INSTITUT PASCAL – PHOTON – Microsystèmes Capteurs Chimiques

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Title of PhD subject: Development and characterization of an original Silicon/graphene bi-layer structure dedicated to hydrogen detection

Summary: *In the actual context of climate change and energy transition due to the tremendous use of energy fossils resources increasing the greenhouse emissions, French government has announced a national plan for hydrogen development [1]. In fact, hydrogen (H_2) is a promising energy vector that can be used to tackle the global warming since it can produce energy without generating CO_2 or any greenhouse gases. Additionally, it also possesses higher energy density meaning that with less input material a higher energy output can be obtained compared to same unit using fossil fuels. However, for the success of its large deployment, several aspects should be taken into account. Hydrogen is a lightweight and tiny gaseous molecule that can easily generate leaks, furthermore it is an explosive gas at a certain concentration in air [2]. So during the whole process of hydrogen production, storage and distribution to end-user, a complete safe and secure infrastructure should be in place.*

To provide solution for security and safety requirement that should support the national hydrogen plan, the MSCC team strive to develop resistive sensor employing an original bi-layer structure based on silicon/graphene sensitive material for the detection of hydrogen. The project in this thesis submitted to EDSPI ranking is to develop such a sensor. The materials we aim to develop are silicon/graphene bi-layer structure. Such an association offer the possibility to combine the advantage of silicon and graphene in the same structure:

- the silicon will be nanostructured by physical or chemical methods and then decorated with palladium nanoparticles to enhance its reactivity to hydrogen. The nanostructuration is here intended to amplify the reactivity towards hydrogen via active sites generation.

- the graphene with its higher surface area (theoretical value of 2600 m^2/g [3]) will be also decorated with palladium nanoparticles that will activate catalytic sites for its reactivity towards hydrogen.

- the developed Si/Graphene structure where both the graphene and silicon effects are combined will ensure the stability and sensitivity of the structure, and benefit from the hydrogen reactivity to palladium [4].

This new bi-layer structure will be also completely characterized with the new Hall effect platform of the team to understand its properties and get insight into the electronic interaction for understanding the mechanism between the hydrogen and the materials. This thesis will contribute also to the development of a new research field in the research team around the silicon-graphene based sensors.

Références :

[1] - https://www.vie-publique.fr/discours/276268-bruno-le-maire-08092020-hydrogene-decarbone
[2]- AFHYPAC, Données de base physico-chimiques sur l'hydrogène, in: F. Hydrogene (Ed.) L'encyclopédie
[3] - F. Bonaccorso, L. Colombo, G. Yu, M. Stoller, V. Tozzini, A.C. Ferrari, et al., Science, 347(2015) 1246501.
[4] - L. Moumaneix, A. Rautakorpi, T. Kallio, ChemElectroChem, 10 (2023) e202201109.