**Research Topic for the ParisTech/CSC PhD Program**

**Field (cf. List of fields below):** 2. Chemistry, Physical Chemistry and Chemical Engineering
**Subfield:** (Applied Physics, Chemistry, Mathematics, Mech. Eng. etc…): Chemistry
Title: **Functionnalized nanomaterials for gas sensing**
**ParisTech School:** Interface
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Environmental monitoring is required to protect the public and the environment from toxic contaminants and pathogens that can be released into a variety of media including air, soil, and water. Moreover, the global environmental monitoring market is poised to grow at a CAGR of 7.5% during 2015-2020, and is expected to reach a value of ~$20.5 Billion in 2020 [1]. As an example: The air segment in the environmental sensing and monitoring market is anticipated to reach USD ~7.7 billion by the end of 2019. This augmentation is driven by different factors such as the massive scale of urbanisation and population growth, development of policies to reduce water, soil and air pollutants and the increase of monitoring environmental stations. **In this framework, the development of low-cost, easy-to-use, miniaturized, portable and long-term monitoring of environmental sensors allowing accurate measurements of air pollutants is needed**.

Nanomaterials such as carbon nanotubes, graphene and transition metal dichalcogenides (TMDs), such as $MoS_2$ or $WS_2$, $MoSe_2$ as well as black phosphorus (also known as phosphorene) are one of the best promising candidates for the future development of nanosensors applications[2-3]. This originates from their high surface area (dense number of adsorption sites), high electrical conductivities and low electrical noise (a small change in carrier concentration induced by gas exposure induces significant changes in electrical conductivity), as well as appropriate band gap opening (that can be tuned by the number of the layers in the case of TMDs) [4-6]. In addition, carbon nanotubes and 2D materials can be operated at room temperature, which is impossible in metal oxide semiconductors [8]. In this thesis, we will develop **a reliable and selective new generation of gas sensors based on nanomaterials, based on carbon nanotubes or on 2D materials, that will be used to detect and quantify sensitively and selectively air pollutants (NOx and CO for example) in various environments.**

## Required background of the student:

- Master in materials sciences or chemistry or physical chemistry.
- Strong background in nanomaterials.
- Skills in microstructural and spectroscopic characterization techniques is preferred.
- Applicants must be self-driven and highly motivated.
- Excellent interpersonal and communication skills.

## A list of 5(max.) representative publications of the group: (Related to the research topic)

1- P. Bondavalli, P. Legagneux and ***D. Pribat***, "CNTFET based gas sensors: state of the art and critical review", *Sensors and Actuators B*, **140**, 304 (2009).

2- ***Fatima. Bouanis***, Costel S. Cojocaru, Vincent Huc, Evgeny Norman, Marc Chaigneau, Jean L. Maurice, Talal Mallah, Didier Pribat,. " Direct synthesis and integration of individual, diameter-controlled SWNTs " *Chem. Mater.*, 2014, **26** (17), pp 5074–5082

3- P. Bondavalli, L. Gorintin, G. Feugnet, G. Lehoucq and ***D. Pribat***, "Selective gas detection using CNTFET arrays fabricated using air-brush technique, with different metals as electrodes", *Sensors and Actuators B: Chemical***, 202**, 1290 (2014).

4- G. Magadur, J.S. Lauret, G. Charron, ***F. Bouanis***, E. Norman, V. Huc, C.S. Cojocaru, S. G Coca, E. Ruiz, T. Mallah. "Charge transfer and tunable ambipolar effect induced by assembly of Cu(II) binuclear complexes on carbon nanotube field effect transistor devices. *J. Am. Chem. Soc.*, 2012, **134** (18), 7896–7901.

5- Gurvan Magadur, ***Fatima Bouanis***, Evgeny Norman, Régis Guillot, Jean-Sébastien Lauret, Vincent Huc, Costel-Sorin Cojocaru and Talal Mallah. « Electrical-field-induced structural change and charge transfer of lanthanide–salophen complexes assembled on carbon nanotube field effect transistor devices. *Chem. Comm.*, 2012, 48, 9071-9073.

**Bibliography:**

[1] http://www.marketsandmarkets.com

[2] M. Meyyappan, Carbon Nanotubes: Science and Applications, CRC Press, Boca Raton, Fla, USA.

[3] S. Cui et al. *Nature Communications,* 6, DOI: 10.1038/ncomms9632.

[4] Q. H. Wang et al. *Nat. Nanotechnol.,* 7 (2012) 699.

[5] H. Li et al. *Nat. Mater.,* 15 (2016) 48.

[6] G. Lu et al. *J. Chen , Nanotechnology*, 20 (2009) 445502.