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zernike institute for  
 advanced materials

# NWO Graduate Program in Advanced Materials

## Organic-Inorganic Hybrid Perovskites: Physical Properties and Optoelectronic Devices

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PhD. Proposal submitted to  
 Zernike Institute for Advanced Materials  
 Faculty of Mathematics and Natural Sciences  
 University of Groningen

By

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 Top Master in Nanoscience  
 (S2300664)

February 2014

## Research Proposal

### 1. TITLE OF THE PROJECT

Organic-Inorganic Hybrid Perovskites: Physical Properties and Optoelectronic Devices

### 2. ABSTRACT

Recently, organic-inorganic hybrid perovskite materials have become pre-eminent in photovoltaic technology because of the high light-harvesting capabilities demonstrated in perovskites such as  $\text{CH}_3\text{NH}_3\text{PbX}_3$  ( $\text{X} = \text{Cl}, \text{Br}, \text{I}$ ). These perovskite absorbers are prepared from low-cost and abundantly available components, which allow cheap photovoltaic devices. The power conversion efficiency of solar cells based on these materials exceeds 15% over the past four years. Nonetheless, the physical mechanisms driving the high efficiencies in these solar cells are unknown. In this project, we propose to study the physical properties of these materials and devices to uncover the fundamental mechanisms responsible for their exceptional performances in solar cells. A combination of various microscopy, spectroscopy and electrical characterization techniques will be used.

### 3. APPLICANT

Sampson Adjokatse

Prof. dr. Maria A. Loi (1<sup>st</sup> Promotor)

### 4. INSTITUTE

Photophysics and OptoElectronics Group (POE)

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## 5. DURATION OF THE PROJECT

The project will start in September 2014. The duration will be 4 years.

## 6. PERSONNEL

The research will be conducted in the Photophysics and OptoElectronics research group of the Zernike Institute for Advanced Materials, in collaboration with Solid State Materials for Electronics research group. The project will be carried out with support and assistant from the following personnel:

### 6.1. Senior scientist(s)

Name	Task in Project	Time
Prof. dr. Maria A. Loi	Supervision and management	10%
Prof. dr. Thomas T.M. Palstra	Supervision	2%

### 6.2. Junior scientist(s) and technicians

Name	Task in Project	Time
Sampson Adjokatse	Experiments and analysis	100%
Daniel Balazs	Experiments and analysis	10%
Dr. S. Z. Bisri	Supervision and analysis	5%
Dr. Hong-Hua Fang	Experiment and Analysis	5%
Arjen Kamp	Technical support	10%

## 7. COST ESTIMATES

### 7.1. Personnel positions

One 'onderzoeker in opleiding' position for 4 years.

### 7.2. Running budget

15 k€ per year for consumables laboratory maintenance, conference attendances and summer schools.

### 7.3. Equipment

#### 7.3.1. Available equipment

Solution based deposition techniques (spin coater, blade coater, dip coater)

UV/Vis/NIR Spectrophotometer (Shimadzu UV-3600)  
 Thermal evaporator for deposition of different metals  
 AM 1.5G Solar simulator  
 External quantum efficiency set up  
 Semiconductor Parameter Analyzer (Agilent E5270B)  
 Keithley 2400 SourceMeter  
 Ti:Sapphire Laser & Hamamatsu Streak Cameras  
 Laser Scanning Confocal Microscope  
 Atomic force microscope (Multimode AFM Nanoscope IIIa SPM Controller)

### 7.3.2. Required equipment

No additional budget is required for new equipment.

### 7.4. Infrastructure and other support

The Zernike Institute for Advanced Materials, Rijksuniversiteit Groningen, is a multidisciplinary scientific institute with laboratories equipped with state of the art facilities that can be accessed by its members. This project will be conducted in the Zernike institute and access to the clean room and laboratory facilities for sample preparation and measurement (fume hood, flow box, glove box with solution based deposition techniques) maintained by the Chemistry of (Bio)organic Materials and Devices research group, Photophysics & OptoElectronics (POE) research group and the NanoLab Groningen (member of NanoLab NL network) will be provided. Laboratory and measurement facilities for materials synthesis and fundamental characterization will be provided by our collaborators (Solid State Materials for Electronics research group), also in the Zernike Institute.

