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LC Vision Application to Solution Components Structure Investigation

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For detecting the solution quality of different materials we suggested to study their solid components structure with NLCs. The operation process consists of solution drying, thin NLC layer application on solid components and imaging study of deformed NLC structures with polarizing microscopy and software that keep the information on solid components structure. We present new achievements in medicine to illustrate the results of non-invasive detecting of some cancer particularities and erythrocytes pathology. For perfume products we suggest new criterion for detecting scents smell durability. In beverage foods we suggest new technology to examine the difference between original products and counterfeit samples.

Keywords: liquid crystal layer deformation; polarizing microscopy; structure detecting

1. INTRODUCTION

The study of solution properties is very important problem in many fields of human activity such as medicine, biology, chemistry, security, perfume, beverage foods, etc. Very often the main solution properties depends on the solid components structure. In many cases the structure homogeneity of solid components determine the solution operation characteristics. For detecting the solution quality of different materials we suggested to study solid components structure with NLCs as unique recording media [1,2]. The investigations were devoted to a new class of objects: solution solid components of different materials: urethra dry components for cancer detecting, erythrocytes' pathology, perfume components structure, tea and wine components structure.

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Dosated drops of solution were applied on microscope table glass substrate using instrument Affymetrix GMS 417 Arrayer (Genetic MicroSystems) or manually at the temperature $T = 20^{\circ}C$ and the humidity $H = 60\%$. We examined solution sediments after drying on open air.

2. THE BASIC PRINCIPLE OF LC VISION

The recording of the surface inhomogeneities becomes possible if the NLC deformed layer is illuminated in transmissive or reflective modes and observed through optical microscope with crossed polarizes and appearing figure is compared to the background structure. The principle scheme of the NLC technique is shown on Figure 1.

The light intensity over NLC layer I(x,y) modulated by deformed NLC structure is described by equation:

$$I(x, y) = I_0 \sin^2[\delta(x, y)/2] \tag{1}$$

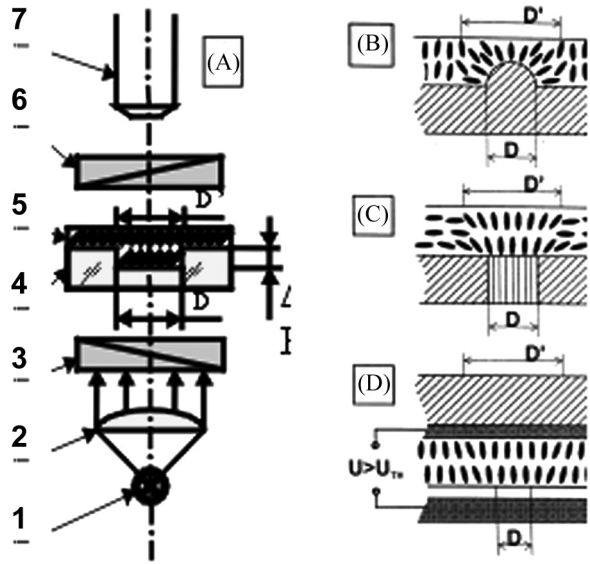

FIGURE 1 Scheme for visualizing defects on optical surfaces and patterns of NLC deformation in vicinity of the most typical defects: A, B-microrelief defects; C-structural defect; D-electrical or magnetic fields distribution. 1-radiation source; 2-condenser lens; 3-polarizer; 4-sample; 5-NLC layer; 6-analyzer; 7-microscope. D-defect size; D'-size of defect image in NLC layer.

The phase delay δ(x,y) caused by the NLC birefringence is equal to:

$$\delta(\mathrm{x},\mathrm{y}) = \frac{2\pi}{\lambda}\left[-n_0 \cdot H + \int_0^H n(\mathrm{x},\mathrm{y},\mathrm{z})dz\right] \tag{2}$$

Here H is the thickness of NLC film; n(x,y) is the film reflective index of deformed zone; n_0 is the refractive index of a non-deformed layer. If the orientation field has no twist deformation then only orientation bending occurs, hence:

$$\mathrm{n}(\mathrm{x},\mathrm{y},\mathrm{z}) = [\mathrm{n}_\mathrm{e}^{-2}\sin^2\varphi(\mathrm{x},\mathrm{y},\mathrm{z}) + \mathrm{n}_0^{-2}\cos^2\varphi(\mathrm{x},\mathrm{y},\mathrm{z})]^{-1/2} \tag{3}$$

Here φ(x,y,z) is the deflection angle of the long axis of the molecules with the respect to the surface normal; n_0, n_e are the refractive indices of NLC layer for ordinary and extraordinary polarization. The usual value of NLC optical anisotropy has the value 0,05 . . . 0,2 but in extreme cases it may be up to 0,4. It permits to use very thin layers to obtain sufficient value of phase delay.

