

Laser-induced marking in glasses and polymers doped by light-absorbing microinclusions and nanocrystals

[1] Organization (10.5 points)

Project Leader :

Kateryna Zelenska, Ph.D. (Faculty of Physics, Taras Shevchenko National University of Kyiv, Ukraine)

Representative at RIE :

Toru Aoki, Ph.D., Prof. (Research Institute of Electronics, Shizuoka University, Japan)

Participants :

Serge Zelensky, Dr., Professor (Faculty of Physics, Taras Shevchenko National University of Kyiv, Ukraine)

Volodymyr Gnatyuk, Ph.D., Assoc. Prof. (V. E. Lashkaryov Institute of Semiconductor Physics of the National Academy of Sciences of Ukraine, Ukraine)

Maxim Sychoy, Dr., Professor (Saint-Petersburg State Technological Institute (Technical University))

Sergey Gagarsky, Ph.D., Senior Scientist (Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics)

[2] Research Progress (10.5 points)

The project research was dedicated to the laser-induced marking in glasses and polymers doped by light-absorbing microinclusions and nanocrystals. Absorption, photoluminescence spectra and XAS of the obtained glass samples with different additives were studied.

During Dr. *K. Zelenska's*, Dr. *V. Gnatyuk's* and Prof. *T. Aoki's* visit to Thailand in June 2017 and Prof. *T. Aoki's* visit to Ukraine in August 2017, a plan of research was discussed in details.

Dr. *K. Zelenska*, Dr. *V. Gnatyuk* and Prof. *T. Aoki* attended the The 13th International Conference on Correlation Optics "Correlation Optics'17" in

Chernivtsi, Ukraine, 11-15 September 2017, and the 16th International Conference on Global Research and Education, Inter-Academia 2017 (iA-2017) in Iasi, Romania, 25-28 September 2017, where they presented scientific results and discussed further research plan.

The participants of the project were involved in organizing of the 18th Intern. Young Scientists Conf. "Optics & High Technology Material Science" SPO 2017 which was held at the Faculty of Physics, Taras Shevchenko National University of Kyiv, 26-29 October 2017.

[3] Results (10.5 points)

(3 – 1) Research results

CuCl nanocrystal additives in fluorophosphate glass enhance the absorption of samples in the ultraviolet spectrum region. Moreover, CuCl nanocrystals can be a source of blue-green luminescence and two-photon absorption.

Samples of glass doped with CuCl nanocrystals were darkened on the exposure to mercury-vapor lamp UV radiation for 6 hours (Fig. 1).

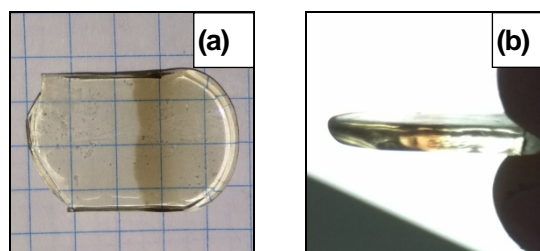


Fig. 1. Photo of the fluorophosphate glass sample doped with CuCl nanocrystals after the exposure to UV radiation for 6 hours employing a mercury-vapor lamp.

The average Cu K-edge absorption coefficient $\mu(E)$ for Cu foil and the fluorophosphate glass sample doped with CuCl nanocrystals before and after UV lamp exposure is shown in Fig. 2.