### 7.5. Budget summary (in k€)

The expenses are summarized in the table below, all related consumables will be provided by the Photophysics and OptoElectronics research group.

	2014	2015	2016	2017	2018	<b>Total</b>
Personnel (positions)						
PhD student	4/12	1	1	1	8/12	4
Postdoc	-	-	-	-	-	-

Technician	-	-	-	-	-	-
Guests	-	-	-	-	-	-
Personnel Costs (in k€)	15	50	50	50	35	200
Running Budget (in k€)	6	15	15	15	9	60
Equipment (in k€)	-	-	-	-	-	
<b>Total</b>	21	65	65	65	44	260

## 8. RESEARCH PROGRAMME

### 8.1. Introduction

Concerns about environmental pollution, exhaustion of fossil fuels and increasing global crisis have accelerated the search for clean and cheaper renewable energy sources in the past decades. Arguably, the most abundant clean source of sustainable energy that is capable of yielding sustainable economic growth with minimum detrimental impact of the environment is sunlight. Nevertheless, the challenge in harnessing this energy is the development of low cost, efficient and stable photovoltaic (PV) devices. Besides the commercially available crystalline silicon-based solar cells, which continue to advance in efficiency and reduce in cost of fabrication over the past four decades [1], there are many other newer solar cell technologies that promise lower cost solar power. One of such emerging PV technologies, which promise to be a serious contender for utility-scale solar power is the solution-processed hybrid perovskite-based solar cell technology [2-10].

Perovskite materials constitute a very important niche within materials science displaying a multitude of properties including insulating, antiferromagnetic, piezoelectric, thermoelectric, semiconducting, conducting, colossal magnetoresistance, ferroelectricity and superconducting [11,12]. They are a class of materials that adopt the same crystal structure as calcium titanate ( $\text{CaTiO}_3$ ) with the generic formula,  $\text{ABX}_3$  where the A and B sites usually accommodate inorganic cations of various valency and ionic radius and the X site accommodates anions (halogen or oxygen). By replacing the A cations with suitable organic species, a sub-family of organic-inorganic hybrid perovskite is created [11].

Organic-inorganic halide perovskite materials have attracted much attention recently due to the impressive high efficiencies recorded in perovskite-based photovoltaic over a very short period since the seminal work of T. Miyasaka and co-workers in 2009 [3]. The crystal structure of these materials is composed of an octahedrally coordinated lead (Pb) atom with corner-sharing halogens

and A-site organic ligands [Fig. 1(left)]. Presently, the crystallographic data on the precise position of the organic ligands are not known. Fig. 1(right) shows the comparison of the impressive rate of increase in the perovskite-sensitized solar cell (PSSC) efficiencies with leading second-generation solar cells: amorphous-silicon (a-Si), dye-sensitized solar cells (DSSCs) and organic photovoltaic (OPV). Perovskite-sensitized solar cells have emerged from the field of dye-sensitized solar cells (DSSCs) [14]. This emergence was motivated by the quest to find more advanced materials which absorbs strongly over a broader range than conventional dyes and also combines good optical absorption characteristics with efficient charge-transport properties. The first perovskite-sensitized solar cell was reported by T. Miyasaka's research group and had power conversion efficiency (PCE) of 3.8%, employing mesoporous  $\text{TiO}_2$  sensitized with methyl ammonium lead triiodide ( $\text{CH}_3\text{NH}_3\text{PbI}_3$ ) absorber and filled with iodide/triiodide redox couple [3]. Later, Park's research group optimized the titania surface and the perovskite processing and recorded more than double efficiency (6.5%) in liquid electrolyte-based  $\text{CH}_3\text{NH}_3\text{PbI}_3$ -sensitized solar cell [8]. Subsequently, solid-state perovskite-sensitized solar cells were developed employing organic p-type hole conductor, namely 2,2',7,7'-tetrakis-(*N,N*-di-*p*-methoxyphenylamine)9,9'-spirofluorene(Spiro-OMeTAD) as a hole transporter and methyl ammonium lead iodide chloride ( $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$ ) perovskite or  $\text{CH}_3\text{NH}_3\text{PbI}_3$ . These devices yielded between 8 and 10% maximum sun power conversion efficiencies respectively [4,2].

