e-ASIA Joint Research Program
Progress Report

1. Project Title: **Fundamental study of the Physical properties of Metal Oxide single nano-wires and nanoparticles for bio-nano-sensing**

2. Joint Research Period: 02/06/2018 ～ 30/12/2022

3. Principal Investigators:

- Russia: Victor Koledov Leading Reseracher Kotelnikov IRE RAS.
  - Planned Funding Period: 02/06/2018 – 02/06/2021.

- Myanmar: Than Zaw Oo Professor, Department of Physics, University of Yangon.
  - Planned Funding Period: Month, Day, Year – Month, Day, Year

- Vietnam: Ngo Thy Hong Le, Dr, Institution Institute of Materials Science
  - Planned Funding Period: 30/12/2019-30/12/2022.

- Philippines: Gil Nonato C. Santos, Professor, Physical Department De La Salle University – Manila
  - Planned Funding Period: 04/15/2019-04/14/2022.

4. Summary of the Progress of the Joint Research:

The purpose of the project is to synthesize the arrays of the metal and metal oxide nanostructured and nanosized materials: MnO_2 nanoparticles, arrays of nanotubes TiO_2, SnO_2 and ZrO_2, nanowires of ZnO, TiO_2 and $LaMnO_3$ and others, as well as to develop the technology of 3D nanomanipulation of individual nanoscale objects based on nanotweezers made from Ti_2NiCu alloy with shape memory effect (Fig.1). The groups of project participants in co-operation made samples of metal and metal oxide nanomaterials, characterized their properties. Using an improved nanomanipulation system, individual nano-objects were selected (Fig.2) and experiments were performed to create prototypes of electrical, electrochemical, and photonic structures in which functionalized nanomaterials can demonstrate the properties of the gas nanosensors (Fig.3).

Based on the data obtained, the 3 prototypes of macroscopic sensors were being created: a glucose concentration sensor based on a Cu/MnO_2 nanocomposite and a sensor of volatile organic compounds (VOCs) consisting of ZnO and SnO_2 nanowires. Besides, the feasibility study has been conducted for ethanol gas detection using electrochemically deposited hematite (α-Fe2O3) nanoparticle films. Preliminary results indicated that the response of the hematite nanoparticles-based sensor is as high as 1.34 at 300 C (ethanol concentration - 1000 ppm) and sensing stability is good in the temperature range (27-300 C).

ZnO nanowires were prepared by hydrothermal method. The FE-SEM images of nanowires are shown in Fig. 4. Each ZnO nanowire is 50–100 nm in diameter. The average length of the nanowires is about 3-5 µm. Fig. 5 displays the XRD diffraction spectra of the ZnO nanowires with indexed peaks. indexed as the hexagonal wurtzite ZnO structure.

The prototype of the VOCs sensor was created on the base of ZnO and SnO_2 nanomaterials. The current-voltage (I-V) graphs were determined (Fig 5). The study is currently on the stage when synthesized nanomaterials are trained to detect VOCs that can be used as biomarkers for lung diseases and meat spoilage. In this stage, after determining the I-V characteristics of the nanomaterials, the best samples with high semiconductor characteristics will be utilized for gas sensing. A 5-mL volume of each VOC (namely octanol, nonanal, hexanal, valeraldehyde, and acetaldehyde) was sealed on a vial. The fume of the gases was collected using a syringe to be injected into a closed environment with the gas sensor. The change in voltage reading was used as an indicator of VOC sensing. The selectivity and sensitivity of SnO_2 and ZnO sensing nanomaterials were analyzed by plotting the data in the radar plots to detect the specific VOCs (see Fig. 6). The testing method for characterization of the performance of the VOCs nanosensor has been developed by Philippines group (Fig. 7).

5. Scientific Achievements and Implemented Activities (Research Exchange, Workshop, Publication, etc. if any): **For this item, please fill in the attached Excel file.*

Publications: 8 journal articles and 3 papers in Conference proceedings were published.

During the visits of the representatives of the Philippines and the Republic of Myanmar to Russia the discussions, joint experiments, and speeches at the International Workshop in Kotelnikov IRE RAS, Moscow, and at a special session at the international conference METANANO2019 in St. Petersburg were held. Russian group members have visited Vietnam and Myanmar for co-operative work, discussions, and conference presentations.

6. Future Goals and Plan of Activities within and after the project period:

According to the working plan in the next year period, the experimental works will be done on improvement of nanomanipulation system design, it will be provided to all the parties and used to study the bottom-up nano-integration of the nanomaterials and construction of the highly sensitive nanosensor prototypes.

Next Year it is planned to make the exchange visits of the parties for the co-operative study of bottom-up nano-integration. The publication of the articles in a special issue on nanomanipulation in the Nanomaterials journal is planned : (https://www.mdpi.com/journal/nanomaterials/special_issues/nano_maniplt)

7. Recommendations and Comments to the Program (if any):
(ex. Any support to request from the Program in order to achieve item 6.)

