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PHOTODIELECTRIC CHARACTERIZATION OF LIGHT-DRIVEN Au/TiO_2 NANOMOTORS IN LIQUID MEDIUM

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Apstract: This article reports on photodielectric properties of hydrocolloids of TiO_2 particles and Au/TiO_2 hybrid particles of lateral dimension of ~200 nm. Illumination of the colloids with visible light did not cause measurable changes in their electrical conductivity, while the application of UV (365 nm) light led to photoinduced increase in conductivity of up to 2%. The photogeneration of ions in water, regardless of the presence of the particles, makes a dominant contribution to the photoinduced increase in conductivity of the colloids.

Keywords: photodielectric; colloids; TiO_2; nanomotors.

1. INTRODUCTION

The scientific community shows a growing interest in investigation of light-driven micro- and nano-motors [1,2]. The main challenge in this research area presents the possibility of controlling the actuation of small-sized objects with the use of light energy as a locomotion-driver, which places the study of light driven micro/nano motors in the focus of active research field. There is still no a significant application of hybrid particles that transform light into mechanical energy, but this can be expected in the near future. The mechanisms that enable the transformation of light into electrical/electrochemical energy and then into mechanical energy can be very complex. Information on the type of ions generated in the vicinity of light-driven particles is poor or completely unavailable. Bearing in mind the experience from the study of photovoltaic systems, photodielectric spectroscopy can significantly contribute to the study of those mechanisms [3]. The aim of this article is to show the preliminary results of the photodielectric characterization of water-based colloids with TiO_2 and Au/TiO_2 photo-active particles, and to indicate the benefits of photodielectric spectroscopy in this field of research.

2. EXPERIMENTAL

The colloids were obtained by five-minute sonication of TiO_2 particles and Au/TiO_2 hybrid particles in distilled water. The size of the particles is roughly 200 nm and they were obtained using the procedures described in the previous study [4]. The concentration of hybrid particles in colloids is 0.3 mg/ml. Measurements of the photodielectric properties were performed at room temperature in the experimental set-up shown in Figure 1. The colloids, of 0.3 ml in volume, were placed in the measuring cell, while illumination was performed through a steel mesh on the chamber cover, with the irradiance of 0.6 mW/cm^2 (λ=365 nm). The components of the