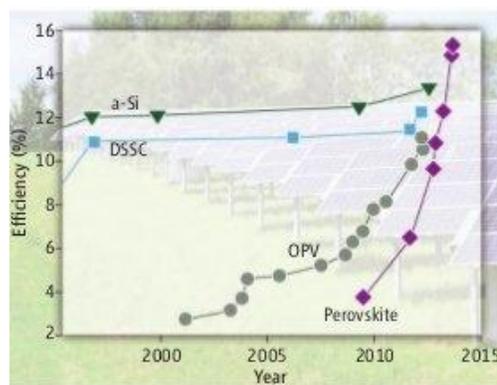
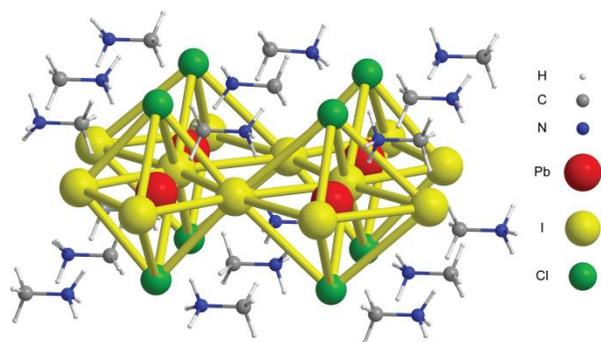


Figure 1. Possible crystal structure of the hybrid perovskite  $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  [16]. **(Left)** Comparison of the rate of increase in perovskite solar cell efficiencies with leading second generation solar cells: amorphous silicon (a-Si), dye-sensitized (DSSC) and organic (OPV). Adapted from [13] **(Right)**

The impressive power conversion efficiencies recorded based on the hybrid halide perovskite materials and the drive to achieve lower cost and higher efficiencies has resulted in various device

architecture modifications (Fig. 2). This has led to the replacement of the original DSSC geometry with the mesoporous  $\text{TiO}_2$  with other simpler device structures. For example, in the studies of Kim *et al.* [4] and Heo *et al.* [15], the thin perovskite layer was sandwiched between a n-type mesoporous  $\text{TiO}_2$  photoanode and a p-type hole transporting layer such as Spiro-OMeTAD. Lee *et al.*, replaced the electron-accepting mesoporous  $\text{TiO}_2$  with insulating  $\text{Al}_2\text{O}_3$ , which acts as a scaffold instead of an electron-accepting layer and recorded faster charge transport, implying a good electron transport property of the perovskite and obtaining 10.9% efficiency. They also measured an increase in the open-circuit voltage ( $V_{oc}$ ) by 200 to 300 meV [2]. Etgar *et al.*, have also demonstrated good hole-transport properties in a simple two-component  $\text{TiO}_2$ -  $\text{CH}_3\text{NH}_3\text{PbI}_3$  solar cell with 5.5% efficiency but lower  $V_{oc}$  [9]. These studies indicate the ambipolar charge transport capabilities of  $\text{CH}_3\text{NH}_3\text{PbI}_3$  and other hybrid perovskite materials studied [6]. Thus, perovskite materials have the capabilities of not serving only as a light harvester but also as a charge-carrier transporter. Very recently, the use of compact electron-transport layer based on ZnO nanoparticles resulted in 15.7% efficiency [7].

