Structural and Optical Properties of Copper Iodide Thin Films for their Application in Organic Electronic Devices

Zenon Hotra, Lesya Voznyak, Natalya Kostiv, Dmytro Volunyuk, Georgiy Pakhomov, Grzegorz Łuka, Bartłomiej Witkowski, Łukasz Wachnicki.

Abstract – **Structural and optical properties of vacuum deposited copper iodide (CuI) thin films were investigated. From the XRD pattern it was found that CuI film exhibit polycrystalline cubic γ-phase with a preferential orientation along (111) plane. Photoluminescence spectrum of CuI films characterized by one peak with maximum at 417 nm, that corresponds to exciton band gap recombination of cubic γ-CuI.**

Keywords – **copper iodide, γ-CuI, X-ray diffraction, vacuum deposition, scanning electron microscopy.**

I. INTRODUCTION

Control of structural and optical properties of thin films plays significant role in their further application in organic electronic devices, in particular organic light-emitting diodes (OLED) and organic pho cell (OPVC).

Inorganic Copper iodide (CuI) is one of the promising materials for application in organic electronic devices [1]. CuI can have tree crystalline phases, α, β and γ. A low-temperature γ- CuI has attracted a most attention because it is wide bad gap (3.1 eV) p-type semiconductor with unusual optical properties [2]. CuI characterized by high conductivity and exhibits high optical transparency (over 80%) in a visible wavelength range CuI. These properties make CuI thin films very useful as hole collector in dye-sensitized solar cell [3, 4], as hole-injection layer in OLED [5, 6]. Also CuI has a great potential for application in blue organic light – emitting structures. In previous works were described properties of CuI thin films prepared by different methods, namely pulse-laser deposition [7], magnetron sputtering [8], spraying method [9] electrochemical deposition [10], etc.

In [5] work has shown the efficient using of thin vacuum deposited CuI films as hole-injection layer in OLED structures. However, optical and structural properties of their don't described. In this work structural and optical properties of vacuum deposited copper iodide (CuI) thin films were investigated.

II. EXPERIMENT

Thin CuI films were prepared on glass and silicon substrates by means of vacuum with pressure ~ 10^{-5} Torr. The film deposition was due to sublimation of original powder CuI from molybdenum boats at temperature 300°C. The substrates were kept at room temperature during deposition. The deposition rate of CuI was 0.3 nm/s. Thickness of investigated films was determined using cross-section image (Fig.1) and was 75 nm. Cross-section image, scanning microscopy image and X-ray diffraction pattern were carried out on silicon substrate using Hitachi SU-70 scanning electron microscope (SEM). Transmission spectrum was measured on Shimadzu UV-2450 spectrograph. Photoluminescence measurements were performed with Fluorolog-3 FL3-11.

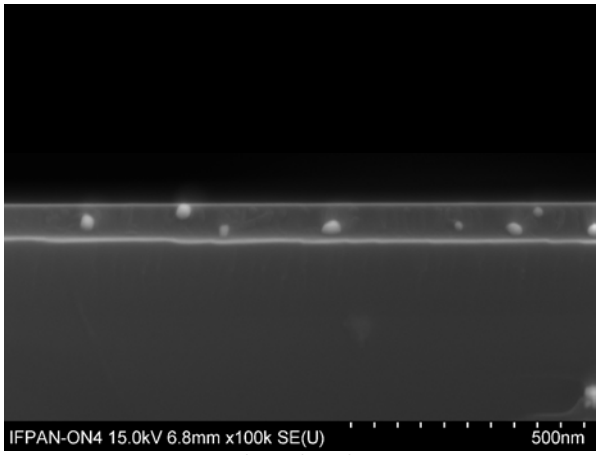

Fig. 1 The cross-section of CuI film formed on silicon substrate.

III. RESULT AND DISCUSSION

Fig. 2 shows the X-Ray diffraction pattern of CuI thin films formed by mean of vacuum deposition.