The recording process is simple, obvious and informative. One may optimize the image contrast by rotating polarizer and analyzer. The main and virtually the sole operation to put a uniform NLC layer on the substrate surface. Such layer may be applied using a rotating table or even a simple paintbrush. The heating of NLC up to the temperature of transition to isotropic phase makes the film after cooling more uniform in thickness. The resolution of the NLC layer depends on its thickness and approximately is equal to 2000 lines/mm. The wetting conditions may be changed by special dopants and surfactants. The reliable results in visualizing the defects on the surface are obtained by repeatable applying and removing NLC layers and observing the stable defects images. The NLC layers are easily removed by a solution of alcohol or acetone. The NLC film distorts the real images of the defects because of its elasticity. To receive the information about the real size of the defects when only the size of their images is known a theory was developed. The theory was used to describe in a simple analytic form the defect's image formation process and its relation to NLCs [3,4].

Another problem of LC vision theory is the sensitivity of the NLC technique. It is apparent that such sensitivity depends on the experimental conditions, physical nature of defect origins and the sort of NLC material. On the first stage the phase delay that appears during the radiation transport through the NLC layer was theoretically considered. It was regarded as function of the surface interaction energy fluctuations induced by surface defects. But now in doing so we have to take into account the average interaction energy. In this

case the sensitivity S is given by derivative:

$$S = d\Phi/dE, \tag{4}$$

Here E is the fluctuation of interaction energy. But for final sensitivity determination the methods of information theory of optical image are to be applied. They permit to take into account the thermal LC-noise as well as that of surface itself, the regular surface pattern spectrum and recording device transfer function. This approach gives the limits of NLC technique sensitivity and resolution in visualizing the defects [2].

Simplicity, efficiency and high sensitivity have given an opportunity of LC vision application in material science, mineralogy, crystallography, metallography, thin film technology, medicine and biology.

3. LC VISION APPLICATION TO URETHRA DRY COMPONENTS FOR CANCER DETECTING

The problem of malignant tumors is one of the most actual in modern medicine. It consists not only of the development of effective patients treatment methods but in objectification of microscopic diagnosis of neoplasm.

The routine diagnostic methods are based on optical microscopy modifications in view of spectral, luminescent and fluorescent features of the growth images. The essence of luminescent and fluorescent methods is based on the properties of some photosensitive materials to be collected in malignant tissues in the much greater degree, than the surrounded normal tissues, that under certain conditions allows receiving luminescent and fluorescent tumor images. These methods are suitable for detecting malignant growth on outside surfaces of a body in dermatology and cosmetology, and also on internal surfaces observed with the application of endoscope's technique [5]. Advantage of the methods is an opportunity to study the efficiency of undertaken medicine measures in real time. However the methods are unacceptable for microscopic diagnosis.

For traditional histological diagnosis tissue sections of 4–5 μ thick are prepared of the block after freezing or embedding in paraffin. Then sections are placed on an object glass and treated with organic dyes. Haematoxylin and eosin are usually used as dyes and that impart different colors to the nucleus and cytoplasm in the cell. The malignant character of a tumor is verified by observing in light microscope cell atypism features and invasive particularities of malignant growths. The disadvantage of the method is, that the observable

distinctions in some cases are too week, that the diagnosis is made in the greater degree on intuition of the experts, rather than on objective criterion revealing. The absence of objective criteria for diagnosis can sometimes result in irreparable mistakes.

The new optical criterion for objective diagnosis of malignant growth in tissues of human beings and animals based on NLC technique was suggested and confirmed with experiments. The new phenomenon was discovered that on malignant tissues of animals and human beings NLC molecules have homeotropic orientation while on benign tissues they have planar or tilted orientation. Through a light microscope with crossed analyzer and polarizer in all investigated cases malignant growth decorated with NLC looked black (except for clear distinct vessels and elements of linkage skeleton). At the same time NLC molecules on normal tissues and benign tumors always looked white or color [6]. The similar pictures were observed in dog and human tissues.