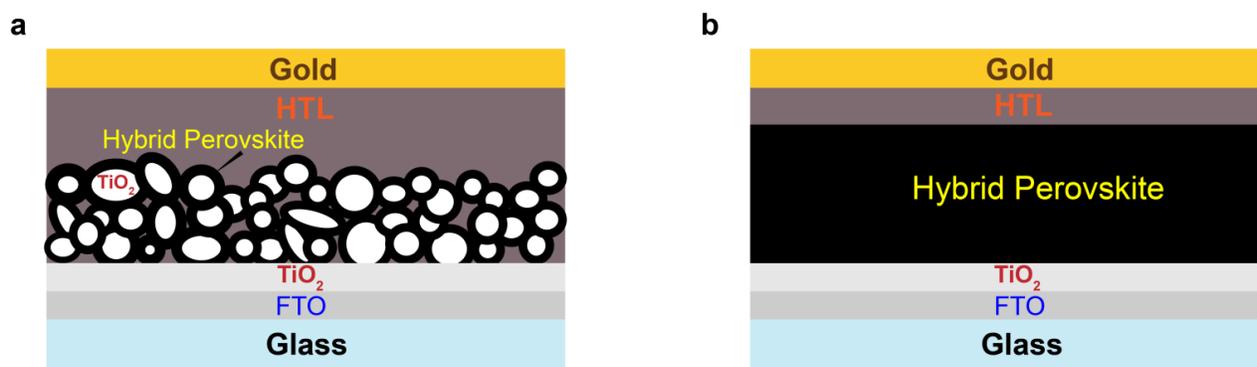


Figure 2. Two architectures of hybrid perovskite solar cells. (a) Hybrid perovskite solar cell on mesoporous  $\text{TiO}_2$ , (b) Planar hybrid perovskite solar cell. [16]

To understand the fundamental photophysical mechanisms underlying the remarkable performance of these materials, independent investigations by Snaith's research group [14] and Nripan Mathews and collaborators [15] on the dynamics of the photoexcited species showed that the electron-hole diffusion lengths in solution-processed  $\text{CH}_3\text{NH}_3\text{PbI}_3$  exceeds 100 nm. Snaith and co-workers also measured values of the diffusion length exceeding 1  $\mu\text{m}$  for the  $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  mixed halide perovskite, an order of magnitude greater than the already remarkably high value of 100 nm for the pure iodide. Hence, giving that one of the bottleneck for low efficiencies in low-temperature solution-processed photovoltaic is poor exciton or electron-hole diffusion lengths which are typically about 10 nm, this high values measured in the hybrid perovskites heightens the hope to

push the efficiency toward that of thin-film copper indium gallium selenide (CIGS) cells (PCE of 20.4%) and then toward and beyond that of single crystalline silicon devices (PCE of 25%).

Current perovskite absorbers producing these remarkable high efficiencies have band gap energy around 1.55 eV (corresponding to photon absorption at 800nm) and photovoltage of 1.1 V as reported by Snaith's group [2]. This implies that the energy loss which is 0.45 eV, may be due to electron injection or hole extraction or both, in which case, the loss by electron injection or hole extraction is about 0.23 eV. If the perovskite material acts as not only a light harvesting material but also as an electron (hole)-transporting material, then the photovoltage will be determined (apart from about 0.3 – 0.35 V losses) by the difference between the Fermi energy of the perovskite material and the valence (conduction) band energy of the hole (electron)-transporting material. Thus, a perovskite layer that acts as both light harvester and ambipolar charge-carrier transporter can potentially achieve photovoltage exceeding 1.1 V. Similarly, further improvement in the quality of the active material with higher mobilities can result in fill factors (FF) exceeding 0.7.

## 8.2. Main Goals and Research Questions

In spite of the steep increase of the power conversion efficiency in perovskite-sensitized photovoltaic devices over a very short period from April 2009 to January 2014, where the beginning PCE of 3.8% has rapidly improved to 15.7%, this technology is still suboptimal. Among the diverse limitations such as light reflection by the substrates (transparent conducting oxides, glass, quartz, etc.) and the lack of better charge transporting layers, the main limitation to optimal performance is due to the large-scale inhomogeneity (and reproducibility) in film uniformity and layer thicknesses. On the other hand, the mechanisms underlying such exceptional performances are not clearly understood. Therefore, the main goals of this proposed research are in two-fold. *Firstly, to investigate the physical properties of the hybrid perovskites by studying the fundamental photophysical mechanisms that makes hybrid perovskites promising for solar energy conversion and other electronic applications. Secondly, to strategically optimize the hybrid perovskites through better control over all the processing parameters and device configuration to enhance performance, reproducibility and stability.* To achieve these goals, we put forward the following fundamental questions that need thorough studies.

1. What is the exact chemical composition and structure of hybrid perovskites and how does it influence the behaviour of charge-carrier transport?
2. What is the stability of hybrid perovskites and what can be done to change the chemical

composition to increase it?

3. How can the morphology of these hybrid materials be controlled in thin films?
4. What are the charge transport properties?
5. What is the role of each interface in the device architecture?
6. Is it possible to reach analogous optical and electrical performance using lead-free hybrid compounds, thus reducing the toxicity and environmental impact of this future technology?

