Lighting Applications Of Turbid Liquids

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In this work the scattering effects and transmissions of different liquid samples were analysed to find a mixture that can not only be used as a homogenous diffused panel light but also as a transparent window. This should be done by filling these liquids between two glass plates and illuminating them from the edge.

1 Introduction

In the Center of applied research at Universities of Applied Sciences, ZAFH LED OASYS, different types of energy-efficient out coupling systems of LED light are developed. This work focuses on an alternative to conventional luminaires. As part of the LED OASYS project a transparent panel light was developed that can be used as window but also as a luminaire. It is illuminated from the edge so that integrated nano-particles scatter the light towards the its upper and lower side. Currently, these luminaires are realized with a special type of nano-particle-filled acrylic glass called *PLEXIGLAS LED* as seen in Fig. 1, that was invented by EVONIK Industries.In this work several liquids were investigated with respect to their optical properties in order to point out a cheap and easy-to-produce alternative to this special material.

Fig. 1 *The EVONIK* PLEXIGLAS LED left*: without illumination highly transparent,* right*: illuminated as homogenously diffused luminaire, caused by integrated scattering nano-particles*

2 Materials

Different liquids were chosen based on the tyndall-effect and the so called "'ouzo-effect"'. Both describe scattering at particles in the size of approximately the wavelength of light. These effects are known from sun-irradiated fog or from the opacity of aniseed liquors. Some samples of laundry detergents were investigated that consist of micelles,formed by molecules that are both, hydrophobic and hydrophilic [1], but also samples of spirituous beverages like Absinth and Raki that show the "'ouzo-effect"' by building a micro emulsion with aniseed-oil and water. To get a closer view on the "'ouzo-effect"', the involved ingredients were investigated in a three-component-system consisting of the aniseed-oil anethole, the alcohol isopropanol and distilled water.

3 Methods

For the use of turbid liquids in an interior lighting the mixture has to meet two demands: On one hand the sample has to show pronounced scattering effects, on the other hand the sample has to be transparent enough so that no difference to a normal glass plate can be detected by human eyes. In order to quantify this effect, scattering was measured for all samples with the goniometer Gonio$'2\pi$. The corresponding intensities in the area over $180°$ within the plane of incidence were plotted in a polar graph. Additionally, the overall transmission of the samples was measured. For lighting applications, only some parts of the scattered light can be used. These are the rays that can leave the receptacle and are not reflected back into the mixture caused by total reflection. The sample that met the best temporal stability and that showed the largest amount of scattered light was additionally evaluated with respect to its spectral transmission. From these results a graph can be obtained showing the scatterers concentration over the coefficient of transmittance. Adding a logarithmic regression makes it possible to obtain an equation that allows it to calculate the amount of the ingredients in order to receive a mixture with a defined transmission.

4 Results of scattering measurement

The polar plots were displayed in a logarithmic scale to cope with the high differences in intensity (almost no light at $90°$ up to the maximum of the laser-source at $180°$) In Fig. 2 the results of the measurement from $0°$ to $180°$ at distilled water are added to $180°$ to $360°$.

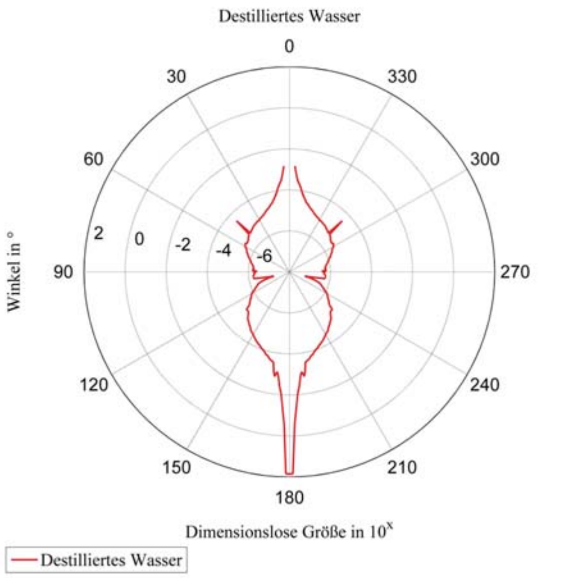

Fig. 2 *Measurement of scattered light from distilled water plotted logarithmically from $0°$ to $360°$*

For better comparability all sapmles were standardized with distilled water and all concentrations of a sample were plotted in one graph. This made it possible to calculate the integrated intensity over the whole area without the influence of total reflectance. They were compared in another graph. The three-component-system: anethole, isopropanol and distilled water was chosen for further investigations on the UV-VIS 500 due to a preceding study of Erika Eiser [2] who proclaimed a good long term stability in homogeneity and good light-scattering performance.

5 Results of transmission measurement

In order to get a mathematical connection between the chemical concentration optical transmission it was necessary to create different samples that were different in only one component. Therefore, the samples were mixed such, that a fixed amount of anethole as well as isopropanol and different amounts of distilled water were added. These samples are shown in Fig. 3.

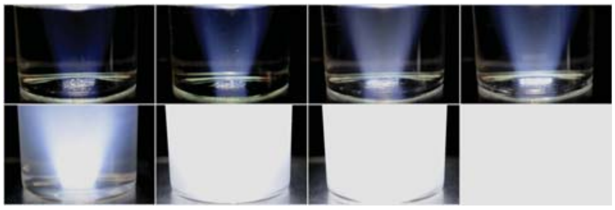

Fig. 3 *7 samples of the anethole-isopropanol-distilled water-system with different concentrations and turbidity illuminated from the bottom*

Out of the measurement a graph could be plotted with the relative amount of distilled water over the transmission-coefficient. In this graph a curve of regression was added to gain this equation:

$$y = 0.1 * log(\tau) + 4.24 \qquad (1)$$

with y as the amount of water in ml and τ as the coefficient of transmission in $1/m$.

That makes it now possible to calculate the ingredients of the mixture for getting a defined transmission.

6 Conclusion

Most of the samples that were investigated indicated the postulated preferences. Some had only a short-term-stability in homogeneity, others gave only weak scattering-light. But in sum most of the samples indicated good scattering effects and a homogeneity that has been stable during the time of this work. Related to the special acrylic glass *PLEXIGLAS LED* (type 0E012XL) the scattered light of the three-component-system was about 20.4% in the usable area without total reflectance but at higher turbidity. However, all investigated samples revealed noticeable homogenous scattering of light at very low costs and a very easy mixing procedure. Owing to the transmission measurement and the resulting equation it is now possible to easily create a defined turbidity for further investigation.

References

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[2] E. Eiser, N. L. Sitnikova, R. Sprik, and G. Wegdam, "Spontaneously formed trans-anethol/water/alcohol emulsions: mechanism of formation and stability," Langmuir **21**(16), 7083–7089 (2005).