Application 2059

Hydrogen storage measurements in graphene-based materials

Nadhira Bensaada Laidani

Fondazione Bruno Kessler, Trento, Italy

The necessity of hydrogen in specific mobile applications and energy backup system is promoted by the growing demand of sustainable solutions and the interface of discontinuous renewable energies. Hydrogen storage is well known to be the major bottleneck for the use of H2 as energy carrier and despite the huge scientific and industrial effort in developing a novel practical solution for the hydrogen storage, actually there are only few storage systems available for niche markets. The request for energy storage systems is growing as fast as the energy availability from renewable sources, and the greatest challenge in the development of sustainable hydrogen economy resides in the development of efficient, cheap and safe materials for H2 storage.

It is emerged from the past EU projects (STORHY, NESSHY, COSY, NANOHY, FLYHY, EDEN, SSH2S, BOR4STORE, HYPER) that hydrogen storage in solid state is one of the best solutions to seek. It provides the best performance in terms of gravimetric and volumetric density (higher than compressed and liquid storage), in particular for hydride based-materials (e.g. magnesium hydride), but there are many other options for innovative materials at present under research, such as the carbon-based class of materials and porous carbons (graphene, MOFs and organic compounds). Some of the main obstacles for an optimal use and performance of these materials are related to the high reaction enthalpies, low-pressure release and high working temperatures, which reduce their industrial and commercial exploitation and application.

Graphene seems to have big potentials, thanks to its extremely high surface and peculiar properties, and a big potential for accepting and hosting on its surface nanoparticles, intercalates, functional groups able to improve both sorption thermodynamics and kinetics.

The present application aims at evaluating the H2 sorption capacity of bulk nanostructures of Graphene or Graphene-like composites, with metal and metal oxide decoration, intercalation and/or functionalizations. Nowadays, FBK is involved in two projects related hydrogen storage in solid state materials : EDEN and FET FLAGSHIP GRAPHENE.

EDen is a European project, supported by FP7 – JTI FCH. It aims at developing an innovative embedded system for the storage of energy, thank to combination and thermal integration between a SOFC (capable to work like SOE) and an innovative solid-state hydrogen storage tank. The project goals are to develop an innovative tank and a well-optimized material to achieve hydrogen uptake about 1.5 g/min with a volumetric density of 40 g/l. A magnesium-based material is under development as core material for EDen project. Particularly, FBK is working on an innovative process to deposit a thin layer of catalyst on magnesium grains surface in order to improve sorption kinetics

and to further protect its surface from air or oxidizing molecules. The synthetized materials are characterized or their sorption capacity in order to optimize the catalyst application process and to quantify the material storage capacity improvement.

In HORIZON 2020, research on Graphene is supported by FET Graphene flagship, which aims at studying every possible application of Graphene in different fields of science and engineering. In this context, WP 9 of the project (a work package dedicated to energy application), and in particular its Task 4 (hydrogen storage) is related to the in-depth study and development of technologies and applications of Graphene for hydrogen storage. FBK is involved in this project with other important european scientific institutes, including CNR-Nano of PISA (Task leader), UMEA university, TU Dresden and University of Cambridge. Graphene will be processed in several ways in order to improve its hydrogen storage capacity and kinetics: surface functionalization, chemical intercalation between graphene's sheets and management of its curvature.

The present project aims at a collaboration with JRC Petten [SolTeF] to characterize such innovative nanostructures of Graphene in terms of physical and chemical properties, including the H2 storage thermodynamics (enthalpy, entropy of reaction or interaction, equilibrium pressure…) and kinetics aspects. Such investigations need highly accurate volumetric or gravimetric techniques in a wide range of pressure values (from vacuum to 150-200 bars) and temperature (77-300K or more) in order to cover as much as possible chemisorption and physisorption characteristics of our materials. FBK has a wide expertise and facilities for surface characterization (XPS, UPS, Tof-SIMS, AFM), as well as hydrogen sorption measurement and testing set-up. In FBK a suitable and innovative instrument for in-depth studies of hydrogen sorption is being developed, based on a differential pressure apparatus (DPA), which allows volumetric measurements with an approach different from the standard one for this kind of measurements, by using a highly accurate differential pressure transducer.
In this regard, H2FC program is a great opportunity to have a free access to an important European hydrogen facility, equipped with well-calibrated and accurate volumetric and gravimetric measurement instrument. FBK intends to collaborate with JRC laboratory SolTeF within the FET Flagship Graphene project to have expert support for material validation and access to the extended characterization facilities. The present application is specifically aiming at:

A. Utilizing instruments and the available expertise in H2FC to characterize and validate the different graphene-based materials produced and studied in the frame of FET Flagship Graphene project, in particular: characterization of hydrogen physisorption, in the typical range of pressure (0-150/200 bar) and temperature (77-300 K) for carbon based materials. Both gravimetric and volumetric measurements are useful for such materials.

B. Comparing the results with the ones obtained with a homemade instrument and validate them, in terms of accuracy and sensitivity.

H2FC European Research Infrastructure is a perfect matching project with our activities and objectives.
Free access to European facilities, guaranteed by H2FC project, includes and promotes researchers mobility. FBK intends exploiting such option to provide experience to its researchers in the main recent materials characterization techniques for the hydrogen storage application.
The SolTeF (JRC-04) facility is the best suited facility with state-of-the-art instrumentation.