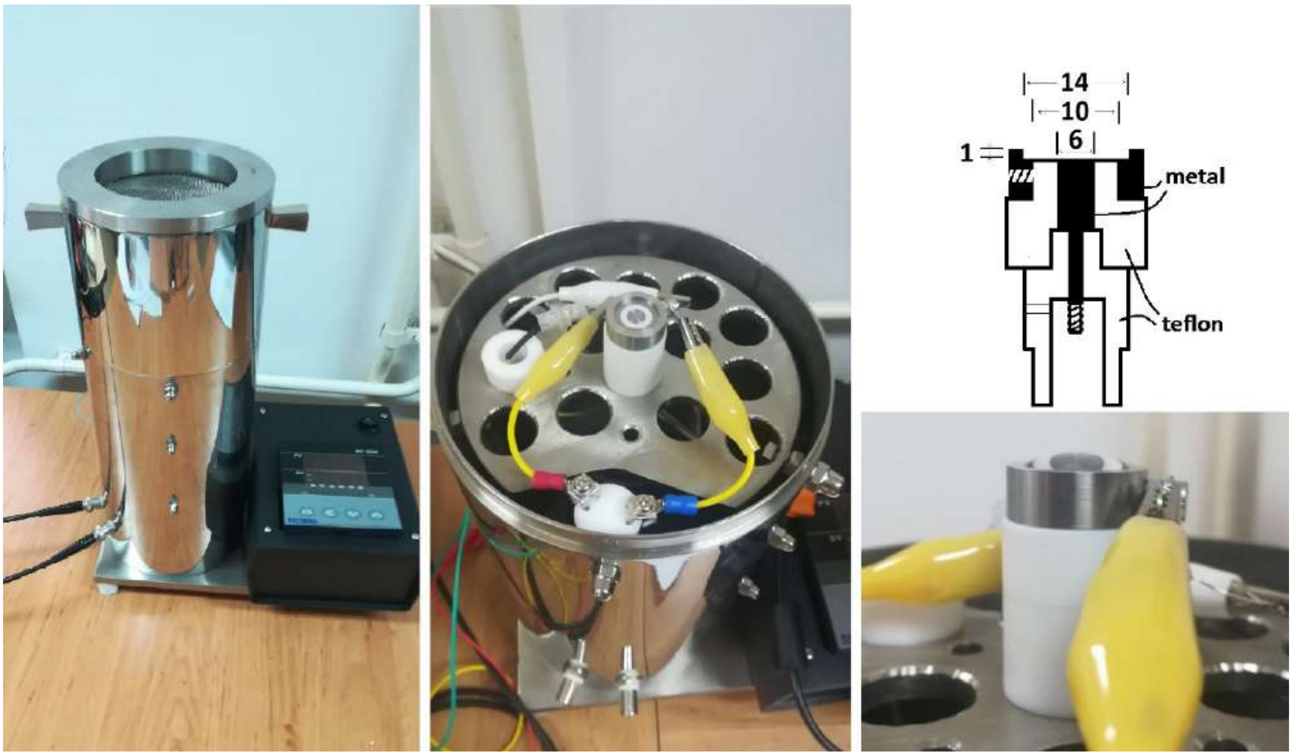

Figure 1. *Details of the experimental chamber, the dimensions shown are in mm.*

AC conductivity of the colloids, *G* - conductance and *B* - susceptance, were measured in the range 20 Hz - 62 kHz using an Agilent 4284A LCR meter. The measured conductivities are directly shown, without any conversion to the specific conductivities. The measurements were performed in consecutive dark-light-dark cycles.

3. RESULTS

The components of AC conductivity of the water and the tested colloids are shown in Figure 2 (measured in the dark). The colloids show higher electrical conductivity compared to distilled water, which is rationalized to be due to the charge that occurs at the contact of water and particles, as well as residual ionic impurities from the particle production process that have passed into the water.

Illumination of the samples with visible light did not affect their electrical conductivity; while the exposure of the samples to UV light, λ=365 nm, caused an increase in their conductance and susceptance. Figure 3 shows the photo-induced changes in conductivity due to exposure of the samples to UV_{365} light. Photo-induced increases in conductance are shown in Figure 3a, where can be seen that the distilled water shows a greater increase in conductance compared to the colloids. This observation could mean that the amount of photogenerated charge in water is greater than in the colloids, but this is actually not the case because Figure 3 shows the percentage photoinduced increases in conductivity and distilled water shows lower conductances in the dark compared to the colloids (Figure 2a). It can be argued that the presence of the particles in water, as in this experiment, did not contribute to a significantly greater photogeneration of charges than it already exists in distilled water. In other words, under the described experimental conditions, the photogeneration of the charge already existing in the water was the dominant determinant of the photoinduced increase in the electrical conductivity of the examined colloids.

Figure 3b shows the photoinduced changes in the susceptance (capacitive conductivity) of distilled water and the colloids. The influence of the presence of the particles in the water is clearly seen through the higher values of photoinduced susceptance at low frequencies compared to the water. In general, the photoinduced changes in the components of AC conductivity can originate from thermal and photoinduced ions and dipoles, also the conductivity is affected by changes in the mobility

