Shellac hologram

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Abstract. The results of experimental research of rainbow holograms made of edible shellac, analysis of diffraction efficiency and analysis of the hologram lifetime in various environmental conditions are reported in this work. The properties of shellac as a food biopolymer allow to use it for creation edible holographic coatings on food and pharmaceutical products. Edible shellac holograms can be use for creation images not using food dyes, original appearance, labels, sensors of shelf life and observance of storage regulations of products.

1. Introduction

The idea of creation edible rainbow holograms appeared at the end of the 20 century and remains relevant today [1]. The holograms can be applied to food products in order to provide them an original appearance. The advantage of rainbow holograms is the ability to create bright color images on the surface of edible products without food dyes. The holograms can be applied to pharmaceutical products as a label. They are formed directly on the pill surface and protect the products from falsification [2]. Some organic polymers such as agar, gum arabic, pectin, gelatin, silk fibroin, albumin can be a good material for edible rainbow holograms creation [1-4].

In this research shellac as the material for creation edible rainbow holograms is presented. Shellac is used in the food and pharmaceutical industries as coating and glazing agent.

2. Materials and methods

Shellac is compounds of aleuritic acid, shellolic acid, jalaric acid and other aliphatic acids. Shellac has the form of thin flakes, the color of shellac depends on the degree of purification and can has color from yellow to dark brown. Shellac is water-insoluble, highly soluble in alcohol, has a melting temperature 75-80°C [5].

Some physical properties of shellac were measured. Viscosity of alcohol shellac solution was measured by viscometer «Visco Basic Plus» at temperature 22.5°C. Optical characteristics were obtained using refractometer «Refractometr PTR 46» and «Shimadzu UV-1800», microscope "Olympus STM-6" with a magnification of 100× was used to observe the samples. To estimate diffraction efficiency of the samples the intensities of the diffracted and transmitted rays of a diode laser with a wavelength of 625 nm were measured by luxmeter "TKA-PCM-06". Diffraction efficiency is estimated as the ratio (in %) of light intensity in the first diffraction order to the sum of the intensities in the first and zero diffraction orders [6]. Moisture capacity of shellac films was estimated as percentage of water absorbed by the film in relation to film mass, films were in an environment with a humidity 90% and temperature 35°C during the day. Measurement results are presented in table 1.
Table 1. Shellac properties

| Property                               | Value    |
|----------------------------------------|----------|
| Viscosity of shellac solution, mPa/s   | 9.5      |
| Moisture capacity of shellac films, %  | 0.6      |
| Refractive index of shellac films      | 1.44     |
| Average thickness of shellac films, μm | 8        |
| Transmittance coefficient of shellac films in 350–900 nm | 70–83%   |

Hologram samples were prepared by the nanoimprinting method [7]: a drop of shellac solution was placed on a substrate, covered with a silicone mold, dried at room temperature, than the mold was removed. The diffraction grating of silicone mold has a period of 600 lines per mm. The thickness of the film with a diffraction relief is near 8 microns, the film is breakable, so it is difficult to use it as an isolated holographic element. A holographic coating was formed directly on the surface of different substrates like as glass, caramel, chocolate and marzipan.

3. Experimental results

The samples of diffraction gratings made of shellac on the glass surface were exposed to temperature and humidity, the diffraction efficiency was controlled. A graph of the diffraction grating degradation is presented in figure 1 (a,b).

![Figure 1(a, b)](image)

**Figure 1(a, b). (a) Diffraction grating degradation at temperature 35°C and different humidity: 1 – 90%, 2 – 70%, 3 – 50%, 4 – 30%; (b) Diffraction grating degradation in humidity 10% and different temperature: 1 – 35°C, 2 – 40°C, 3 – 50°C.**

The diffraction grating degradation was not observed at temperature of 35°C and a humidity of 30% (line 4) and significant degradation occurs at a temperature of 35°C and a humidity of 90% (line 1) during one hour. Under the influence of temperature 50°C degradation occurs within an hour. Lifetime of the shellac diffraction gratings can vary from an hour to a year depending on the storage conditions. Lifetime of grating stored in conditions with temperature 35°C and humidity 10% is 75 days. At the same temperature and increasing humidity the lifetime is reduced: in humidity 50% lifetime is 3 days, in humidity 70% – 240 minutes, in humidity 90% – 180 minutes.

Infrared spectrums of shellac films before exposure of humidity and after exposure of humidity are shown in figure 2. When shellac absorbs water molecules, the main changes are observed in the region of valence oscillations of the C=H groups 1735cm⁻¹ and 1712cm⁻¹. Changes in the region of deformational oscillations of C–O bonds in –C–O– and –C–O–C groups (1250cm⁻¹ and 1035cm⁻¹) indicate the formation of associates of water molecules with shellac.
Figure 2. Infrared spectrums of shellac films: 1) before exposure of humidity; 2) after exposure of humidity.

Despite the low moisture capacity of shellac films, the absorbed water affects on the preservation of the diffraction grating, what is confirmed by decrease of the diffraction efficiency. The surface changes of the shellac diffraction gratings due to exposure of 90% humidity for an hour are shown in figure 3 (a, b).

Figure 3 (a, b). (a) The surface of the shellac diffraction gratings before exposure of humidity, the diffraction efficiency – 9%; (b) The surface of the shellac diffraction gratings after exposure of humidity, the diffraction efficiency – 1%.

When shellac gratings stored at room temperature about 18-25 and humidity not higher 50% lifetime is about one year. This feature of shellac diffraction grating can be used to creation holographic sensors – indicators of compliance with the storage conditions of food and pharmaceutical products.

Shellac holograms can be use for decoration food products. In previous work rainbow holograms were made of chocolate [8] and caramel [9]. The lifetime of caramel holograms was about 40 hours, and the lifetime of chocolate holograms was about 3 months. In this research shellac holograms were applied on surface of caramel, chocolate and marzipan (figure 4). The diffraction efficiency of the grating on the caramel surface in transmitted light was 4.5%, in the reflected light – 3%. The diffraction efficiency of the grating on chocolate surface and marzipan surface was 2.1% in reflected light. The iridescent color of the samples is clearly distinguishable by an eye despite the small values of diffraction efficiency. Using of shellac holograms allowed to increase the lifetime to a year and to create hologram on porous surface of marzipan.
4. Conclusion
Shellac can be used as an optical biopolymer for creation edible rainbow holograms. These holograms have sufficient diffraction efficiency to observe a bright visual effect. The peculiarity of the diffraction gratings made of shellac to destruction under the influence of temperature and humidity of the environment creates conditions for the creation of holographic sensors – indicators of storage regulations for food and pharmaceutical products.

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