### **8.3. Research Methodology**

To answer the research questions above, we shall study the physical properties of the hybrid perovskite. We shall also fabricate field-effect transistor and solar cell devices based on these materials and investigate their working mechanisms. Microscopy and spectroscopy techniques in combination with other structural and charge-transport characterization methods will be employed. Various organic-inorganic hybrid perovskites will be studied. In particular, we shall study pure and mixed organolead trihalide hybrid perovskites with methylammonium (MA) or formamidinium (FA) organic cations, which have shown very impressive power conversion efficiency as active layer of solar cells.

#### **Chemical Composition**

The formation of hybrid perovskites from precursor solutions and the conditions under which they are formed are critical to the materials physical properties. Similarly, the presence and absolute amounts of the components (precursors) in the sample can affect its properties. The materials performance may also depend on the crystallinity of the perovskite absorbers. For instance, results from ongoing work in our research group show that large variations of crystal dimensions are occurring during the precursors reaction. In order to understand and control the effect of the exact chemical composition, crystallinity and structure of the perovskite materials on the transport behaviour of the photoexcitations, we will utilize X-ray diffraction (XRD) analysis. This will aid to provide information about the chemical composition and crystallinity, and measure structural parameters of the materials.

#### **Morphology and Stability**

The effective transport of charge carriers requires a homogeneous and continuous structure of the active layer. This means that the morphology of the active layer thin film is crucial to the performance of the device. For instance, pinholes and cracks in the active layer can greatly affect

the performance of the device [20] or even shortcut the electrodes. Fig. 3 gives the SEM of the morphology of pristine  $\text{CH}_3\text{NH}_3\text{PbI}_3$  and  $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  films on glass [17]. Similarly, optical micrographs from our preliminary samples ( $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  films) made on either glass or poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) on indium tin oxide (ITO/PEDOT:PSS) are shown in Fig. 4. These images illustrate the inhomogeneous and incomplete coverage of the perovskite film as a result of uncontrolled crystallization of the perovskite, which produces large morphological variations. This limits the maximum capabilities of these materials or the prospects of their practical applications.

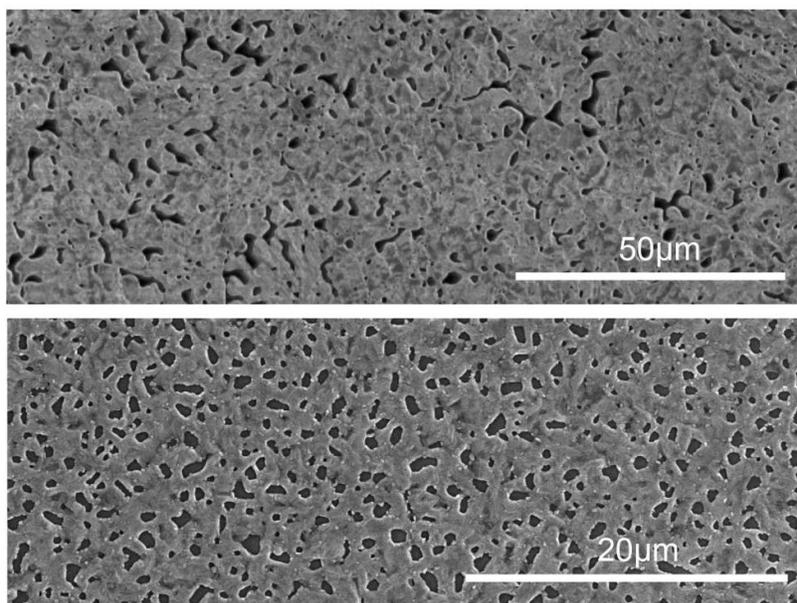


Figure 3. Top view of the morphology of a pristine  $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  (**Top**) and pristine  $\text{CH}_3\text{NH}_3\text{PbI}_3$  (**Bottom**) films formed on glass [17].

