



Master in Photonics – “PHOTONICS BCN” Master ERASMUS Mundus “EuroPhotonics”

MASTER THESIS PROPOSAL

Laboratory: Department of Electronics and Biomedical Engineering

Institution: University de Barcelona (UB)

City, Country: Barcelona, Spain

Title of the master thesis: Influence of Electron Mobility on the Performance of Inkjet-Printed Graphene–Perovskite Hybrid Photodetector.

Name of the master thesis supervisor and co-supervisor:

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Scholarship: Eligible for a scholarship

Keywords: Perovskites, graphene, inkjet printing, photodetectors, wearable applications, electron mobility

Objective:

To investigate the influence of varying electron mobility on the performance of graphene-perovskite hybrid photodetectors via inkjet printing.

1. Summary of the subject (maximum 1 page):

Inkjet printing is emerging as a superior alternative to traditional lithography for flexible, stretchable, and sustainable electronics due to its precision, scalability, cost-effectiveness, and eco-friendly nature [1], [2], [3]. Conductive inks based on materials such as silver, graphene, or carbon nanotubes enable precise control over conductivity, print quality, and adhesion, essential for advanced device fabrication (Fig. 1). Perovskites, with their strong light absorption, tunable bandgap, and defect tolerance, further enhance optoelectronic performance and are well-suited for inkjet-printed solar cells, LEDs, and photodetectors [4]. When integrated with graphene, renowned for its high carrier mobility, perovskites enable fully printed, high-performance photodetectors. This combination leverages perovskites' optical properties and graphene's electronic characteristics to create novel device architectures for energy, display, and sensing applications. A typical device structure is illustrated in Fig. 2. The solution processability of both materials allows the formulation of printable inks, where sequential deposition forms interfaces that induce photoluminescence quenching and convert light into electrical signals. The resulting photocurrent, proportional to illumination intensity, depends strongly on the printed layer properties, among which the electron mobility play a key role as shown in equation (1) From this relationship, it is evident that varying the carrier mobility μ plays a critical role in enhancing the responsivity of photodetectors, as it directly contributes to the amplification of the photocurrent especially in devices operating based on photoconductive mechanism.

$$R_{ext} = \frac{I_p}{P_{in}} \frac{\tau_{life} \mu V_{ds}}{L^2} \quad (1)$$

Where

R_{ext} = External responsivity (A/W),

I_p = Photocurrent (A), i.e., the current generated due to light exposure,

P_{in} = Incident optical power on the active area of the device (W),

τ_{life} is the carrier lifetime,

μ is the charge carrier mobility,

V_{ds} is the source-drain bias voltage,

L is the channel length, and

$\frac{\tau_{life} \mu V_{ds}}{L^2}$ also known as gain

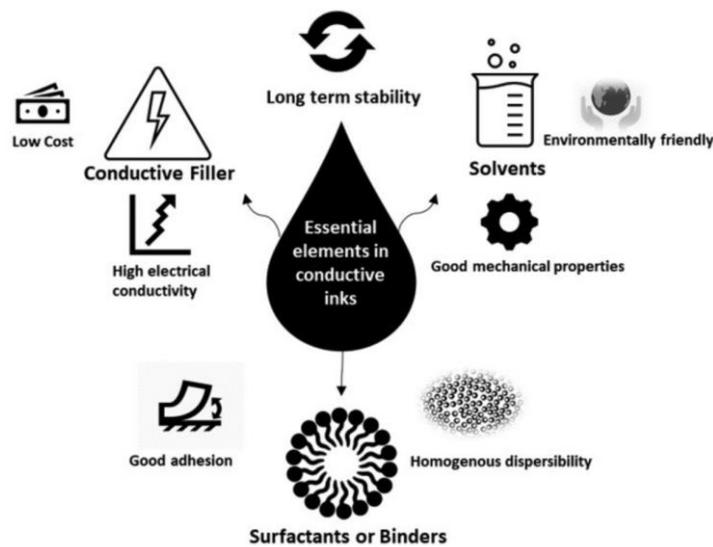


Fig 1. Summary of the most essential elements and properties considered for conductive inks preparations [5]