Unfortunately, due to the pandemic, the time for experimental work and visits has been reduced. An extension of the project is recommended.

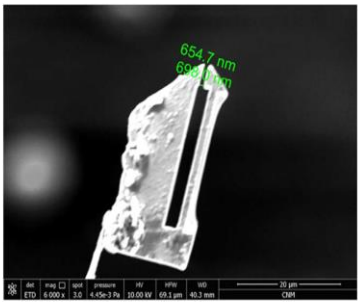

Fig.1. Ti2NiCu based composite nanotweezers on the tip of the tungsten microwire.

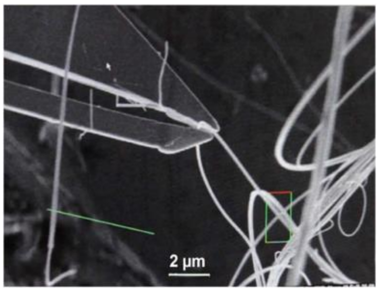

Fig.2. 3D manipulation of semiconductor nanowires using shape memory composite nanotweezers.

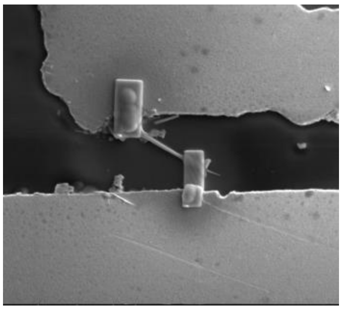

Fig. 3. The integration of the semiconductor nanowire biosensor.

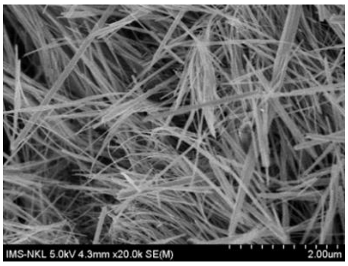

Fig. 4: SEM image of ZnO nanowires

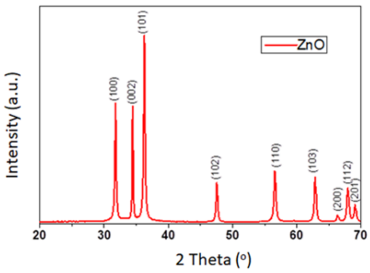

Fig. 5: X-ray diffraction pattern of ZnO

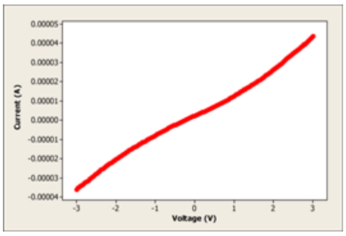

Fig. 6. I-V curve for the ZnO nanosensor shows resistance of 7.0 x10^4 Ω.

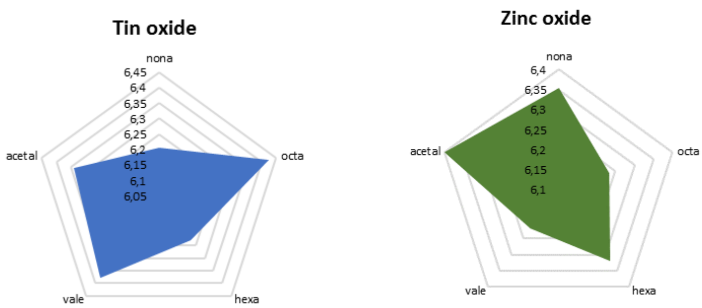

Fig. 7. Selectivity and sensitivity capability of SnO and ZnO sensing nanomaterials were analyzed by plotting the data in a radar plot to detect VOCs: nonanal, octanol, hexanal, valeraldehyde, and acetaldehyde.

Fig. 8. Testing the prototype of VOCs nanosensor by Philippines group.

Lists of Achievements and Implemented Activities

1. Original Publication of Articles etc.

【Notes】
Please fill in **only the achievements of this project** by country in order of publication date. Only "published" is targeted, but please write "in press" too only for Final Report.
Please count Proceedings with peer review as original paper.
The information on this form is only disclosable. Please submit Non-disclosable information in a separate file.