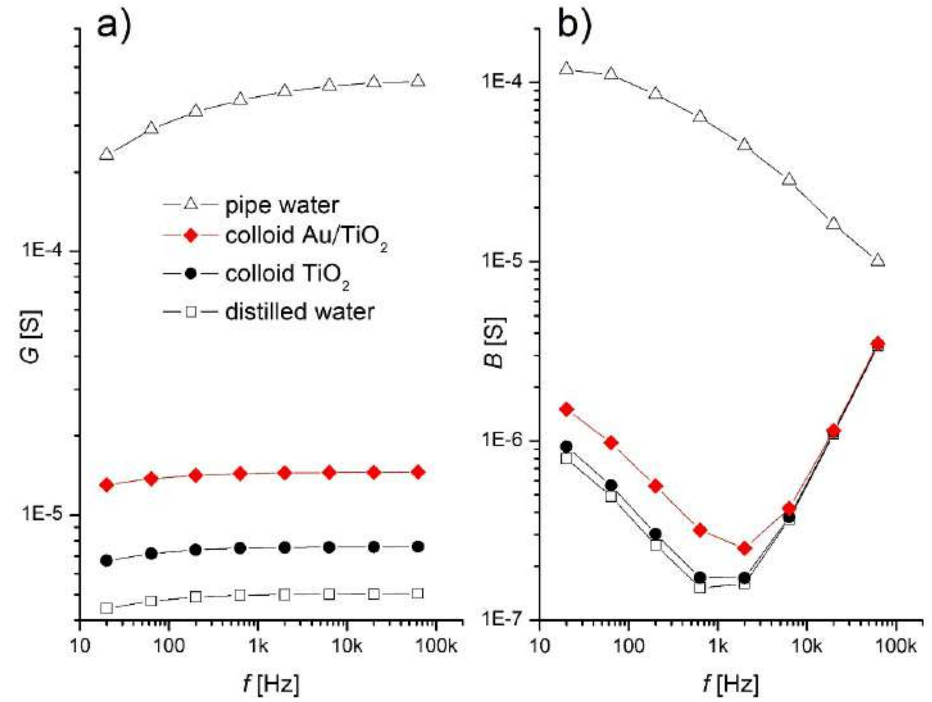

Figure 2. *The components of AC conductivity of the liquid samples: a) conductance and b) susceptance.*

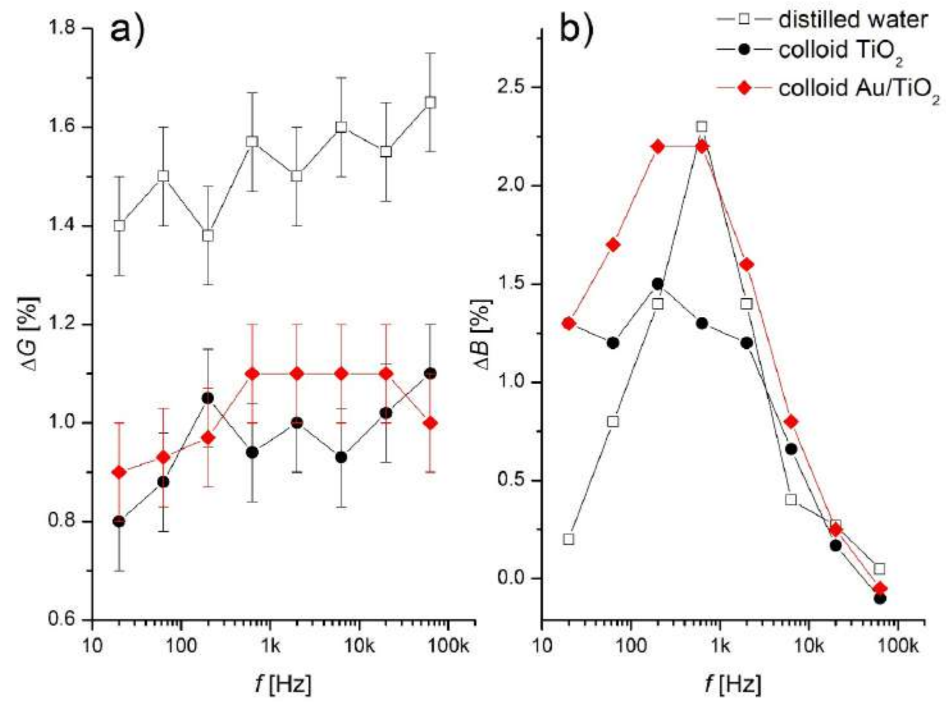

Figure 3. *Photoinduced increases in a) conductance and b) susceptance of the samples.*
The changes are shown as percentage changes relative to pre-illumination (dark) values.

of dipole/ion structures due to slight heating [3,5]. However, additional analyses are needed for a more comprehensive understanding of the mentioned processes in this type of hybrid colloids.

Figure 4 shows the measured conductance of the samples during their exposure to dark-UV-dark cycles, while Figure 5 shows the corresponding susceptance behaviour. These results highlight the most prominent dif-