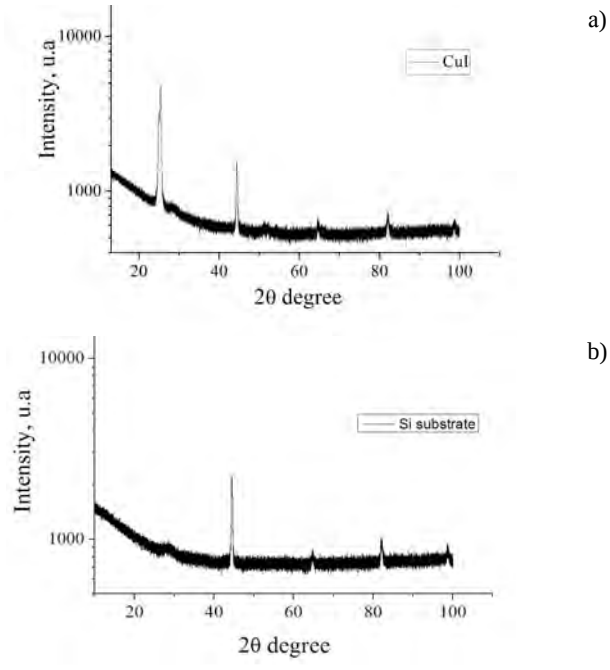

Fig.2 X-Ray diffraction pattern of vacuum deposited thin film (a) and silicon substrate (b).

Zenon Hotra, Lesya Voznyak, Natalya Kostiv, Dmytro Volynyuk - Lviv Polytechnic National University , S. Bandery Str., 12, Lviv, 79013, UKRAINE
E-mail: zhotra@polynet.lviv.ua
Georgiy Pakhomov - Institute for Physics of Microstructures of the Russian Academy of Sciences Russian Federation, 603950 Nizhny Novgorod, GSP-105
Grzegorz Łuka, Bartłomiej Witkowski, Łukasz Wachnicki – Institute of Physics, Polish Academy of Sciences, Al.Lotnikow 32/46, 02-668 Warsaw, Poland

The peak at 25,4°(Fig.2,a) characterizes polycrystalline cubic γ – phase of CuI with orientation along (111) plane [7]. Another peaks indicate the structure of silicon substrate (Fig.2,b).

Scanning microscopy image is shown in Fig.3. SEM image characterized the polycrystalline structure of CuI films that correlates with the XRD result.

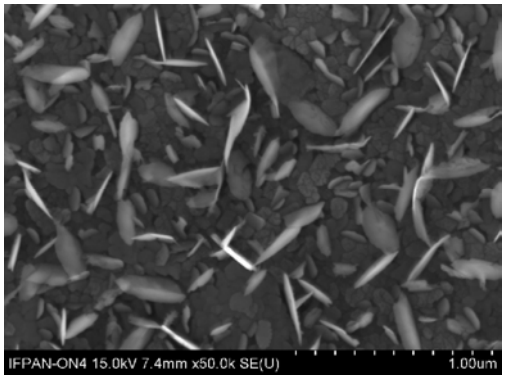

Fig.3 Scanning electron microscopy image of thin CuI film.

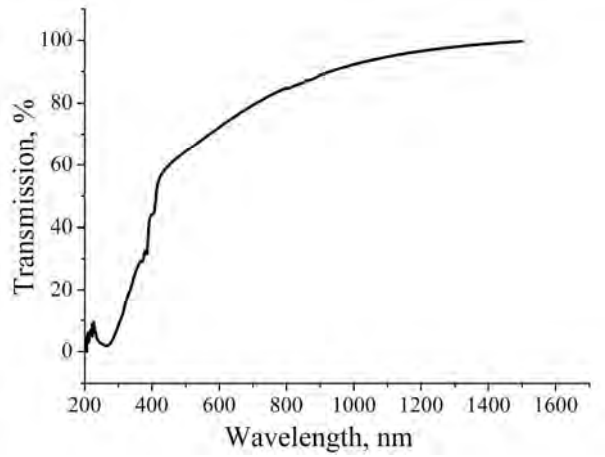

Fig.4 Transmittance spectrum of thin CuI films.

CuI thin films with thickness of 75 nm exhibit optical transmittance over 80% in the visible wavelength range 400–900 nm (Fig.4). Therefore, CuI films are promising for use as transparent contacts in OLED and organic solar cell technologies.

Fig. 5 shows photoluminescence spectrum of CuI films obtained at room temperature.

