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To whom it may concern

I would like to present our competences in the field of microelectronics, optoelectronics, and photonics and express our willingness to cooperate in the course of CHIST-ERA programme.

I represent the team from Division of Microelectronic and Nanoelectronic Devices (MND) that consists of 2 tenured professors, 2 associate professors, 5 assistant professors, and ~10 PhD/diploma students. The team possesses appropriate knowledge, and experience in the field of semiconductor devices, and technology, as well as theoretical studies, simulations, and optical characterization of various microelectronic and photonic materials, including dimensionality reduced structures such as thin films, nanocrystals, and waveguides. The competences of MND's team is proved by the participation in several European Projects and ICT programmes, e.g., *"Nanophotonics with metal – group-IV-semiconductor nanocomposites: From single nanoobjects to functional ensembles – NaMSeN"* (V4-Jap/3/2016), "*Silicon-based nanostructures and nanodevices for long term microelectronics applications – NANOSIL*", "*Pulling the Limits of NanoCMOS electronics – PULLNANO", "Silicon-based Nanodevices – SINANO"*. Furthermore, the MND's team has participated in the research projects which were focused on microelectronic and photonic devices, e.g., "*Tunable hyperbolic metamaterials for photonic devices of novel generation – HYPERMAT*" (TECHMATSTRATEG1/347012/3/NCBR/2017) or "*Ultra-fast detector PhotoGraph based on graphene – PHOTOGRAPH*" (GRAFTECH/NCBR/13/20/2013) within national programmes.

We have direct access to unique technological laboratory "clean-room" with the purity class 100/1000 that I'm personally responsible for in terms of administrative and research issues. Such a laboratory allows for the fabrication of different microelectronic and photonic test structures. Recently, after receiving financial support under "Warsaw Labs" program (POIG.02.01.00-14-138/08), technological and characterization capabilities of this lab have been expanded significantly. The possibility (not yet available) working on 4-inches semiconductor substrates and achievement resolution of photolithography process around the 1 µm, led our laboratory to obtain the technological compatibility with more foreign partners, making it easier for us entering into cooperation and implementation of joint research projects.

The research infrastructure in the clean-room allows for the high-temperature processing: dry and wet oxidation and diffusion by using Thermco 4" wafers-compatible furnaces. Moreover, we provide the full line-up of plasma processing tools made by Oxford Instruments Plasma Technology (OIPT). These apparatus cover: Reactive Ion Etching – RIE (both, fluorine and chlorine chemistry for etching of conductive and dielectric layers, as well as very shallow ion implantation), Plasma Enhanced Chemical Vapor Deposition – PECVD (the deposition of amorphous silicon, silicon oxide, nitride and oxynitride) and one of the modern reactor for reactive magnetron sputtering – PVD System 400. The latter system allows for highly repeatable, computer controlled multilayer deposition in one vacuum chamber (without exposing to atmosphere) of conductive materials (Ti, TiN, Al) and metal oxides, nitrides or oxynitrides (HfO_x, HfO_xN_y, TiO_x, GdO_x, AlN, AlO_x, AlO_xN_y). Apart from the conductive and dielectric layers, we have ready-to-use processes for the fabrication of amorphous semiconductor films with the high transparency – Indium-Gallium-Zinc Oxide (IGZO) that already has replaced the amorphous silicon (a-Si) as the semiconductor material in Thin-Film Transistors (TFTs) for e.g. display applications. The optical and electrical parameters of these materials can be also optimized in order to receive high-transparency, high-absorbance or for anti-reflective coatings applications. Such a feature can be very useful in the development of highly innovative microelectronic and photonic structures and devices beyond nowadays available solutions.

The results of the fabrication of multi-layers in the ultra-thin regime are depicted in Fig. 1. These structures have been fabricated with the use of equipment for reactive magnetron sputtering available at MND's laboratory facility.