The discovered phenomenon was explained by the surface tension value difference on malignant and benign tumors. The results of calculations and experiments are in good agreement with F. Kahn rule: the surface tension γ of malignant tissue (homeotropic orientation) $< \gamma$ of MBBA:EBBA $< \gamma$ of normal tissue (planar orientation) [7]. The main advantage of suggested technique is the objective detecting of pathology. The main disadvantage of LC vision application to cancer detecting is the necessity of surgical operation.

We suggest non-operating method based on LC vision in order to replace the invasive technique by non-invasive method. Non-invasive detecting of some cancer particularities may be realized by examination of patient biological liquids, for example urine. Cytological investigations of nucleus distribution in urine sediment give the possibility to attribute patients to the group of high risk of cancer progress.

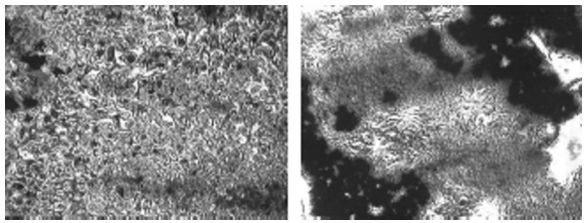

FIGURE 2 Kidney cancer (black zones) visualized with NLC applied on nucleus in urine sediment (left). Urethra cancer (black small lines) visualized with NLC applied on urine sediment (right). MBBA + EBBA, 100^x.

The dried samples of urine with pathology were examined with LC vision technique. The results are presented on Figure 2.

The NLC layers have homeotropic orientation on urine sediment as on malignant tissues (black zones). The results open the perspective for non-invasive cancer detecting based also on other types of biological liquids examination.

4. LC VISION APPLICATION TO ERYTHROCYTES PATHOLOGY DETECTING

Cardiovascular and blood diseases are the most common illness of the humanity all around the world. One of the main reasons of the disease is the blood rheology violation caused by erythrocytes membrane defects in form and elasticity. The detecting of erythrocytes viscoeleastic properties is the problem of current importance for early stage leukemia detecting, malaria sickness and operator overload regimes. The main parameter is erythrocytes elasticity that is responsible for penetrating inside capillary. That is why few methods for erythrocytes pathology detecting were developed. The principle of 3D erythrocytes orientation by combined use of elliptical and point tweezers is described in paper [8]. The use of elliptical and point tweezers for orientation of an assembly of human red blood cells demonstrated that the rotation speed depends on erythrocytes pathology. Laser diffraction technique of erythrocytes deformation under the hypoosmotic hemolysis was developed in paper [9]. All methods are based on the difference of erythrocytes membrane elasticity in normal and pathology state.

The smear of blood was formed on a glass substrate by another glass substrate. The sample was dried up at the open air and examined with NLCs. It was discovered that usual oviform of erythrocytes in NLC matrix turned to right-angle form (shown by orthogonal lines on Fig. 3). The phenomena may be explained by molecular interactions

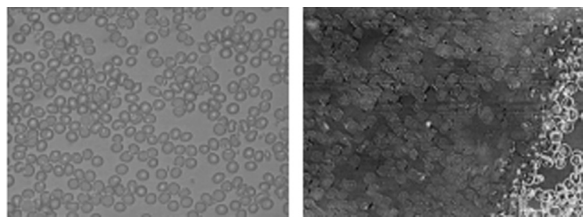

FIGURE 3 The normal erythrocytes have oviform outside of NLC matrix (left), while inside of NLC matrix erythrocytes have the rectangle figures (right). Healthy person; 5CB, 1 μk. 250^{x}.

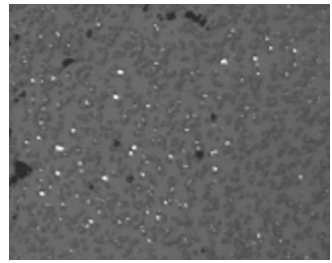

FIGURE 4 Erythrocytes with pathology have deformed rectangle figures and looks like white spots. 5CB, 1 μk. 100^x.

anisotropy. From the other side the erythrocytes with pathology demonstrated deformed rectangle figures (Fig. 4). The obtained phenomena may be used as new independent criteria for erythrocytes pathology detecting.