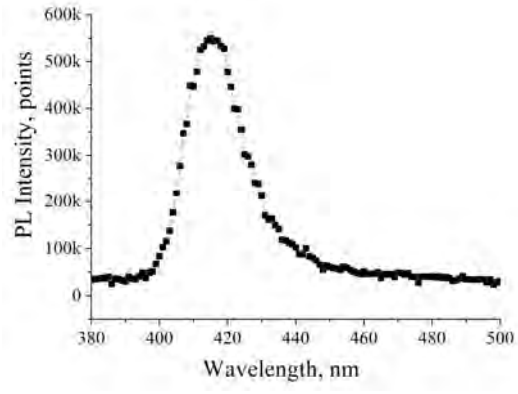

Fig.5. Photoluminescence spectrum of vacuum deposited CuI films.

Photoluminescence spectrum of vacuum deposited CuI films is characterized by one peak at 417 nm (Fig.5). Emission at 417 nm can be attributed to exciton band gap recombination of γ-CuI [10].

IV. Conclusion

In conclusion, structural and optical properties of thin CuI films formed by means of vacuum deposition were investigated. It was found, that vacuum deposited thin CuI film characterized by polycrystalline γ-phase with orientation along (111) plane and photoluminescence in blue wavelength range with maximum at 417 nm.

References

[1] G. Luka, P. Stakhira, V. Cherpak, D. Volynyuk, Z. Hotra, M. Godlewski, E. Guziewicz, B. Witkowski, W. Paszkowicz, A. Kostruba, "The properties of tris (8-hydroxyquinoline) aluminum organic light emitting diode with undoped zinc oxide anode layer, " *J. Appl. Phys.*, vol 108, pp. 064518-064522, Sep 2010

[2] P.M. Sirimanne, M. Rusop, T. Shirata, T. Soga, T. Jimbo, "Characterization of CuI thin films prepared by different techniques," *Mater. Chem. Phys.*, vol. 80, pp. 461–465, 2003.

[3] M.Rusop, T.Shiratya, P.M. Sirimanne, T.Soga, T.Jimbo, M. Umeno, "Study on the properties and charge generation in dye-sensitized n-TiO2/dye/p-CuI solid state photovoltaic solar cell," *Appl. Surf. Sci.*, vol. 252, pp.7389-7396, 2006.

[4] V.P.S. Perera, K. Tennakone, "Recombination processes in dye-sensitized solid-state solar cells with CuI as the hole collector," *Solar Energy Mater. Solar Cells*, vol. 79, pp. 249–255, 2003.

[5] Z.Hotra, P.Stakhira, V.Cherpak, D.Volynyuk, F.Ivastchyshyn, V.Tataryn, G.Luka, "Characteristics of organic light emitting diodes with copper iodide as injection layer," *Thin Solid Films*, vol. 518, pp.7016-7018, Sep. 2010.

[6] J.V. Grazulevicius, Z.Yu. Hotra, V.V. Cherpak, P.Y. Stakhira, D.Yu. Volynyuk, J. Simokaitiene, A. Tomkeviciene, A. Bucinskas, V.M. Yashchuk, A.V. Kukhta, I.N. Kukhta, V.V. Kosach, "3,6-Di(9-carbazolyl)-9-(2-ethylhexyl)carbazole based single-layer blue organic light emitting diodes", *Synth. Metal.*, vol. 161, pp.1343-1346, July 2011

[7] P.M. Sirimanne, M.Rupos, T.Shirata, T. Soga, T.Jimbo, "Characterization of transparent conducting CuI thin films prepared by pulse laser deposition technique," *Chem. Phys. Lett.*, vol.366, pp. 485-489, Sep.2002

[8] T. Tanaka, K. Kawabata, M. Hirose, "Transparent, conductive CuI films prepared by rf-dc coupled magnetron sputtering," *Thin Solid Films*, vol.281, pp. 179-181, 1996.

[9] Y.H.Yan, Y.C.Liu, L.Fang, Z.C. Lu, Z.B. Li, S.X.Zhou, "Growth of CuI buffer layer prepared by spraying method," *Trans. Nonferrous Met. Soc. China*, vol. 21, pp.359-363, 2011

[10] Honglan Kang, Run Liu, Keli Chen, Yifan Zheng, Zhude Xu, "Electrodeposition and optical properties of highly oriented γ-CuI thin films," *Electrochimica Acta*, vol. 55, pp. 8121–8125, 2010.