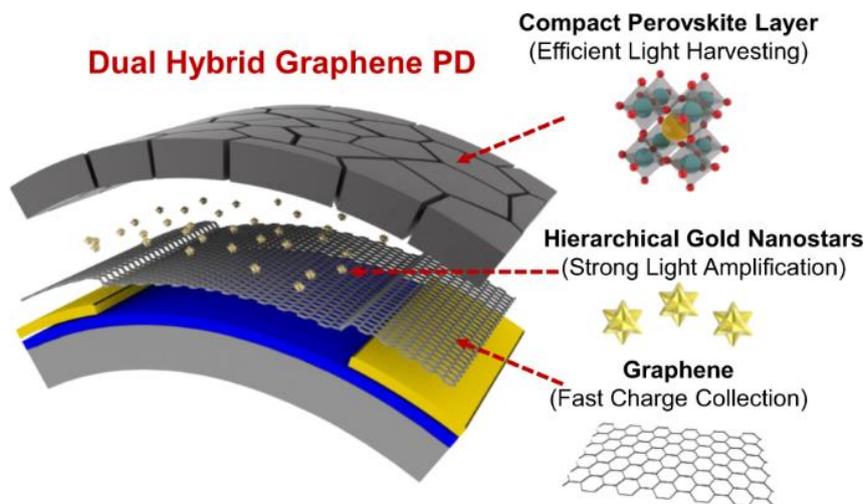


Fig 2. Illustration of typical device structure [6].



The master student will be integrated in the ongoing European Union project “PIXIE SENS” to continue the project related to fabrication of photodetector with varying electron mobility of graphene. In principle the student will be involved in ink formulations, inkjet printing and studying the effect of varying electron mobility on the performance of fully inkjet printed graphene-perovskite hybrid photodetector devices on various substrates such as polyester, glass and polyimide for wearable and sensing applications.

2. Workplan and timeline:

Sr. No	Timeline (months)	1 st	2 nd	3 rd	4 th	5 th	6 th
1	Literature Review						
2	Starting hypothesis and objectives						
3	Formulation of conductive and active inks						
4	Inkjet printing process optimization						
5	Device fabrication : electron mobility modification and device fabrication						
6	Characterization, testing and interpretation						
7	Final report, thesis writing and presentation						

3. Key learning outcomes

- Mastering of inkjet printing techniques and other fabrication techniques like spin coating and evaporation
- Integration of physics, materials science, optoelectronics and photonics
- Analytical and characterization expertise including material properties, lasers, detectors and optoelectronic measurements
- Project management and research skills
- Innovation and problem solving in cutting-edge technologies
- Working in an international group with possibilities of continuing research activities

4. References:

- [1] J. Khan *et al.*, “Flexible and highly selective NO₂ gas sensor based on direct-ink-writing of eco-friendly graphene oxide for smart wearable application,” *Chemosphere*, vol. 367, p. 143618, Nov. 2024, doi: 10.1016/j.chemosphere.2024.143618.
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- [3] J. Khan, M. Mariatti, S. A. Zubir, A. Rusli, A. A. Manaf, and R. K. Khiretdin, “Eco-friendly alkali lignin-assisted water-based graphene oxide ink and its application as a resistive temperature sensor,” *Nanotechnology*, vol. 35, no. 5, p. 055301, Jan. 2024, doi: 10.1088/1361-6528/ad06d4.
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- films via inkjet printing and its application in colour conversion layers,” *Nanoscale*, vol. 17, no. 30, pp. 17803–17815, Jul. 2025, doi: 10.1039/D5NR01385B.
- [5] Y. Z. N. Htwe, M. Mariatti, and J. Khan, “Review on solvent- and surfactant-assisted water-based conductive inks for printed flexible electronics applications,” *J. Mater. Sci. Mater. Electron.*, vol. 35, no. 18, p. 1191, Jun. 2024, doi: 10.1007/s10854-024-12927-4.
- [6] Y. H. Lee *et al.*, “Flexible high-performance graphene hybrid photodetectors functionalized with gold nanostars and perovskites,” *NPG Asia Mater. 2020 121*, vol. 12, no. 1, pp. 1–12, Dec. 2020, doi: 10.1038/s41427-020-00260-1.

