Sorbonne University & Nanyang Technological University Joint Doctoral Program

Doctoral position available (Starting October 2020)

Ferritin nanocages used as programmable bricks for biomolecular electronics

PhD Supervision (cotutelle)

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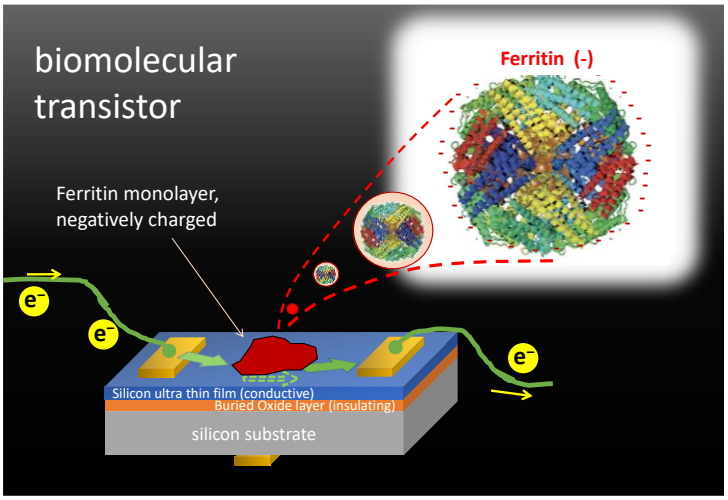
Biomolecular electronics is the development of a reliable approach for integrating proteins and peptides into electrical circuits. It takes advantage of the Nature's structuring processes that are robust and precise with the goal of achieving reproducible and reliable electronic operations [1]. This PhD work will explore the fundamental properties of nature-derived molecules as the building blocks for biomolecular electronics.

Ferritin is a protein known as the main iron cellular storage molecule in the human body. It is also an attractive candidate to be incorporated into electrical junctions because of its unique architecture made of a protein shell with an iron core [2]. Moreover, ferritin can be "engineered" so that it carries either positive or negative charges. By assembling a monolayer with these charge-controlled ferritins on the top of a Field-Effect Transistor architecture, it will be possible to control the amount of electrical current flowing through the device. This transistor will be "gated" by a programmable proteins layer (see Figure).



Ferritin nanocages will be deposited on a silicon substrate. Since they can be charged, they will modulate the conductive channel of the transistor. By mixing (+) charged and (–) charged ferritins, it is possible to modulate the conductivity of the transistor.

The goal of the present PhD work is to develop this prototype device and demonstrate that such a biochemical monolayer gives rise to new architectures for innovative electronic devices or advanced sensors.

At Nanyang Technical University (Singapore). The PhD candidate will learn how to assemble ferritin nanocages, adjust their charge, and graft optical dyes on the ferritin [3]. Deposition of ferritin as an ordered monolayer on a silicon substrate will also be carried out. This work will be done in the School of Chemical and Biomedical Engineering in Singapore under the supervision of Assoc. Pr. Sierin LIM.

At Sorbonne University (Paris). The PhD candidate will learn how to measure ultra-low electrical currents [4] and local charges [5] using advanced equipment such as a conductive-AFM (atomic force microscopy) and a KPFM (Kelvin Probe Force Microscope). This will be applied to the ferritin monolayers: morphology, surface charge of the layer. The PhD candidate will also fabricate Field-Effect Transistors and test the concept of programmable ferritin bricks. This will be done in the Institut des NanoSciences de Paris (INSP), in Paris under the supervision of Pr. Olivier Pluchery.

References:

[1] Amdursky N, Głowacki ED, Meredith P. Macroscale Biomolecular Electronics and Ionics. *Adv Mater*. 2019;31(3):e1802221. doi:10.1002/adma.201802221

[2] Kumar, K.S., Pasula, R.R., Lim, S. and Nijhuis, C.A. (2016), Long-Range Tunneling Processes across Ferritin-Based Junctions. Adv. Mater., 28: 1824-1830. doi:10.1002/adma.201504402

[3] Pasula, R. R.; Lim, S., Engineering nanoparticle synthesis using microbial factories. *Eng. Biology* **2017,** *1* (1), 12-17.

[4] Pluchery, O.; Caillard, L.; Dollfus, P.; Chabal, Y. J., Gold nanoparticles on functionalized silicon substrate under Coulomb blockade regime: an experimental and theoretical investigation. *J. Phys. Chem B* **2018,** *122* (2), 897-903. https://doi.org/10.1021/acs.jpcb.7b06979

[5] Zhang, Y.; Kang, J.; Pluchery, O.; Caillard, L.; Chabal, Y. J.; Wang, L.-W.; Sanz, J. F.; Salmeron, M., Nanoimaging of Organic Charge Retention Effects: Implications for Nonvolatile Memory, Neuromorphic Computing, and High Dielectric Breakdown Devices. *ACS Applied Nano Materials* **2019,** *2* (8), 4711-4716. https://doi.org/10.1021/acsanm.9b01182

PhD conditions: fixed salary of 1685€/month (*salaire brut* in France) + travel fees Paris-Singapore (1 round trip /year)

Duration: 3 years. Start between Oct. and Dec. 2020.

Candidate profile: the candidate should hold a master degree (M2 degree in Europe) in physics, physical chemistry, biophysics or biochemistry. Strong interests in physical characterization are expected: AFM, KPFM, optical characterization, AFM data analysis. Some basics knowledge on electronic devices and electrical characterization are an advantage. Knowledge in biochemistry and practice are an advantage.

Admission: Fill in the online Google Form where you will need to submit a **CV** + **motivation letter**.
https://docs.google.com/forms/d/e/1FAIpQLSd2uadjStbQKmkrfN1rNdpR9pz5t9OeePIBWpSTMQfNeWoFEQ/viewform?usp=sf_link (a Google account is needed)
*** You can also send your CV + Motivation Letter directly to SLim@ntu.edu.sg and olivier.pluchery@insp.jussieu.fr ***
Applications should be received before Sept. 30th, 2020

In the motivation letter, please explain why you want to undertake a PhD, why you are interested in this particular topic, and what your vision is on working in two cities such as Paris and Singapore.

Situation with COVID-19. Due to the present worldwide sanitary crisis, travelling between Paris and Singapore will be difficult. Depending on the residence country of the PhD student, the topic will be adapted so that it can be started without delay in any of the two countries.