МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ДВНЗ «Прикарпатський національний університет імені Василя Стефаника»
Кафедра фізики і хімії твердого тіла
Фізико-хімічний інститут
Навчально-дослідний центр напівпровідникового матеріалознавства
Державний фонд фундаментальних досліджень

АКАДЕМІЯ НАУК ВИЩОЇ ШКОЛИ УКРАЇНИ

НАЦІОНАЛЬНА АКАДЕМІЯ НАУК УКРАЇНИ
Інститут фізики напівпровідників ім. В.Є. Лашкарьова
Інститут хімії поверхні ім. О.О. Чуйка
Інститут металофізики ім. Г.В. Курдюмова
Інститут загальної і неорганічної хімії ім. В.І. Вернадського
Українське фізичне товариство
Інститут інноваційних досліджень

XVI МІЖНАРОДНА КОНФЕРЕНЦІЯ З ФІЗИКИ І ТЕХНОЛОГІЇ ТОНКИХ ПЛІВОК ТА НАНОСИСТЕМ
(присвячена пам'яті професора Дмитра Фреїка)
Матеріали

Івано-Франківськ, 15-20 травня, 2017

Ivano-Frankivsk, May 15-20, 2017

Materials
XVI INTERNATIONAL CONFERENCE ON PHYSICS AND TECHNOLOGY OF THIN FILMS AND NANOSYSTEMS
(dedicated to memory Professor Dmytro Freik)

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
Vasyl Stefanyk Precarpathian National University
Physics and Chemistry of Solid State Department
Physical-Chemical Institute
Educational Research Centre of Semiconductor Material
State Fund of Fundamental Research

ACADEMY OF SCIENCE OF HIGH SCHOOL OF UKRAINE

NATIONAL ACADEMY OF SCIENCE OF UKRAINE
V.E. Lashkarev Institute of Semiconductor Physics
Chuiko Institute of Surface Chemistry
G.V. Kurdyumov Institute of the Physics of Metals
V.I. Vernadsky Institute of General and Inorganic Chemistry
Ukraine Physics Society
Institute of innovation research

УДК 539.2
ББК 22.373.1
П 80

XVI Міжнародна конференція з фізики і технології тонких плівок та наносистем (присвячена пам'яті професора Дмитра Фреїка). ***Матеріали.*** / За заг. ред. проф. Прокопіва В.В. – Івано-Франківськ : Прикарпатський національний університет імені Василя Стефаника, 2017. – 388 с.

Представлено сучасні результати теоретичних і експериментальних досліджень з питань фізики і технології тонких плівок та наносистем (метали, напівпровідники, діелектрики, провідні полімери; методи отримання та дослідження; фізико-хімічні властивості; нанотехнології і наноматеріали, квантово-розмірні структури, наноелектроніка, тощо. Матеріали підготовлено до друку Програмним комітетом конференції і подано в авторській редакції.

Для наукових та інженерних працівників, що займаються проблемами тонкоплівкового матеріалознавства та мікроелектроніки.

Рекомендовано до друку науково-технічною радою Фізико-хімічного інституту ДВНЗ «Прикарпатський національний університет імені Василя Стефаника»

XVI International Conference Physics and Technology of Thin Films and Nanosystems (dedicated to memory Professor Dmytro Freik). ***Materials.*** / Ed. by Prof. Prokopiv V.V. – Ivano-Frankivsk : Publisher Vasyl Stefanyk Precarpathian National University, 2017. – 388 c.

The results of theoretical and experimental researches in directions of the physics and technology of thin films and nanosystems (metals, semiconductors, dielectrics, and polymers; and methods of their investigation; physic-chemical properties of thin films; nanotechnology and nanomaterials, quantum-size structures; thin-film devices of electronics, are presented. The materials preformed for printing by Conference's Organizational Committee and Editorial Board, are conveyed in authoring edition.

For scientists and reserchers on the field of thin-film material sciences and nanoelectronics.

Electroactivity of Al in Al-Doped ZnO Films

Ievtushenko A.I.[1], Dranchuk M. V.[1], Karpyna V.A.[1], Lytvyn O.S.[2,3], Tkach S.V.[4], Baturin V.A.[5], Karpenko O.Y.[5], Lashkarev G.V.[1]

[1]*I. Frantsevich Institute for Problems of Material Science, NASU, Kyiv, Ukraine,*
[2]*V. Lashkarev Institute of Semiconductor Physic, NASU, Kyiv, Ukraine*
[3]*Borys Grinchenko Kyiv University, NASU, Kyiv, Ukraine*
[4]*V.Bakul Institute for Superhard Materials, NASU, Kyiv, Ukraine*
[5]*Institute of Applied Physics, NASU, Sumy, Ukraine*