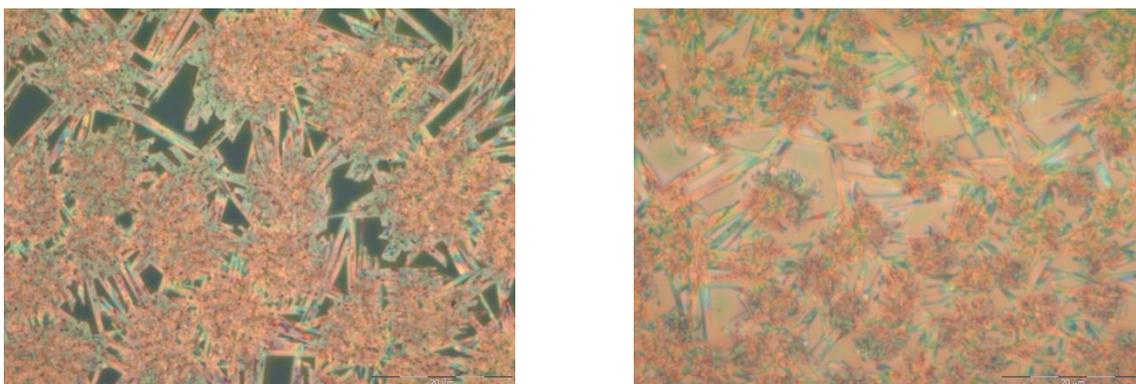


Figure 4. Optical micrographs of the morphology of pristine  $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  (**Left**) and PbS-OA-treated  $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$ ; OA refers to oleic acid (**Right**).

To avoid low-resistance shunting paths, lost light absorption and enhance the efficiency in the solar cell, we will investigate the effect of morphology on material and device performance to strategically optimize the perovskite film formation. Different solution-based deposition techniques such as spin coating, which is fast but results in non-equilibrium structures and blade coating, which can be used to produce thin films on large areas will be employed. With the spin coating method, the quality of the thin film can be optimized by adjusting spinning parameters such as acceleration, spinning speed, spinning time, concentration and temperature of the solvent, vapour pressure of solvent, etc. The parameter optimization in blade coating has a larger optimization space; speed, temperature of the substrate, and the gap between the blade and the substrate can be optimized. Precision layer-by-layer technique such as dip coating, which provides ordered monolayer deposition will also be used in this study. Other processing parameters such as atmosphere, annealing temperature, film thickness, solvent and mass evaporation and transport rate will be controlled. These processes will enable us to understand the crystallization process. Knowing the effect of these parameters and techniques, we will be able to achieve the desired perovskite coverage and smoothness.

Beside the deposition techniques described above, the morphology can be improved by modifying the perovskite film in a heterostructure. As was done for  $\text{TiO}_2$ , we propose to use semiconducting nanocrystals (NCs) as a scaffold to improve the perovskite morphology and to enlarge the active layer absorption.

### **Photoexcitation Dynamics**

Qualitative and quantitative information about the electronic structure and the dynamics of the photoexcited species in these materials will be obtained by optical spectroscopy. Absorption spectroscopy will be used to measure the transitions between the electronic states and to obtain information about the absorptivity and band gap of the materials. Transient-absorption spectroscopy will be used to separately identify the dynamics of charge carriers and provide information about the influence of the chemical composition and the behaviour of the photoexcited species. This method will also be used to measure electron-hole diffusion lengths.

A very informative technique to investigate the electronic structure of the samples is photoluminescence (PL) spectroscopy (steady-state and time-resolved PL). The intensity and spectral content of the emitted PL is a measure of various important material properties including

quantum yield, defect states, and recombination mechanisms. Thus, the material quality, carrier lifetime, purity and degree of crystallinity will be evaluated by measuring the PL intensity, peak energy and linewidth respectively. In particular, time-resolved photoluminescence (TRPL) will be used to provide information about the dynamics of ongoing processes upon excitation. The nature of the excited states and the understanding of possible energy losses can be obtained by analyzing the decay time of the excitations. Based on the relation between the chemical composition and lifetime of the photoexcitations, we will be able to strategically optimize the material. New semiconducting hybrid perovskites will be designed with a wide range of organic and inorganic components. Organic ligands beside methylammonium and formamidinium will be investigated. Moreover, since lead compounds are undesirable for environmental reasons, lead-free hybrid perovskites will be designed by replacing Pb atom with non-toxic atoms with similar outstanding properties such as but not limited to Cu and Sn.

### **Charge-Carrier Transport**

For improved performance in the photovoltaic cells, efficient transport of the charge carriers within the hybrid perovskite material is especially critical. Therefore, the charge transport properties, particularly carrier mobility and charge trapping will be described using field-effect transistor (FET) configuration. In this case, the current between two electrodes is modulated by a third electrode (gate), which allows electron or hole enhancement, providing an easy way of separate and precise investigation of both charge carrier transport.