I joined the University of Barcelona (UB) as a professor in 1995 (full professor 2011). My research between 1995 and 1999 focused on materials for microelectronics. In a second phase, between 1999 and 2009, I established myself as a group leader and initiated several research projects (as a Principal Investigator) in optoelectronic devices and materials. In my first European project as a Principal Investigator (SINERGIA, 2000), I delved into integrated photonics. Subsequent European projects in FP6 and FP7 as a Principal Investigator and as a Work Package leader in the fields of photonics and integrated optoelectronics included PHOLOGIC and LANCER. My first national project as a Principal Investigator was NANOMEM(2001), focusing on Si nanocrystals and nanomemories, which I continued with other projects as a Principal Investigator and coordinator (NANOSIGE, OASIS, SILUZ). During this phase, I supervised 6 doctoral theses and 10 research projects.

The third phase encompasses the period from 2010 to the present day. My consolidated group, GEF (Electro-Photonics Group), increasingly focuses on photonic and photovoltaic devices and applications, as well as LED lighting systems. I enhanced international visibility through my role as a Principal Investigator and Work Package leader in numerous European projects (HELIOS, NASCENT, MULTISCALE SOLAR, FET Open Phenomen, and currently FET Open Drop it) and national projects (LASSI, LEOMIS, SENA, METALONIC, and currently PRITES). During this phase, I supervised 11 doctoral theses and numerous third-cycle research projects, master's theses, and undergraduate theses. With the material and human resources obtained from various competitive projects, I established and equipped several research laboratories with analysis and fabrication techniques: i) Optoelectronics, ii) Photonics, iii) Photovoltaic devices, iv) Design and simulation for electro-photonics, and v) Deposition methods (evaporation, inkjet, spin coating, electrospray).

Scientific Production Achievements: >320 indexed publications, >40 invited conferences, >350 contributions to congresses, 2 patent applications, 1 PCT patent, and 1 patent in exploitation. I founded the start-up company Enlighting Technologies in 2017 (now Kumux) to commercialize advanced spectral control systems for luminaires, in which UB participates. I have been awarded 5 six-year research periods. Throughout my professional career, I have led a total of 7 National Plan projects as a Principal Investigator, 4 special actions, 7 integrated actions, and 2 infrastructure projects. I have also served as a partner Principal Investigator in 7 European projects.

Management and Evaluation Achievements: I directed the master's and doctoral programs in Devices, Sensors, and Actuators at UB for 7 years (1998-2006). Throughout my career, I coordinated doctoral programs and participated in the committees for doctoral programs in the Faculty of Physics, including Physics, Nanoscience, and Photonics. Between 2011 and 2016, I served as an evaluator for ANECA for national accreditations. I have acted as an evaluator for numerous projects for ANECA, and in particular, I was a member of the evaluation panels for projects in the TEC area from 2004 to 2010. Between 2012 and 2018, I participated as a remote evaluator, panel member, rapporteur, and vice-chair in IST, Nano, MAT, and FET open projects. I also conducted evaluations for the Catalan accreditation agency. I contributed to the development of study plans for degree programs in Physics, Electronic Engineering, Systems Computing, and master's programs in Photonics, Nanoscience and Nanotechnology, Renewable Energies, and Sustainability. I am the director of the Technology Transfer Center (CEMIC) at the Department of Electronic and Biomedical Engineering at UB and a



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member of the management committees of the UB Institute of Nanoscience and Nanotechnology (IN2UB) and the Catalan Society of Physics (SCF). Additionally, I represent my institution in various national and international associations such as SECPHO, IEEE, ECS, EPIC, and others.