5. LC VISION APPLICATION TO PERFUME COMPONENTS STRUCTURE DETECTING

The objective metrology of testing smell and taste is absent. The problem of objective taste and smell examination of the samples at the first glance seems to be unrealizable if relates to a liquid or gaseous phases. But the problem is much easy to solve if to examine the local source of smell and taste in solid state. In this case the possibility appears to detect the structure of the material that is responsible for the parameters and quality. There are two different aspects of smell and taste: from material science point of view it is possible to visualize the structure of smell and taste source; from human perception point of view it is the subject of individual psychology and physiology. Unfortunately the exact correlation between physical description of the sample structure and its smell and taste is absent in principle. The problem is similar to the situation when we have to describe the colors of the sample but cannot compare them with the result of individual human visual perception. The reason is that physical objective description is not equal to subjective human impression. But from practical point of view it is possible to find some approximation in comparison sample structure and its quality properties.

The main disadvantage of LC vision application to taste and smell examination of products that very important volatile components unfortunately disappear in the process of drying.

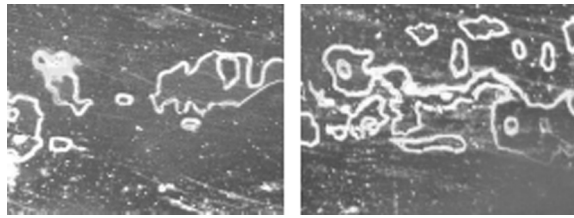

FIGURE 5 Solid components structure of volatile solvents: toilet water, visualized with MBBA:EBBA. 32^x.

In our experiments we examined toilet water and different perfume samples. The results are presented on Figures 5 and 6. Some of structures consist specific aromatic inclusions that help to identify the samples (Fig. 5). The difference in structures usually is so evident, that it may be observed directly by eye. For special cases the optical recognition technique may be used for increasing the reliability of detecting. Structure detecting may be used for control the parameters of liquids and solvents and to distinguish the goods of high quality from falsification. We also suggest the new criterion for detecting scents smell durability for perfume production. It was observed that if to apply NLC layer on perfume droplet just after it drying the NLC assume transition to isotropic phase induced by cloud of perfume molecules (Fig. 7a). After full perfume molecules evaporation the back transition to nematic phase takes place (Fig. 7b). The stay of NLC molecules in isotropic phase may be used as the criterion of durability in the case of standard metrological conditions. It was found out that the stay in isotropic phase depends of droplet size, type of NLC and temperature.

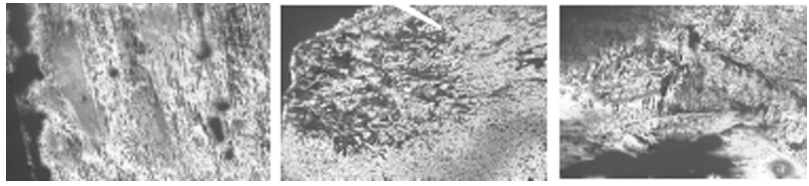

FIGURE 6 Structures of different perfumes solid components, visualized with MBBA:EBBA. 100^x.

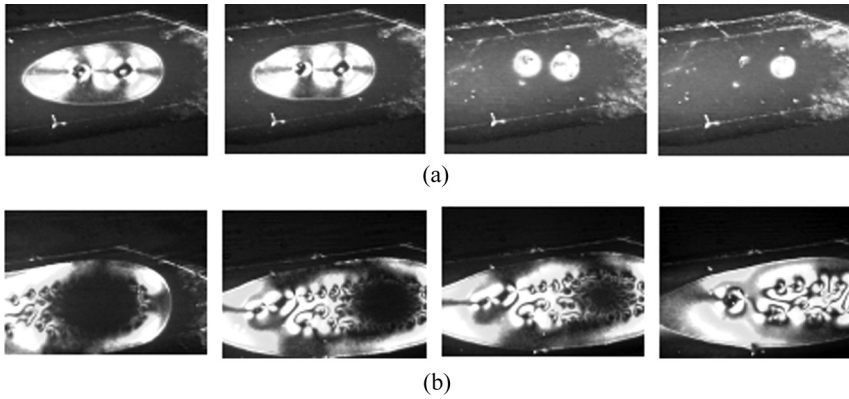

FIGURE 7 The stages of NLC phase transitions induced by perfume droplet. The transition to isotropic phase took 22 min (upper rank). The stay in isotropic phase took less than 10 min. The transition to nematic phase was longer and took 36 min. (low rank), caused by the influence of perfume cloud.

