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CEFIPRA

INSTITUT FRANÇAIS India

# Job offer – PhD in Graphene Field Effect Transistor and Gas Sensing

**Research Project Short Title as Submitted to CEFIPRA: "**STOMACHING SENSE**"**
**Principal Investigator contact: "**Prof. Benoît PIRO, piro@univ-paris-diderot.fr**",** Université Paris Cité
**Reference Number of the Job Offer:** IFI_CEF_24_06

## Project description

- **Keywords:** Electrolyte-gated transistors; Graphene ; Gas sensor ; Food intolerance ; Printing techniques ; Medical device

- **Context:**

  Breath analysis is a matured medical procedure. One of the tests normally undertaken is $H_2$ detection for determining lactose intolerance and small intestinal bacterial overgrowth (SIBO). However, usage of $H_2$ alone results in false negatives for up to 60%. A solution found to this issue is the simultaneous detection of $H_2$ and $CH_4$, today undertaken utilizing costly and complicated optical means. A few researchers have reported the use of field-effect transistors (FETs) for $H_2$ detection, with $MoS_2$, SiNW, or $SnO_2$ NPs. For $CH_4$, there are many reports on detection via electrochemical sensing e.g., on $La_{0.87}Sr_{0.13}CrO_3$, ITO, Au or Pt. Concerning FETs, an extended-gate GFET functionalized with $VO_2$ was reported. We think that better results can be obtained using an electrolyte gated GFET for which the control gate is a solid electrolyte on one side of the rGO channel and the sensing obtained by functionalizing the other side of the channel.

- **Abstract of the Research Project:**

  Small Intestinal Bacterial Overgrowth (SIBO) and other food intolerances of growing importance are detected in the office of MDs by using breath analysers, not necessarily costly but incomplete (2 gases cannot be sensed at the same time), and/or using mouthpieces containing sensors that must be reused, and/or with sensors far from the mouth, implying more air to be exhaled (not suitable for children or elderly patients). We propose a brand new 2-sided electrolyte gated graphene field effect transistor, functionalized with catalytic nanomaterials, fully obtained by printing on stickers, for detecting $CH_4$ and $H_2$ (along with humidity) in breath.

- **Scientific Objectives of the Project:**

  1. To functionalize reduced graphene oxide with suitable metal (Pt, Pd, Au) and metal oxide semiconductor nanoparticles (vanadium oxide, tin dioxide, indium tin oxide) for methane and hydrogen detection in breath.
  2. To fabricate a brand new 2-side electrolyte-gated graphene-based field effect transistor (2-side EGGFET never described elsewhere) for gas sensing.
  3. To set up a hydrogen+methane sensing measurement unit with breath analysis facility.
  4. To integrate it with a microcontroller for having portable and affordable healthcare monitor for bacterial growth in stomach.

- **Methodology and Timeline of the Project:**

  - **Task 0: Month 1.** Initiation (introduction to the teams, learning equipment and methods).

  - **Task 1: Months 1-3.** Initial screening of material for Graphene functionalisation and synthesis of

functionalize rGO.
GO is functionalized by a single step hydrothermal method. The basic route consists of mixing an aqueous dispersion of GO with catalyst precursors as $V_2O_5$, $SnO_2$, $K_2PtCl_4$, $KAuCl_4$, $Na_2PdCl_4$… A capping/reducing agent is added to the mixture and kept at 180 – 250 °C for 12 hours. After washing and drying, we obtain NP-functionalized GO. An almost similar procedure is used for preparing ITO-functionalized GO. GO is electro-reduced to rGO directly on the EGGFETs.

- **Task 2 : Months 3-12.** Fabrication of 2-sides EGGFETs.
  The 2-sides EGGFET is made following a methods which is being patented and therefore not detailed here. A significant development has to be done here.

- **Task 3: Months 9-18.** Hydrogen and methane sensed independently.
  A methane & hydrogen sensing set up is made. Concentrations of test gases are varied.

- **Task 4: Month 12-24.** Simultaneous measurement of methane and hydrogen.
  The prepared 2-sides EGGFETs are characterized for their transfer characteristics ($I_{DS}$ vs $V_{GS}$ at constant $V_{DS}$) and output characteristics ($I_{DS}$ vs $V_{DS}$ at constant $V_{GS}$) with or w/o functionalization and under target gases. This also provides a fundamental understanding on the doping happening under gas exposure. It is performed using a semiconductor parameter analyser. Sensitivity, limit of detection (LOD), selectivity, effect of humidity, effect of temperature, dynamic range, response and recovery times and stability are investigated.

- **Task 5: Month 18-30.** Optimizations

- **Task 6: Month 30-36.** Thesis writing. Communication and article writing

**Candidate profile**

- Only Indian candidates or candidates with a research experience in India are eligible; French candidates are not eligible
- Applicants for a PhD degree must have a master degree (or be in the process of obtaining one before the beginning of the project) in the field of Chemistry.
- No competences in French language are required.
- Candidate competences and know-how: Physicochemist, Creative and skillful, Experience in printing appreciated and Experience in gas sensing appreciated
- Expected starting date: **01-10-2024** at the latest

**How to candidate ?**

Documents to be provided :

i. A cover letter (reasons for the candidature, professional project …) max 2 pages
ii. A copy of the master's degree or a proof of the program followed (and expected date of end) OR A copy of the PhD degree or a proof of the PhD program followed (and expected date of defense) max 1 page
iii. A copy of results for previous scholarship (max 3 pages)
iv. International curriculum vitae (max 2 pages)
v. Two letters of recommendation: one from any Indian institution and one from the French institution planned to host the candidate –mandatory- (max 2 pages)
vi. All should be submitted within 1 pdf file of no more than 10 pages.

Applications should be submitted to the following email address: msi@ifindia.in mentioning the reference number of the Job offer clearly.

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**Candidates are requested to contact the French scientific principal investigator of the project before submission. A recommendation letter from the scientific principal investigator is mandatory.**

**Benefits:**

- Monthly allowance of €1,710 per month for PhD
- Travel allowance
- University fee
- Carte de séjour fee
- Campus France management fee
- Registration to the French social security scheme

**Selection process:**

Selection is made by a dedicated selection committee of at least 4 persons. Decisions will be transmitted by the Embassy of France to CEFIPRA. **No consideration will be given for candidates with no recommendation letter from the French institution.**

**Criteria for applicants' selection:**

Academic excellence

- Excellence of the Academic background, Academic records, Honors, Letters of support, Participation to international research projects, exchange programmes and conferences.

Motivation and qualities

- Academic maturity: appropriation of the thesis project (stakes and contexts) • Quality of the presentation (oral expression, skills for synthesis, English level) • Maturity of the professional project: capacity to project her/himself within five years in terms of career development.

**About CEFIPRA:**
Indo-French Center for the Promotion of Advanced Research (CEFIPRA/IFCPAR) is an Indian body which promotes scientific cooperation between France and India in advanced fields of Science and Technology. It is supported by the Department of Science and Technology, Government of India and the Ministry of Europe and Foreign Affairs of the French government.