1. 1 Original Publications (Articles co-authored among Research Teams)

All Authors' Names, Title, Journal Name, Volume, Edition, Page, Year of Publication	DOI Code	Publication Status	Remarks (e.g. publication in top level journals etc.)
1. Koledov, V., von Gratowski, S., Nguyen, H. D., Thi, H. L. N., Vu, H. K., Santos, G. N., & Oo, T. Z. (2019). Nano-manipulation and nano-assembling using shape memory alloy nanogripper of metal oxide and semiconductor single nanowires and nanoparticles for biological nanosensors. Advances in Natural Sciences: Nanoscience and Nanotechnology, 10(3), 035003.	doi.org/10.1088/2043-6254/ab2ecd	published	
2. Erfani-azad, A., Shahmirzadi, N. V., Pakizeh, T., Kolodev, V., & von Gratoswki, S. (2020). Metasurfaces based on Functional Materials in THz and Optical Regions. JPhCS, 1461(1), 012125.	doi:10.1088/1742-6596/1461/1/012125	published	
3. Sajor, N. J., Foronda, J. R., Olarve, R. S., Torre, H. D., Santos, M. G., Lopez, T. B., ... & Gratowski, S. V. (2020). Synthesis of Metal Oxide Nanomaterials for Early Lung Disease Detection. JPhCS, 1461(1), 012149.	doi:10.1088/1742-6596/1461/1/012149	published	
4. Oo, T. Z., Min, W. N., Wint, T. H. M., Koledov, V., & von Gratowski, S. (2020). MnO_2 and TiO_2 based Nanocomposites for Macroscopic and Individual Nanodevices in Sensing, Energy Storage and Photocatalysis Applications. IOP Conf. Series: Journal of Physics: Conf. Series 1461 (2020) 012124.	doi:10.1088/1742-6596/1461/1/012124	published	

5. Mechanical bottom-up nano-assembling and nanomanipulation using shape memory alloy nano-gripper Svetlana von Gratowski, Victor Koledov, Nguyen Huy Dan, Ngo Thi Hong Le, Vu Hong Ky, Preecha Yupapin, Sergey Petrenko, Gil Nonato Santos, Than Zaw Oo. Proc. of International Conference on Physics, Mandalay 2018 (ICPM2018), Myanmar	https://icpm2018.mutnp.org/	published	
6. Nanomanipulation of Metal Oxide Nanomaterials N J Sajor, R S Olarve, G N Santos, V Koledov and S V Gratowski. Proc. 2019 International Nanotechnology Conference in the Philippines (INCP2019)		published	
7. MECHANICAL NANO-MANIPULATION USING NOVEL FUNCTIONAL MATERIALS BASED NANOTOOLS FOR BREAKTHROUGH BOTTOM-UP- NANO-ASSEMBLING HNOLOGIES S.von Gratowski, V.Koledov. S. von Gratowski, V. Koledov, S. Petrenko, Nguyen Huy Dan, Ngo Thi Hong Le, Vu Hong Ky. Proc of International Conference Nanomeeting - 2019. 21.05.2019 - 24.05.2019 Minsk, Belarus		published	Minsk, Belarus
7	Total		

1. 2 Original Publications (Articles by Single Team only)

All Authors' Names, Title, Journal Name, Volume, Edition, Page, Year of Publication	DOI Code	Publication Status	Remarks (e.g. publication in top level journals etc.)	Country name of the team
8. Myat Su Tun, Htoo Thiri Htet, Hsu Thazin Myint, Win Naing Min, Me Me Theint, Than Zaw Oo "Potentiodynamic Bottom-Up Growth of Cu/MnO2 Composite Films as Glucose Sensing Electrode" Journal of Materials Science and Applied Energy 8(2) (2019) 408-414		published		Myanmar
9. Theint Hay Mar Wint, Michael F. Smith, Narong Chanlek, Fuming Chen, Than Zaw Oo and Prayoon Songsiriritthigul "Physical Origin of Diminishing Photocatalytic Efficiency for Recycled TiO2 Nanotubes and Ag-Loaded TiO2 Nanotubes in Organic Aqueous Solution" Catalysts 10(7) (2020) 737 [doi:10.3390/catal10070737]	ISSN (Print): 2286-7201, ISSN (Online): 2651-0898	published		Myanmar
10. Enhanced Optical and Photocatalytic Properties of Au/Ag Nanoparticle-decorated ZnO Films, V.D. THINH, V.D. LAM, T.N. BACH, N.D. VAN, D.H. MANH, , D.H. TUNG, N.T.H. LIEN, U.T.D. THUY, T.X. ANH N.T. TUNG, and N.T.H. LE, Journal of ELECTRONIC MATERIALS 49(4) (2020) 2625	https://doi.org/10.1007/s11664-020-07973-7	published		Vietnar
11.Influence of the morphorlogy of ZnO materials on photocatalytic reduction of CO2, Vu Duy Thinh, Vu Dinh Lam, Ta Ngoc Bach, Le Thi Hong Phong,Phung Thi Thu, Do Hung Manh, Ngo Thi Hong Le, THE 11th INTERNATIONAL CONFERENCE ON PHOTONICS & APPLICATIONS (ICPA-11), 4 - 7 November 2020. Hoa Binh City, Vietnam.	https://iop.vast.ac.vn/activities/HNQHQP_ICPA/11/prog_VIE.html	published		Vietnam
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