University of Eastern Finland
Institute of Photonics

Proceedings

Seventh International Workshop Nanocarbon Photonics and Optoelectronics

Spa Hotel Casino, Savonlinna, Finland

Editors:
Esko Kauppinen
Alexander Obraztsov
Yuri Svirko

Joensuu, Finland
2018

Workshop Co-Chairs

Esko Kauppinen, Aalto University, Finland
Alexander Obraztsov, M.V. Lomonosov Moscow State University, Russia
Yuri Svirko, University of Eastern Finland, Finland

Program Committee

Esko Kauppinen, Aalto University, Finland
Alexander Obraztsov, M.V. Lomonosov Moscow State University, Russia
Elena Obraztsova, A. M. Prokhorov General Physics Institute, Russia
Yuri Svirko, University of Eastern Finland, Finland

Organizing Committee

Hannele Karppinen, University of Eastern Finland, Finland
Dmitry Lyashenko, Texas State University, USA
Yuri Svirko, University of Eastern Finland, Finland

NPO2018 Sponsor Organisations

Influence of electrochemical hydrogenation on the surface photocurrent in the Ag/Pd nanocomposite

A. S. Saushin, R. G. Zonov, V. M. Styapshin, E. V. Alexandrovich, G. M. Mikheev
Institute of Mechanics, Udmurt Federal Research Center of the UB RAS, Izhevsk, Russia 426067
alex@udman.ru

1. Introduction

Light-induced surface currents have attracted a considerable attention recently [1]. In our studies [2, 3] we have shown that Ag/Pd nanocomposite films are able to generate photon drag effect surface current. This allows one to employ this material, which is widely used in electronics, for visualizing polarization of powerful laser beams and/or spatial orientation of the Ag/Pd film with respect to the incident laser beam of an arbitrary wavelength. However in the Ag/Pd nanocomposite the photocurrent pulse duration is substantially longer than the duration of exciting laser pulses. That can be due to the presence of Shotky barriers, which are formed by PdO and Ag-Pd solid solution, in the film [4]. It is possible to remove these barriers with the electrochemical hydrogenation.

The aim of this work is the study of electrochemical hydrogenation influence on the temporal profile of the surface photocurrent pulses in the Ag/Pd nanocomposite.

2. Experimental and results

Ag/Pd nanocomposite films were produced in accordance with thick film technology based on burning of a special paste on a ceramic substrate. The size of the film obtained was 12.5×11 mm, while its thickness was about ~10 μm. To measure the photocurrent the film was provided with two parallel film electrodes which were arranged along the opposite sides of the film between the dielectric substrate and the Ag/Pd film.

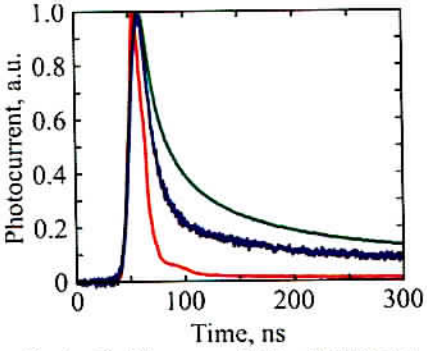

Fig. 1. Oscillograms of the photocurrent pulses before (green line) and after (blue line) electrochemical hydrogenation. Red line shows temporal profile of the excitation laser pulse.

Electrochemical hydrogenation was carried out in weak solution of sulfuric acid in distilled water. The film was placed as cathode into the electrochemical cell with stainless steel anode. Then the Ag/Pd film (cathode) was hydrogenated at a current density of 0.7 mA/cm^2. After some time interval the film was taken out of electrolyte, washed in distilled water and dried. Further, the shapes of photocurrent pulses were recorded. The photocurrent was excited by *p*- and *s*-polarized 532 nm laser radiation. Then the processes of hydrogenating and measuring were repeated. The phase composition of Ag/Pd films was studied with a D2 PHASER X-ray diffractometer using CuK_α radiation.

The oscillograms of photocurrent pulses before electrochemical hydrogenation and after 870 s are presented in Figure 1. The temporal profile of the laser pulses is presented as well. One can see that before the treatment the photocurrent pulse duration (~35 ns) significantly exceeds the corresponding parameter of the laser pulses (~15 ns). Experiments showed that the electrochemical hydrogenation results in shortening of the current pulse time parameters. The photocurrent pulse duration after 870 s hydrogenation is about 21 ns. It is worth noting that the falling edge shape does not match the one before the treatment. Moreover, the electrochemical hydrogenation results in more than 3 times reduction of the photocurrent pulse amplitude. X-ray diffraction measurements showed reduction of the PdO content in the Ag/Pd film with hydrogenation time increase. These pulse changes due to electrochemical hydrogenation can be connected with disappearance of the enhancement effect, which is possible in Schottky barriers formed by PdO and Ag-Pd solid solution.

3. Conclusion

Thus in this work we have shown that the electrochemical hydrogenation of Ag/Pd nanocomposite leads to shortening of nanosecond laser excited photocurrent pulse and changing of its temporal profile.

3. Acknowledgement

This study was supported by the RFBR (Grant No. 18-32-00224).