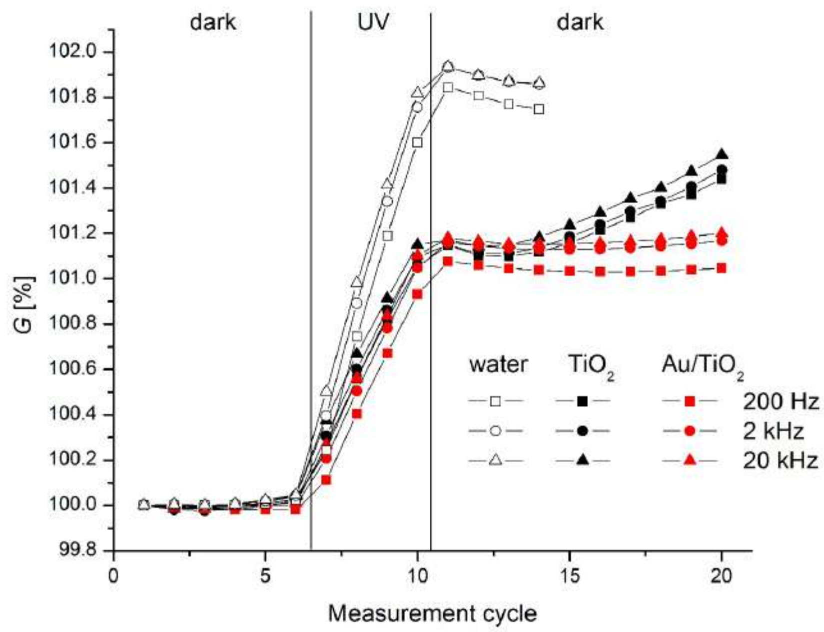

Figure 4. *Conductance measurements, the values were normalized to the values before illumination (100%).*

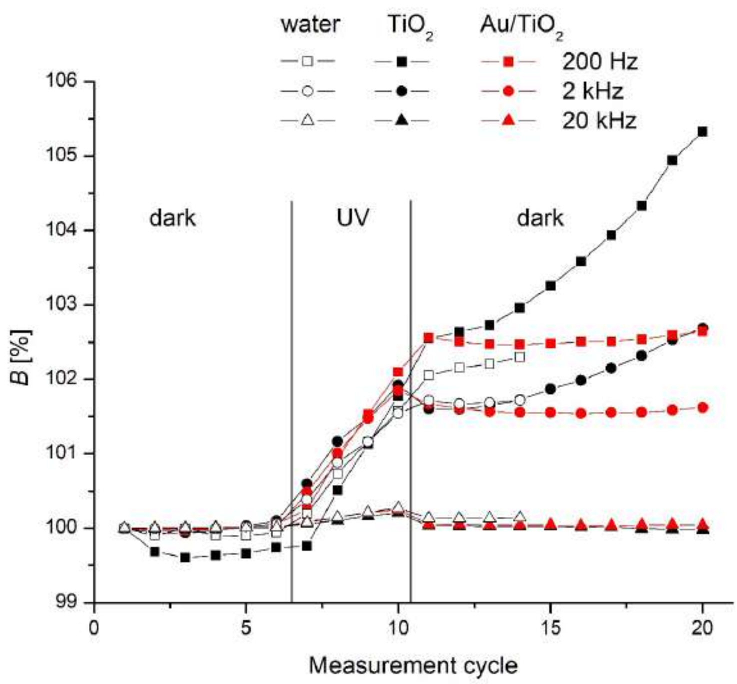

Figure 5. *Susceptance measurements, the values were normalized to the values before illumination (100%).*

ferences in the photoelectric properties of the colloids. It can be seen that the TiO_2 particles continue to generate ions in the aqueous environment even after the light is turned off, while this phenomenon is not expressed in the system consisting of Au/TiO_2 hybrid particles.

4. CONCLUSION

Photoinduced changes in AC conductivity components of water-based colloids with TiO_2 particles and Au/TiO_2 hybrid particles were investigated. Visible light did not induce measurable changes in electrical conductivity, while UV (365 nm) light affected the electrical conductivity of the investigated colloids. At irradiance values of 0.6 mW/cm^2, the relative changes in electrical conductivity were up to 2%. The photogeneration of the charge existing in the water was the dominant effect in the photoinduced increase in the electrical conductivity of the examined colloids.

5. REFERENCES

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ФОТОДИЕЛЕКТРИЧНА КАРАКТЕРИЗАЦИЈА СВЕТЛОСНОГ ПОГОНА Au/TiO_2 НАНОМОТОРИ У ТЕЧНОМ МЕДИЈУ

Сажетак: У овом чланку су приказана фотодиелектрична својства хидроколоида TiO_2честица и Au/TiO_2 хибридних честица бочне димензије ~200 nm. Осветљење колоида видљивом свјетлошћу није изазвало мјерљиве промјене у њиховој електричној проводљивости, док је примјена UV (365 nm) свјетлости довела до фотоиндукованог повећања проводљивости до 2%. Фотогенерација јона у води, без обзира на присуство честица, даје доминантан допринос фотоиндукованом повјећању проводљивости колоида.

Кључне речи: фотодиелектрик; колоиди; TiO_2; наномотори.

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