6. LC VISION APPLICATION TO TEA AND WINE COMPONENTS STRUCTURE DETECTING

The problem of tasting tea quality is very important: every third person in the world drinks a cup of tea everyday. The quality of the tea depends on it taste and aroma. Now the tea quality examine by taster, who usually has to study approximately few hundred samples per month. The result of examination depends on his individual subjective impression. Is it possible to replace the subjective perception of the taster by objective examination?

The first application of NLC for detecting the quality of different sorts of tea using polarizing microscopy is discussed. The received images of tea structure have to be compared with the tea quality by taster. We have examined the different sorts such as Lipton, Lloyd & Gerson, Pr. Java, Pr. Noori, Sir Kent, Sun Cha, etc. The results demonstrate that LC technique gives new information of structure in comparison with direct observation through optical microscope. The different tea types had absolutely different structure after drying on the open air, visualized with NLC (Fig. 8a). The same sorts of tea had similar structures and it was possible to recognize them. One can see also the difference in structure colors. Main part of tea sorts after drying transfer to a firm film similar to polymeric film. The structure at the boundary is different and depends on tea quality. The expensive sorts of tea had inclusions

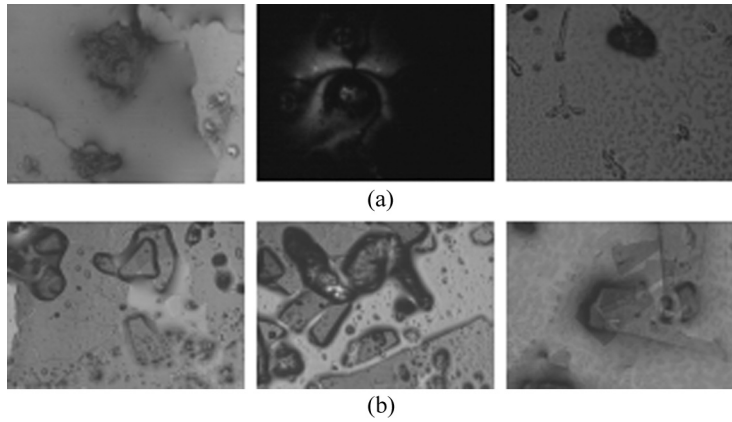

FIGURE 8 (a) The different tea structures after drying on the open air, visualized with NLC. 100^x. Left – Sir. Kent, middle – pr. Java, right – pr. Noori; (b) Structures of Lloyd & Gerson tea solid components, visualized with MBBA:EBBA. 250^x.

minimum in the structure (Fig. 8b). The same LC vision technique was applied to wine testing (Fig. 9a) and inclusions detecting (Fig. 9b).

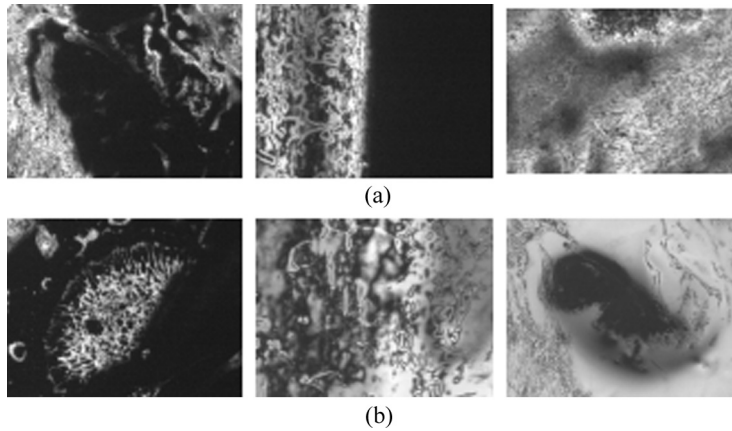

FIGURE 9 (a) Structures of different wines, visualized with MBBA:EBBA. 100^x. Left – Cabernet Sauvignon, middle – Merlot, right – Pinot; (b) Structures of different wines inclusions, visualized with MBBA:EBBA. 250^x. Left – Cabernet Sauvignon, middle – Merlot, right – Pinot.

CONCLUSION

LC vision in application to solution components gives unique information of their structure and opens new horizons for detecting forbidden and dangerous components in solution such as drugs, toxins and explosives.

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