Since our main interest is in the fabrication of efficient solar cells, the main electrical characterization method is the description of light conversion in actual devices. For this reason, solar cells based on the perovskite materials will be fabricated and current-voltage (I-V) characteristics of the devices will be obtained. From the I-V characteristics, important parameters such as the short-circuit current density ( $J_{sc}$ ), open-circuit voltage ( $V_{oc}$ ) and the fill factor (FF) will be measured to determine the efficiencies of the materials and devices.

### **8.4. Research Plan**

The research plan is summarized in the table below. However, deviation from this scheme is possible as a result of unexpected problems or interesting discoveries that might open up new opportunities and lead to new directions.

<i>1-6 months</i>	<i>Investigation of chemical composition and structure of solution-processed organic-inorganic hybrid perovskite samples. Attendance of summer or winter school.</i>
<i>6-12 months</i>	<i>Investigation and optimization of morphological properties of hybrid perovskite samples. Optical measurement. Writing scientific publication.</i>
<i>12-18 months</i>	<i>Optimization, stability study and spectroscopic investigation of hybrid perovskite samples. Attendance of international conference.</i>
<i>18-24 months</i>	<i>Investigation of charge transport properties. Writing scientific publication.</i>
<i>24-30 months</i>	<i>Fabrication, characterization and optimization of hybrid perovskite-based solar cells. Attendance of international conference.</i>
<i>30-36 months</i>	<i>Investigation of the role of interface in the device architecture and optimization of device configuration to enhance efficiency. Writing scientific publication. Attendance of international conference.</i>
<i>36-42 months</i>	<i>Do complementary experiments or new experiments if needed. Writing scientific publication.</i>
<i>42-48 months</i>	<i>Writing scientific publication and PhD thesis.</i>

## 9. APPLICATION PERSPECTIVES

The high demand of industry and society for cheap, clean and safe energy drives the need to replace carbon-, oil- and gas-based energy production. Hence, there is the need for efficient, stable and cheap photovoltaic devices to harness solar energy, which is arguably the most abundant clean source of sustainable energy. To achieve this, materials with low cost and good optical absorption characteristics with efficient charge-transport properties are required.

This study on organic-inorganic hybrid perovskite materials and devices is a step in the right direction to finding a long lasting solution to the energy needs of industry and society. These materials exhibit high absorption characteristics with exceptional device performance exceeding 15%, recorded in less than four years since it was first used in a solar cell device that yielded 3.8% efficiency. The precursor materials are inexpensive and at the same time, easy to synthesize. They can be processed with solution-based techniques at low-temperature, such as spin-coating, blade-coating, dip-coating or printing. Some of these materials have been shown to exhibit ambipolar transport, allowing the possibility to replace the hole and electron transporter in the hybrid cells, thereby simplifying the

device architecture. Thus, from the production point of view, devices based on these materials will ultimately lead to less expensive photovoltaic technology. This holds the promise in fulfilling the energy need of both industry and society.

On the other hand, results from this project will stimulate further research and development in other fields beside optoelectronics, materials science, materials chemistry, solid-state and device physics. This will pave the way for the development of new materials with fascinating physics and chemistry. It will also lead to development of other electronic devices beside the less expensive photovoltaic technology it promises, and possibility to apply the same materials in memories (thanks to the ferroelectric properties) or as emitters in the NIR range.

**10. REFERENCES**

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## CURRICULUM VITAE

### SAMPSON ADJOKATSE

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Groningen, The Netherlands  
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### Career Objective

To become a research professional and embrace research in academia and/or industry where my knowledge and professional experience will fully be shared and to effectively contribute to scientific knowledge.