Transparent conductive oxides (TCO) having a wide band gap, high transparency and conductivity are necessary material for fabrication the photovoltaic heterostructure solar cells, transparent conducting electrodes, window materials, displays, etc. Today, the most widely used TCO are indium tin oxide (ITO), which has suitable characteristics. However, ITO has some drawbacks such as the limited deposits of indium in the Earth's crust causes constant increasing in value of indium, high toxicity and environmental hazard ITO industrial-scale production. These negative factors are the reason to replacement ITO on more safe, economically profitable and affordable material. Zinc oxide doped by donor impurities of Al, Ga or In is a promising material for future electronics and optoelectronics demands. In economic terms, aluminum is the most favorable donor impurity.

Al-doped ZnO (ZnO:Al) satisfies all the above mentioned requirements. It is non-toxic material, with prevalence of raw materials in the Earth's crust, having high stability to hydrogen plasma and temperature changes. ZnO has a wide direct band gap (~ 3,34 eV at room temperature) that allows to be highly transparent (~ 85-95%) in the wide range of wavelengths (300-1000 nm). However, the problem of small electroactivity of donor impurities introduced into ZnO lattice still exists. Therefore, our report devoted to study the influence of Al content on its electroactivity in ZnO film.

ZnO:Al films were grown on Si and glass substrates by reactive magnetron sputtering (MS). To improve the crystalline perfection of the ZnO:Al films and to maintain a constant growth rate we used a new approach in ZnO:Al magnetron sputtering, namely, the layer-by-layer growth method [1]. It is shown that our method allows to grow high quality ZnO:Al films [2]. ZnO:Al films with different concentrations of aluminum impurity were deposited on Si and glass wafers by changing Al concentration in metallic Zn-Al target as well as at sputtering by variation of technological parameters of MS. The set of ZnO:Al films with concentration of Al in the range from 0.2 to 1.2 at.% were grown. For samples characterization, XRD, EDX analysis, atomic force microscopy and transmittance measurements were used. The temperature dependences of electrical resistivity and Hall coefficient were investigated.

The linear character of temperature dependence of resistivity and the value of electron concentration more than $7{\cdot}10^{19}$ cm^{-3} suggested that all ZnO:Al films

were degenerate semiconductors. It was shown that with increasing Al impurity concentration in ZnO its electrical activity was decreased (Fig. 1). The reason for such behavior of electroactivity is self-compensation effect (the compensation of introduced donor impurities by generated own acceptor-type defects) and also dispersion on free carriers. So, even relatively small donor doping of ZnO within 0.2 -1.2 at.% leads to problem with electroactivity of introduced donor elements. Therefore, here we face to hard case: in desire to decrease resistivity in ZnO films down to $1{\cdot}10^{-4}$ Ohm·cm we need introduce a large amount of donor impurity the most of which is non-electroactive and, hence, play the role of scattering centers by forming intrinsic defects, even complex, which significantly decrease the electron mobility that is not large in wide-gap semiconductors. Hence, the only way to obtain the extra low resistivity ZnO films to do the best in the technology of Al-doped thin film deposition and maintain both mobility and electroactivity at a high level. Also, the relationship between structure and morphology of ZnO:Al thin films and electroactivity of Al impurity will be discussed.

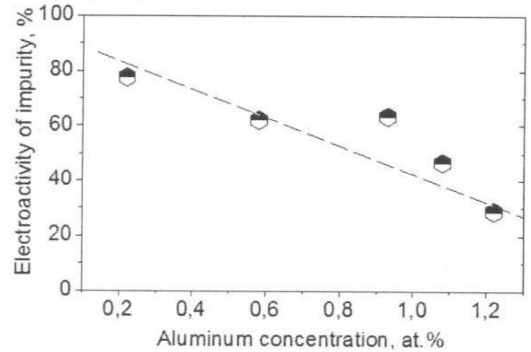

Fig.1. Electroactivity of aluminum impurity in ZnO:Al films. (Dashed line for eye)

1. A.I. Ievtushenko, V.A. Karpyna, V.I. Lazorenko, et al., High quality ZnO films deposited by radio-frequency magnetron sputtering using layer by layer growth method // Thin Solid Films. – 2010. – **518**. – P. 4529 - 4532.

2. A.I. Yevtushenko, O.I. Bykov, L.O. Klochkov, ta in., Vplyv tysku kysnyu na vlastyvosti tonkykh plivok ZnO:Al, vyroshchenykh metodom posharovoho rostu pry mahnetronnomu rozpylenni // Fizyka i khimiya tverdoho tila. – 2015. – T.16, 4. – S. 667-674.