4. References

[1] M. Akbari and T. Ishihara, Opt. Express, **25**(3), 2143 (2017).
[2] G. M. Mikheev, A. S. Saushin, R. G. Zonov and V. M. Styapshin, Tech. Phys. Lett., **40**(5), 424 (2014).
[3] G. M. Mikheev, A. S. Saushin and V. V. Vanyukov, Quantum Electron, **45**(7), 635 (2015).
[4] G. M. Mikheev, A. S. Saushin, V. V. Vanyukov, K. G. Mikheev and Y. P. Svirko, Phys. Solid State., **58**(11), 2345 (2016).

Bipolar polarization-sensitive surface photocurrent pulses in the Ag/Pd nanocomposite

A. S. Saushin[1], V. M. Styapshin[1], G. M. Mikheev[1], Yu. P. Svirko[2]
[1]*Institute of Mechanics, Udmurt Federal Research Center of the UB RAS, Izhevsk, Russia 426067*
[2]*Institute of Photonics, University of Eastern Finland, 80101 Joensuu, Finland*
alex@udman.ru

1. Introduction

It is known that photon drag effect [1] (PDE) and surface photogalvanic effect [2] (SPGE) currents have a unique polarization and incidence angle dependencies. PDE and SPGE can be observed in centrosymmetric media. PDE photocurrent originates from the transfer of the photon momentum to a free charge carrier, while SPGE photocurrent is due to diffuse scattering of the photoexcited carriers in the subsurface layer. However, despite the different underlying physical mechanisms, these photocurrents have almost indistinguishable dependencies on the polarization and the angle of laser beam incidence.

In this work, we observed bipolar photocurrent pulses that results from a competition between PDE and SPGE in the film consisting of metal (Ag-Pd) and semiconductor (PdO) nanocrystallites.

2. Experimental and results

The Ag/Pd samples [3] were fabricated by using the thick-film technology, which is conventionally used to produce hybrid integrated circuits and other electronic devices. The fabricated films have a size of 20×20 mm^2 and thickness of 20 μm. To measure the photocurrent the sample was provided with two parallel film electrodes, which were arranged along the opposite sides of the film between the dielectric substrate and the Ag/Pd film.

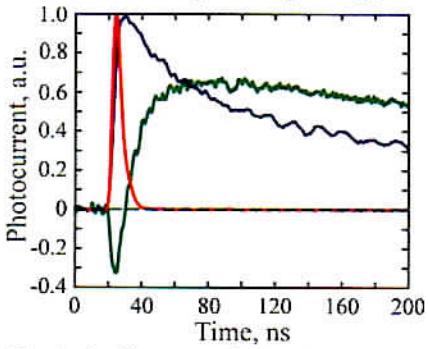

Fig. 1. Oscillograms of the photocurrent pulses induced by *s*-polarized (blue line) and the *p*-polarized (green line) laser beam. Red line shows temporal profile of the excitation laser pulse at 2000 nm.

We measured photocurrent in the Ag/Pd nanocomposite in the spectral range of 1064 – 4000 nm by using a *Q*-switched single-mode Nd^{3+}:YAG laser (repetition rate 1Hz, pulse duration at half-height 19 ns) and optical parametric generator (pulse duration at half-height varied from 6 to 8 ns). The temporal profile of the laser pulses was revealed by the high-speed photodetectors and broadband oscilloscope. The photocurrent was excited by the laser beam passed through a half-wave plate. Rotating the half-wave plate, we controlled the polarization azimuth of the incident beam.

By preforming measurements in the whole wavelength range of 1064 – 4000 nm we found that the *s*-polarized excitation beam produces unipolar photocurrent pulse, which shape is virtually independent of the wavelength (see Fig. 1). In contrast, the temporal profile of the photocurrent produced by the *p*-polarized laser beam essentially depends on the pump wavelength. Specifically, if the excitation wavelength is shorter than 1670 nm, the photocurrent is a unipolar pulse, which lasts longer than that produced by the *s*-polarized beam. However, at the excitation wavelength of 1670 nm, a negative pulse emerges at the leading edge of the positive longitudinal photocurrent. One can observe from Fig. 1 that at a wavelength of 2000 nm, the longitudinal photocurrent is transformed into a distinct bipolar pulse with a sharp negative front and a long positive tail. This is because of the simultaneous generation of the PDE and SPGE photocurrents, which have opposite polarities and different durations as well as different rise and fall times. A large number of photocurrent generation features are presented in the report.

3. Conclusion

Thus we demonstrate that the measurement of photoexcited currents in Ag/Pd nanocomposite allows us to visualize the interplay of the SPGE and PDE. This experimental finding provides a potential to visualize the excitation wavelength without using a spectrum analyzer, i.e. by non-optical means.

3. Acknowledgement

This study was supported by the RFBR (Grant No. 18-32-00224), the Academy of Finland (Grant No. 309672).

4. References

[1] A. F. Gibson, M. F. Kimmitt and A. C. Walker, Applied Physics Letters, 17(2), 75 (1970).
[2] V. L. Alperovich , V. I. Belinicher, V. N. Novikov and A. S. Terekhov, Sov. Phys. JETP, **53**(6), 1201 (1981).
[3] G. M. Mikheev, A. S. Saushin, O. Yu. Goncharov, G. A. Dorofeev, F. Z. Gil'mutdinov and R. G. Zonov, Phys. Solid State., **56**(11), 2286. (2014).