### Personal Profile

Date of Birth: December 14, 1980  
Sex: Male  
Nationality: Ghanaian

### Education

Sept., 12 – present **M.Sc. Nanoscience** (*in progress*), University of Groningen, The Netherlands  
Jul., 08 – Dec., 09 **M.Sc. Theoretical Physics**, African University of Sc. & Tech., Nigeria  
Aug., 02 – May, 06 **B.Sc. (First Class Honors)**, Computer Sc. and Physics, Univ. of Ghana, Legon

### Current Research Interests

- Physical and optoelectronic properties of organic-inorganic hybrid perovskite materials
- Fabrication of optoelectronic devices composed of inorganic nanocrystals and hybrid perovskites

### Recent Research

Master Project (In progress)	Physical characterization of organic-inorganic hybrid perovskites Photophysics & Optoelectronics Group Zernike Institute for Advanced Materials University of Groningen
Supervisor	<b>Prof. dr. Maria A. Loi</b>
Short Project (Mar. – Jun., 13)	Synthesis, structural, magnetic and dielectric properties of potential new multiferroic materials Solid State Materials for Electronics Group Zernike Institute for Advanced Materials University of Groningen
Supervisor	<b>Dr. Graeme Blake and Prof. dr. Thomas T. M. Palstra</b>

### Teaching / Research History

Feb., 11 – Aug., 12 **Teaching Assistant**, Department of Physics, University of Ghana, Legon  
Feb., 11 – Aug., 12 **Adjunct Lecturer**, Regent Univ. College of Sc. and Tech., Accra, Ghana  
Jul., 10 – Dec., 10 **Research Assistant**, Theoretical Science Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India

Sept., 09 – Apr., 10 **Research Student**, Centre for Computational Materials Science,  
Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India  
Aug., 06 – Jun., 08 **Teaching Assistant**, Department of Physics, University of Ghana, Legon

### Selected Awards, Scholarships & Visitorships

- Zernike Institute Grant for Topmaster program in Nanoscience, 2012-2014
- Centre for Computational Materials Science Fellowship, JNCASR - Bangalore, India, 2010 (Research Assistant)
- Centre for Computational Materials Science Visitorship, JNCASR - Bangalore, India, 2009 (Visiting Research Student)
- AUST Graduate Scholarship, African University of Science and Technology, Abuja, Nigeria, 2008-2009

### Selected Extracurricular and Leadership History

2014 - present **Student Ministry Coordinator**, – Vineyard Groningen International Church

2013/2014 **Vice President**, African Students Community, Groningen

2012/2013 **Organizing Secretary**, African Students Community, Groningen

2008/2009 **Student Union Secretary**, African University of Sc. & Technology, Nigeria

2005/2006 **Assistant General Sports Secretary**, University of Ghana, Legon

2005/2006 **Organizing Secretary**, Computer Science Students Association (COMPSSA),  
University of Ghana

2005/2006 **Chairman**, COMPSSA Technology Week Planning Committee, University of Ghana

2005/2006 **Chairman**, PHYSAG (Physics Students Association of Ghana) Week Planning  
Committee, University of Ghana Branch

### Publications

- **Sampson K. Adjokatse**, Abhishek K. Mishra and Umesh V. Waghmare, Dielectric and Piezoelectric Responses of Nylon-7: An *ab-initio* study, *Polymer* **53** 2751 (2012).
- Nelson Y. Dzade, Kingsley O. Obodo, **Sampson K. Adjokatse**, ..., Umesh V. Waghmare, Silicene and Transition Metal Based Materials: Prediction of a 2-dimensional Piezomagnet, *J. of Phys.: Condens. Matter* **22** , 375502 (2010).

### References

Prof. dr. Maria A. Loi

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## Declaration of hospitality and financial support for research costs

Appendix to the Proposal for a PhD research position  
 in the NWO Graduate Programme Advanced Materials, deadline 2 Feb. 2014

Name of the applicant:

SAMPSON ADJOKATSE

Title of the proposal:

Organic-Inorganic Hybrid Perovskites:  
 Physical Properties and Optoelectronic Devices.

By signing this document the staff member declares that she/he is willing to host and supervise the PhD research project that is mentioned above. In addition, the staff member declares that she/he has and makes available the materials, infrastructure and the funding that is needed for covering the research costs (the costs in addition to the salary of the PhD student some funding for travel and training), as described in the proposal.

The signing staff members must be affiliated with the Zernike Institute for Advanced Materials (including the associate members).

Signatures

*Applicant (the student applying for the PhD grant)*

Date:

20/01/14

Name:

Sampson Adjokatse

Signature:

*Daily PhD supervisor (only needed if applicable, in case of supervision by an assistant professor or UD/UHD without ius promovendi)*

Date:

Name:

Signature:

*1<sup>st</sup> Promotor (staff member with ius promovendi)*

Date:

30/01/14

Name:

M.A. Lei

Signature: