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Report

Review of HIT - IE-BAS joint research during the last 25 years

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Abstract

The Department of Electronics and Computer Engineering, Hiroshima Institute of Technology (EC-HIT) started the international joint research with the Laboratory "Physical Problems of Elec-tron Beam technologies" of the Institute of Electronics, Bulgarian Academy of Sciences (IE-BAS) in 1994. More than 30 papers, included a book chapter, were published by implementing the international joint research under 7 Agreements for Academic Cooperation and Exchange between HIT and IE-BAS. Our international joint research is getting the important position in joint research between Japan and Bulgaria. The semiconductor fabrication process such as thin film deposition, Electron and Ion Lithography, Etching, Ion implantation, Plasma treatment, etc., evaluation technique such as X-ray photo-electron spectroscopy, optical spectroscopy, X-ray diffraction, etc., and their simulation technology were used for application in industry, medical service, medicine manufacture, biotechnology, dental, etc. By providing further steps for developing and extending our bilateral relations, this research partnership between the Hiroshima Institute of Technology and the Institute of electronics at the Bulgarian Academy of Sciences can become more stable in the future.

Key Words: joint research, Institute of electronics at the Bulgarian Academy of Sciences, Hiroshima Institute of Technology

1. INTRODUCTION

The international joint research and collaboration between the Department of Electronics and Computer Engineering, Hiroshima Institute of Technology (EC-HIT), and the Laboratory "Physical Problems of Electron Beam technologies" of the Institute of Electronics, Bulgarian Academy of Sciences (IE-BAS) started in 1994. Up to now the joint research is in the framework of seven Agreements for Academic Cooperation and Exchange between HIT and IE-BAS in the fields of physical electronics, nanotechnologies, electronics materials, electron and ion beam technologies, process modelling and simulations, technology optimization for application in industry, in medicine, new approaches in education, etc.

In this review, the main results and selected activities for the last 25 years of our successful joint research and collaboration are presented.

2. CONTENTS

The research results obtained for this period (1994-2019) have been published in more than more than 30 common publications, a significant part of them in prestigious international scientific

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journals such as Microelectronic Engineering, Surface and Interface Analysis, Mathematics and Computers in Simulation, IOP Journal of Physics: Conference Series, Vacuum, Metals, etc., a book chapter [1-21]. The results have been also reported in many international scientific forums such as IEEE International Spring Seminar on Electronics Technology, International Conferences on Electron Beam Technologies (EBT), The Minerals, Metals & Materials Society (TMS), Education and Research Workshop of Electronic Devices, Circuits, Illuminations, and Systems (EDCIS), International scientific conferences “High Technologies. Business. Society”, International Summer School on Vacuum, Electron and Ion Technologies (VEIT), etc.

In 2019, three important anniversaries were celebrated in the history of the bilateral relations between Japan and Bulgaria, namely - 110 years since the official bilateral contacts began, 80 years since the establishment of diplomatic relations between the two countries and 60 years of their recovery.

In 2019, we were celebrating 150 years from the establishment of the Bulgarian Academy of Sciences. Established in 1869, the Bulgarian Academy of Sciences (BAS) is the oldest institution in modern Bulgaria. Nowadays, the BAS is the largest scientific institution in Bulgaria with proven international authority. It carries out scientific work in accordance with the universal values, national traditions and interests.

Electron beam technologies (EBT) celebrate now 70 years from the first machines and industrial technologies based of application of intense electron beams in vacuum. EB technologies and devices are high-tech, environmental, resource-saving methods and devices, key for the development of competitive products with high quality and to achieve sustainable development based on knowledge. They are the foundation of technical progress in micro- and nano-electronics, in the production of new materials and creating new designs of instruments and precision machinery. They are becoming more widely used in the industries of the advanced industrial countries and in new research areas concerning development and optimization of applications of electron beams in nanotechnology, biotechnology, etc.

As a result of our long-term scientific cooperation, a model for computer simulation of the signal formation at surface and thin film analysis by electron spectroscopy was developed [2-6], (Fig.1). A Bulgarian-Japanese Center for Modification of Materials with electron and ion beams was established with the Hiroshima Institute of Technology.

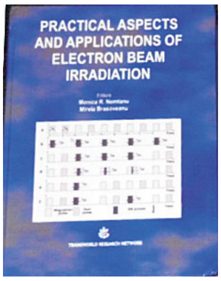

Fig. 1 Book “Photoelectron signal simulation at surface analysis” [6].