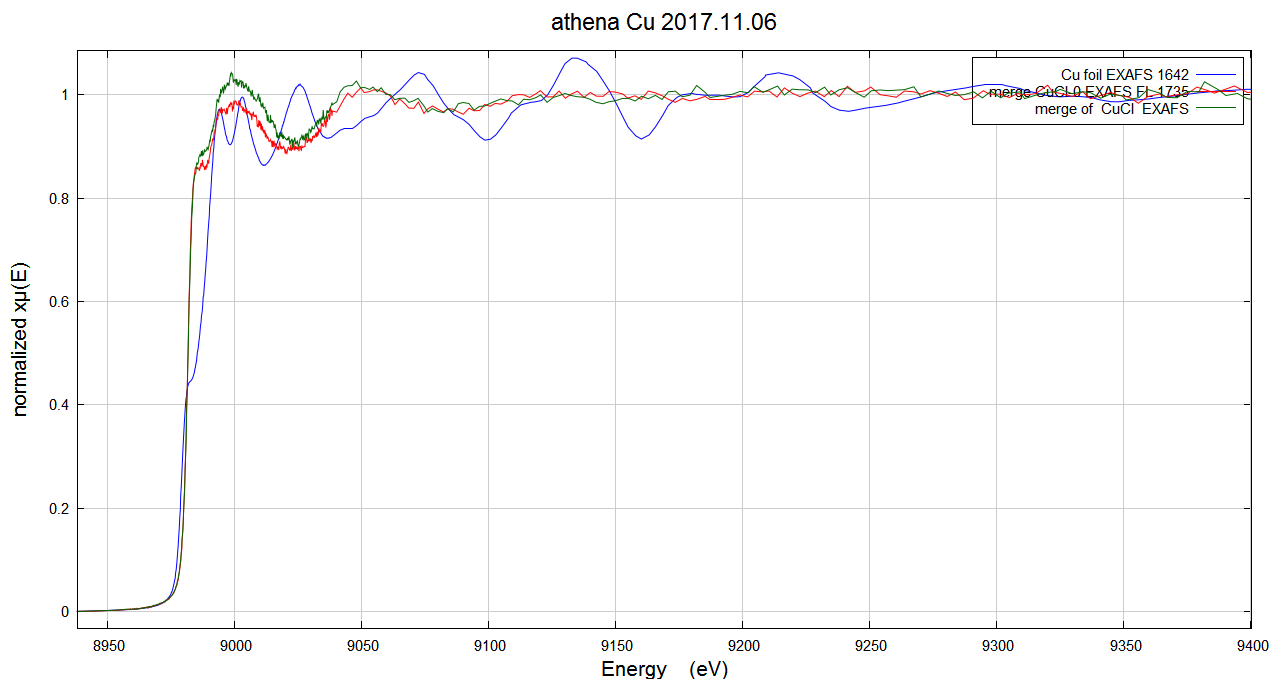


Fig. 2. XAS characterization of Cu K-edge for Cu foil and a fluorophosphate glass sample doped with CuCl nanocrystals before and after UV lamp exposure.

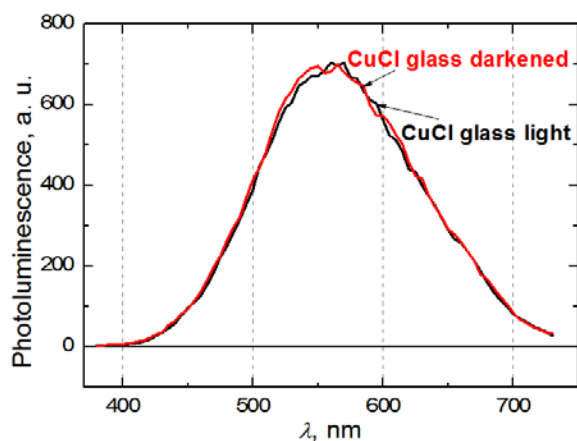


Fig. 3. Photoluminescence spectra of a fluorophosphate glass sample doped with CuCl nanocrystals before and after UV lamp exposure.

No changes in the photoluminescence spectra of a fluorophosphate glass sample doped with CuCl nanocrystals before and after UV lamp exposure were observed (Fig. 3).