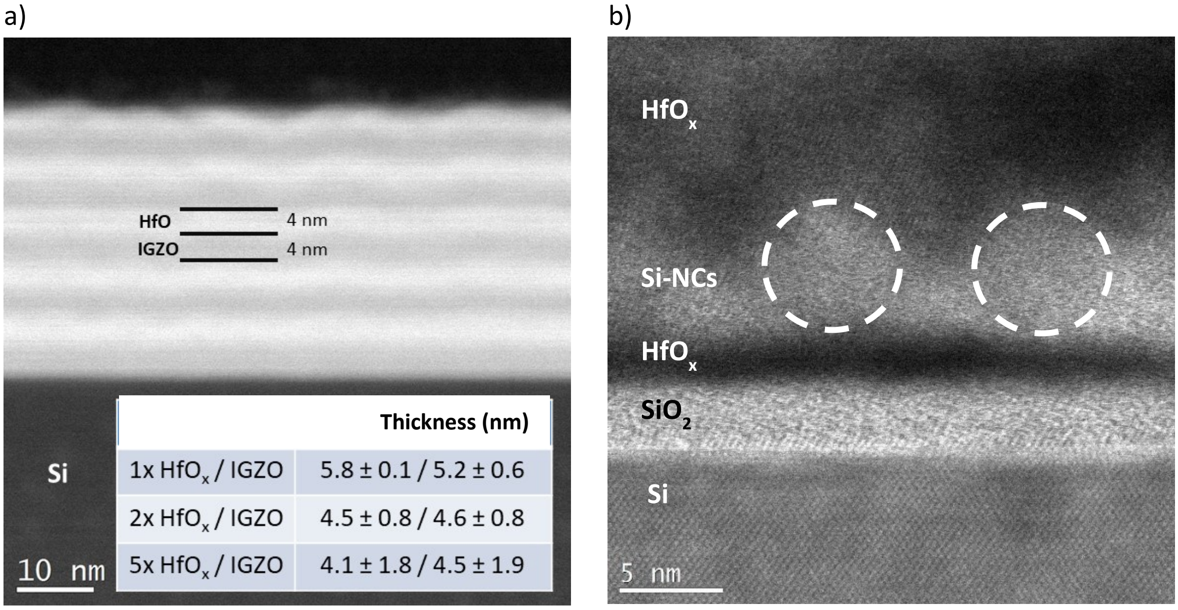

Fig. 1. High-resolution micrographs obtained by Transmission Electron Microscopy (TEM) of multi-layer 'sandwich' structure (5 x HfO_x/IGZO) – (a), and colloidal inorganic silicon nanocrystals (Si-NCs) embedded in hafnium dioxide (HfO_x) dielectric ensemble – (b).

Photolithography based on SUSS MJB4 allows for patterning definition in photoresists and alignment on differently shaped substrates from 5mm x 5mm up to regular 4" wafers. Dry etching techniques (RIE) provide the possibility to achieve pattern resolution down to nanometers regime. Optionally, the lift-off technique is also available. The laboratory is also capable of performing deep anisotropic etching of silicon.

The characterization and diagnosis laboratory at our disposal allows for electrical measurements of fabricated test devices. There can be measured static current-voltage characteristics (I-V), the quasi-static and high-frequency capacitance-voltage (C-V) characteristics and pulse measurements e.g. charge pumping (C-P) current, as well as admittance characterization Y(ω) in the range of 10 mHz – 30 MHz. Based on the analysis of these characteristics a number of basic electro-physical parameters can be calculated. The electrical measurements are performed with the Keithley 4200 and/or Agilent B1500 Semiconductor Characterization System equipped with unique SUSS PM-8 Probe Station, which enables temperature-dependent measurements (in the range of –60°C up to 200°C). The aforementioned apparatus permit a comprehensive characterization of electro-physical properties of investigated semiconductor devices.

Spectroscopy ellipsometry can be used for the determination of the thickness of obtained dielectric and conductive layers. Modern Jobin-Yvon ellipsometer, allowing wide measuring range of 190 – 850 nm is available. Research and characterization capabilities of this apparatus are invaluable since it helps not only the independent study of film thickness and its optical properties but also the estimation of the chemical composition after application of appropriate theoretical models.

The characterization capabilities can be easily extended due to the collaboration with other research teams within the Institute of Microelectronics and Optoelectronics, as well within the University. As an example, our partners provide advanced tools for structural characterization of fabricated materials and structures (High-Resolution Scanning Electron Microscopy – HR-SEM, High-Resolution Transmission Electron Microscopy – HR-TEM, or Atomic Force Microscopy – AFM). The optical properties can be also investigated with the use of spectroscopic methods.

The presented competences allow us to be a part in the research concerned "NOEMS", including:

a. **Fabrication of novel semiconductor, dielectric and conductive materials, including amorphous and transparent semiconductors, and high-k dielectric layers by means of magnetron sputtering, ALD process or plasma techniques**
b. **Optimization of electrical and optical properties of fabricated materials using Design-of-Experiments (DoE) method in order to obtain tailored properties (transparency, reflection, etc.) of obtained layers, that can be used in novel nanophotonic structures which possess tailorable and dynamically controllable spectral and angular optical properties**
c. **Advanced design and modeling of semiconductor and photonic structures using in-house software development capabilities based on well-established models of electromagnetic fields interaction with matter**
d. **Design, modeling and fabrication of nano-photonic multi-layer and metamaterial structures in thin- and ultra-thin regime (especially planar tunable hyperbolic metamaterials) based on novel semiconductor, dielectric, and conductive materials**
e. **Integration of 2D materials (molybdenum sulfide – MoS2, and graphene) and nanocrystals (Si, SiC) for modern optoelectronic and photonic structures**
f. **Research and development activities in the field of artificial-intelligence-based design and optimization of novel photonic structures, which might include neural-network-assisted inverse design**
g. **Electrical (bulk properties, interface properties, contact properties, DC and high-frequency range, pulse measurements, charge-pumping) and structural characterization (surface properties, cross-section, chemical composition, and topography) of fabricated materials and multi-layer structures**
h. **Design and assembly of dedicated measurement tools, power supplies, and embedded systems with the integrated optoelectronic and photonic devices; SMD assembly and reliability tests**

I'm strongly confident that investigators from MND have the knowledge and skills needed to carry on the collaboration within this application. Long years of experience in modeling, fabrication, as well as characterization and diagnostics of the semiconductor devices and photonic structures along with the research infrastructure at their disposal, provide a strong basis for the ultimate R&D success.

Thank you for your time.

Robert Mroczyński