At using the most powerful beams for the production of pure metals and for recycling of metal technogenic materials in vacuum, refining and heat processes are studied, and specific technologies for electron beam melting (EBM) are developed. Computer modeling of processes is applied and on this basis the process peculiarities are investigated and the purity of the obtained metals is optimized. High-purity metals and their alloys have wide spectrum of applications in electronics, medicine, transport, nuclear and chemical industry, special alloys, etc.

Electron beam melting method has proven its advantages as an effective, environmental-friendly method and it plays an important role in the production of ultrapure sputtering target materials and electronic alloys, in metal regeneration from waste products, in the metallurgical-grade silicon purification for the photovoltaic industry, etc. The recycling of metal scrap enables obtaining new materials with improved characteristics (composition and structure) and suitable properties (magnetic, resistance, etc.) for responsible application. Each one of the metals, processing by EBM, is made in a unique way aiming to achieve the superior level of refining of unwanted inclusions. Therefore, there is a need to look for specific technological regimes for e-beam refining for specific raw materials.

The e-beam method provides obtaining metals and alloys processing both natural raw materials and technogenic materials containing these metals or their alloys in the case of lack of such natural raw sources. The global recourses of many valuable metals are exceedingly limited and at the same time, there are some large amounts of metal wastes collected.

Theoretical and experimental investigations dealing with the relations of melting process parameters (such as melting power, the refining time, etc.) and impurities removal at refining of different metals, including non-ferrous and rare metals, refractory and reactive ones are performed aiming to improve the composition and quality of the produced metals and to optimize the process [11,13,17,21].

Data of practical importance are obtained and recommendations for proper process parameters are formulated for processing of various metals such as titanium, tantalum, nickel, etc. The obtained results are important for studying and increasing the efficiency of e-beam melting of metal materials, optimizing the purity, structure and properties of the metals obtained and show possible applications of the method.

Electron beam lithography (EBL) evolved to one of the most important techniques for nanofabrication. EBL is one of the few "top-down" methods and is becoming increasingly widespread in R&D and small volume production due to its flexibility and mask-less nature, very high (sub-10 nm) resolution and accuracy, maturity and affordable price of equipment and in many cases e-beam lithography is the only possible alternative. Resist materials are crucial elements in EBL and their performance determines the final results of the structures patterning.

Application range of EBL is wide, i.e. the development of sensors, nanophotonic devices, high frequency electronics, spintronics, quantum dots, nanowires, nanomechanical devices, etc. Achieving sub-100 nm structures using EBL is a very sensitive process determined by various factors, starting with the choice of polymer resist material and ending with the development process.

Limitations of different positive and negative EB lithography resists such as PMMA, CSAR, SU-8, and HSQ for advanced research and many applications in sensors and microsystems development, surface science applications, etc. are studied [7,9,10,15]. Various process parameters, which determine the accuracy of the profiles in the resists and the size of structures, such as exposure dose, resist thickness, solubility rates, dependences of the linewidth on the dose, etc. and their influence on the limitations of e-beam lithography, are investigated. Experimental and theoretical investigations are performed aiming to improve the resolution of the nano-dimensioned EBL using different resist materials and some application results are also obtained (for gas sensors development, for photonic application, etc.).

Plasma-based ion implantation (PBII) method is used to perform surface modification by the sample in the plasma and applying a high voltage negative pulse voltage. It has been applied to surface modification industrial machinery parts, metal material, and medical technology. PBII with self-ignited plasma (SIP) generated by only pulsed voltages to the test specimen has been applied to the sterilization process [18,19].

Rapid globalization requires for students, teachers, and researchers to have good education, logical thinking, problem-solving, comparative, and research skills, excellent expressiveness, and broad scientific knowledge. The latest main projects related to international education in Japan and some specific approaches in HIT, based on projects promoted by MEXT, were discussed. Some of the newest and most important approaches and trends in the universities' education system aiming at achieving better results and some examples of good practices related to the application of these approaches in the education in Japan, Bulgaria and the United States were also presented [12,14,20].

3. CONCLUSION

By providing further steps for developing and extending our bilateral relations, this research partnership between the Hiroshima Institute of Technology and the Institute of electronics at the Bulgarian Academy of Sciences can become more stable in the future.

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Appendix

Insitute of Electronics, BAS	Hiroshima Institute of Technology

Fig. A1 Logo mark of Institute of Electronics, BAS and Hiroshima Institute of Technology

Fig. A2 Bulgarian Academy of Sciences logo mark

Fig. A3 2019 Japan-Bulgaria Triple Anniversary Commemorative logo mark

Fig. A4 International scientific conference "High Technologies. Business. Society", March 2018, Borovetc