Silicate glass with special components (48.37 SiO₂ : 6 CaO : 10K₂O : 25 Na₂O : 2.5 Al₂O₃ : 7.5 B₂O₃ : 0.05 Sb₂O₃ : 0.5 SnO : 0.05 SeO₂) were prepared with various nanoparticle additives: carbon black, MWCNT, N-RGO, RGO O₂, In, GZO 1%, GZO 2%, CuO, ZnO, Zn₂SnO₄, TiO₂, Hydro Ilmenite TiO₂, Magnetic Leucoxene TiO₂,

Leucoxene TiO₂

Photoluminescence spectra of the glass samples without additives (blank), activated by indium (In), carbon nanotubes (MWCNT) and copper oxide (CuO) were excited by a nitrogen laser with a radiation wavelength of 337 nm and shown in Fig. 4.

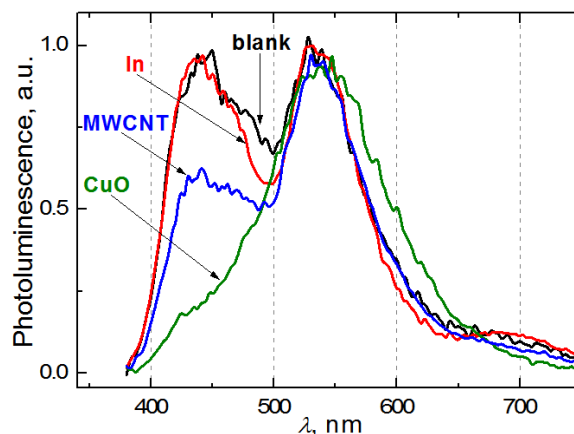


Fig. 4. Photoluminescence spectra of the glass samples: without additives (blank), activated by indium (In), carbon nanotubes (MWCNT) and copper oxide (CuO).

Laser-induced marks were obtained in polystyrene- particle composites under irradiation with 1 (Fig. 5, 1), 3 (Fig. 5, 2), 5 (Fig. 5, 3), 7 (Fig. 5,

4), 10 (Fig. 5, 5), 15 (Fig. 5, 6) and 20 (Fig. 5, 7) laser pulses of YAG:Nd laser with power density of F (a) and 2F (b). The observed mark formation can be attributed to pyrolysis of polymer matrix in vicinity of heated carbon particle up to temperatures of a few thousand Kelvin.

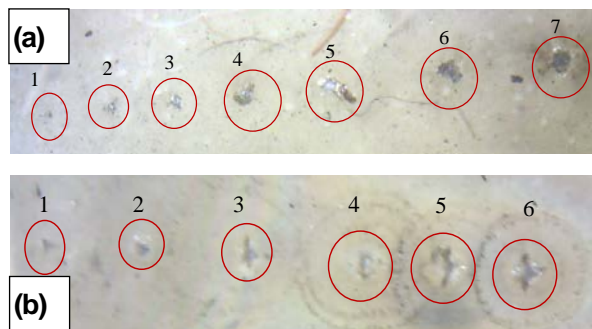


Fig. 5. Photo of laser-induced marks in polystyrene-particle composites under irradiation with 1 (1), 3 (2), 5 (3), 7 (4), 10 (5), 15 (6) and 20 (7) laser pulses of YAG:Nd laser with power density of F (a) and 2F (b).

(3 – 2) Ripple effects and further developments
Obtained results open an opportunity to analyze in details chemical composition of the sample and possibilities of optical recording. A huge amount of the prepared samples will be studied employing another optical methods and treatments.

[4] Achievements (List of Publications) (10.5 points)

(1) V. A. Gnatyuk, Laser-induced creation of parameterized marks in transparent materials for information recording and image formation, The International Workshop on Glass & Optical Materials and Application. (28 June 2017, Nakhon Pathom Rajabhat University, Nakhon Pathom, Thailand). (Invited lecture).

(2) V. A. Gnatyuk, Information recording and image formation with laser-induced parameterized marks, The Seminar at College of Nanotechnology, KMITL. (24 August 2017, College of Nanotechnology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand). (Invited lecture).

