molecular mass (OM 50, OM 100).

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BADANIE ZALEŻNOŚCI STAŁEJ KERRA I WSPÓŁCZYNNIKA KWADRATOWEGO EFEKTU ELEKTROOPTYCZNEGO W OLEJACH METYLOSYLIKONOWYCH OD ICH MASY CZĄSTECZKOWEJ

Streszczenie

Zbadano zależność stałej Kerra i współczynnika kwadratowego efektu elektrooptycznego od masy cząsteczkowej dla wybranych olejów metylosilikonowych. Na podstawie otrzymanych wyników nie można określić charakteru zależności pomiędzy badanymi wielkościami a masą cząsteczkową.