(3) V. Gnatyuk, K. Zelenska, T. Aoki, Doping and metallization of the CdTe crystal surface by laser irradiation of the metal substrate through the semiconductor, The conference on Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XIX

(Conference 10392), Part of 2017 SPIE Optics + Photonics: Optical Engineering + Applications, Technical Program, 2017, Abstract No 10392-46, 161 (San Diego, CA, USA, 6-10 August 2017).

(4) K. Zelenska, S. Zelensky, A. Kopyshinsky, T. Aoki, Laser-induced incandescence of rough and porous carbon superficial layers, The 13th International Conference on Correlation Optics "Correlation Optics'17", Book of Abstracts, 2017, M35 (Chernivtsi, Ukraine, 11-15 September 2017).

(5) K. Zelenska, V. Sklyarchuk, V. Gnatyuk, T. Aoki, Spectroscopic studies of Ni/CdTe/Au Schottky diode X- and γ -ray detectors, The 16th International Conference on Global Research and Education, Inter-Academia 2017 (iA-2017), Book of Abstracts, 2017, Abstract No O.06, 16 (Iasi, Romania, 25-28 September 2017).

(6) V. Gnatyuk, K. Zelenska, V. Sklyarchuk, T. Aoki, Enhanced X/ γ -ray detection efficiency in CdTe-based Schottky diode detectors operated in a stacked mode, The 24th International Workshop on Room-Temperature Semiconductor Detectors (RTSD 2017), 2017 IEEE Nuclear Science Symposium & Medical Imaging Conference (2017 NSS/MIC), Abstract No R-07-23 (Atlanta, USA, 21-28 October 2017).

(7) J. Nishizawa, V. Gnatyuk, K. Zelenska, A. Koike, T. Aoki, Doping of CdTe by Indium or Aluminum with Nd:YAG laser, The 24th International Workshop on Room-Temperature Semiconductor Detectors (RTSD 2017), 2017 IEEE Nuclear Science Symposium & Medical Imaging Conference (2017 NSS/MIC), Abstract No R-07-11 (Atlanta, USA, 21-28 October 2017).

(8) K. Zelenska, V. Karpovych, S. Yablochkov, A. Kopyshinsky, S. Zelensky, T. Aoki, Application of Laser-Induced Incandescence in Studies of Surface of Porous Carbon, The First Materials Research Society of Thailand International Conference (1st MRS Thailand International Conference), Abstract book, Abstract No S15_P48, 15_76, 2017 (Chiang Mai, Thailand, 31 October – 3 November 2017).

(9) V. Karpovych, K. Zelenska, S. Yablochkov, S. Zelensky, T. Aoki, Evolution of Laser-Induced Incandescence of Porous Carbon Materials under Irradiation by a Sequence of Laser Pulses, Thai Journal of Nanoscience and Nanotechnology, in press.

(10) V.A. Gnatyuk, K.S. Zelenska, V.M. Sklyarchuk, T. Aoki, Enhanced X/γ-Ray Detection Efficiency in CdTe-based Schottky Diode Detectors Operated in a Stacked Mode, 2017 IEEE Nuclear Science Symposium and Medical Imaging Conference Record (NSS/MIC),

submitted.

(11) V. Gnatyuk, V. Sklyarchuk, K. Zelenska, T. Aoki, Spectroscopic studies of Ni/CdTe/Au Schottky diode X/γ-ray detectors, Physica Status Solidi A, submitted.

Travelling Report (Mention each travel by CRP budget.)

Name : Kateryna Zelenska

Affiliation : Taras Shevchenko National University of Kyiv, 60 Volodymyrska Street, Kyiv, 01033, Ukraine

Period of time : 23 October - 26 November 2017

Destination : Research Institute of Electronics, Shizuoka University

Purpose : (1) Study of the optical properties of various glass samples with different additives and laser technological approaches suitable for volumetric optical recording and image formation by creation of micromarks in the bulk of different materials. (2) Participation in scientific meetings at Research Institute of Electronics, Shizuoka University during the period of stay.

Name of receiver : Prof. Toru Aoki