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Hardware Article

Low-cost Sieverts-type apparatus for the study of hydriding/dehydriding reactions

Juan Luis Carrillo-Bucio [a], Juan Rogelio Tena-Garcia [a], Eduardo Paul Armenta-Garcia [a], Osiry Hernandez-Silva [b], José Gerardo Cabañas-Moreno [b], Karina Suárez-Alcántara [a,*]

[a] Unidad Morelia del Instituto de Investigaciones en Materiales de la Universidad Nacional Autónoma de México, Antigua Carretera a Pátzcuaro No. 8701, Col. Ex Hacienda de San José de la Huerta, C.P. 58190 Morelia, Michoacán, Mexico

[b] Programa de Nanociencias y Nanotecnología, Centro de Investigación y de Estudios Avanzados del IPN, Av. Instituto Politécnico Nacional No. 2508, Colonia San Pedro Zacatenco, CP 07360 Ciudad de México, Mexico

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ABSTRACT

The design and construction of a low-cost equipment for the study of hydriding/dehydriding reactions of different materials are presented. This is a Sieverts-type apparatus where a small amount (0.2–1 g) of solid hydrogen storage materials can be characterized. The apparatus combines the features of double lines (sample and reference) to eliminate small thermal effects on the reservoir and sample-holder volumes, with a $\Delta p = \Delta p_{sample} - \Delta p_{reference}$ approach to eliminate the need of a differential pressure transducer and to reduce costs. This apparatus can work from vacuum to 10 MPa hydrogen pressure and from room temperature to 673 K. Pressure, temperature and volume data are transformed by a real gases equation state and mass balance into hydrogen uptake or release in wt%. Characterization of typical hydrogen storage materials such as $LiAlH_4$ and Mg is presented to validate the performance of the apparatus.

Specifications Table

Hardware name	"Franky" Sieverts type apparatus
Subject area	Engineering and Material Science
Hardware type	Measuring physical properties and in-lab sensors
Open Source License	Creative Commons Attribution-ShareAlike license
Cost of Hardware	10,000 USD
Source File Repository	Open Science Framework: https://osf.io/zqvps/

* Corresponding author.
E-mail address: karina_suarez@iim.unam.mx (K. Suárez-Alcántara).

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1. Hardware in context

Hydrogen storage technologies are emerging as basic and applied research topics in México. However, the number of research groups are very few as compared with other hydrogen technologies such as PEM-fuel cells or hydrogen production. One of the reasons for this is the high cost of specialized materials, safety systems, and apparatus for testing the hydrogen capture/release properties of solid materials. Thus, an important option is to develop low-cost apparatus for characterization of hydrogen storage materials. In our case, the apparatus must meet the particular conditions of temperature and pressures for the hydriding/dehydriding reactions of the materials studied at the Institute of Materials Research (Morelia): from room temperature to 673 K and from vacuum to 10 MPa hydrogen pressure.

In a general way, the sorption apparatus can be classified as gravimetric or manometric, according to the key variable to be controlled and recorded: mass (weight) or pressure. Each type of apparatus has advantages and disadvantages regarding the simplicity of construction, operation, maintenance, working principle, and cost [1–4]. Here, we present details of the construction of a manometric or Sieverts-type apparatus.

Some Sieverts-type apparatus for the study of hydrogen sorption/desorption reactions are composed of a reservoir volume, a pressure transducer and sample-holder volume (Fig. 1a). Most commercial apparatus use this general configuration [5,6]. In those apparatus, the key variable is the difference of pressure between the pressure registered at time t (instant) minus the initial pressure ($\Delta p = p_{instant} - p_{initial}$). In a second design (Fig. 1b), the apparatus can use a second branch or line, twin of the first one (sample and reference) [7,8]. There, the key variable is the differential pressure between the sample and the reference lines. In this last design, the inaccuracies produced by small thermal variations are reduced. However, this design needs a differential pressure transducer with particular specifications regarding the construction materials, pressure range and accuracy. This leads to the use of expensive differential transducers. In the present work, we expose a low-cost alternative for the construction of a double-line apparatus.

2. Hardware description

Fig. 1c presents the basic design of our Sieverts type apparatus. We combined the double-line (sample and reference) configuration to reduce thermal effects, with the use of twin direct pressure transducers to reduce costs. Here the key variable is the difference of pressure between the pressure at time t (instant) minus the initial pressure at both sample and reference lines. This translates as a delta of deltas for the pressure change, namely [9]:

$$\Delta p = \Delta p_{sample} - \Delta p_{reference} \tag{1}$$

where $\Delta p_{sample} = p_{instant\text{-}sample} - p_{initial\text{-}sample}$, and $\Delta p_{reference} = p_{instant\text{-}reference} - p_{initial\text{-}reference}$.

At the beginning of the experiment, both (sample and reference) initial pressures are equal. During the experiment, the pressure of the reference is essentially constant unless small thermal changes happened. Meanwhile, the increase or reduction in the registered pressure at the sample line beyond the thermal effects indicates the release or the uptake of hydrogen, i.e. the dehydriding or dehydriding reactions, respectively.

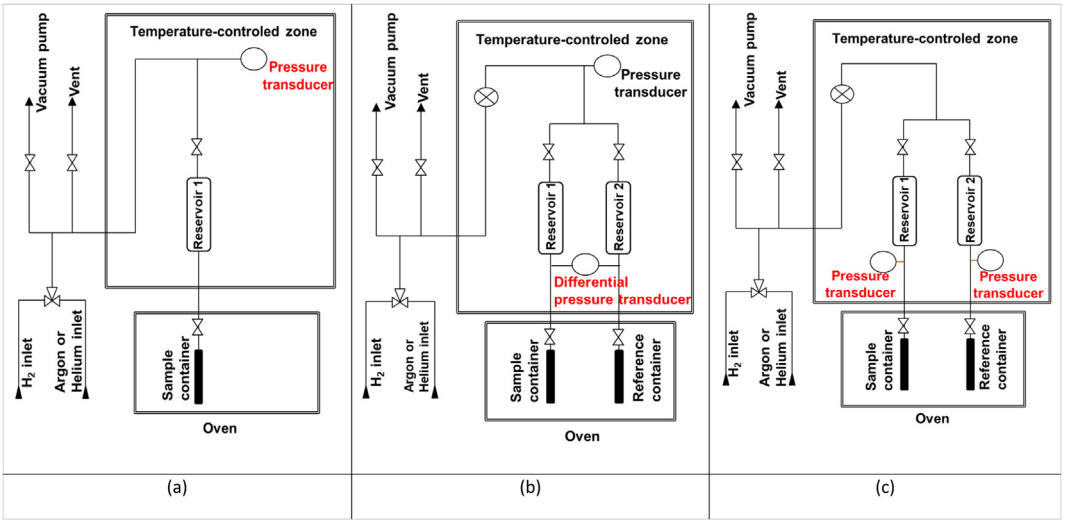

Fig. 1. Possible configurations of the manometric apparatus for the characterization of hydrogen hydriding/dehydriding reactions. (a) Single (sample) configuration. (b) Double (sample and reference) configuration with differential pressure transducers [8]. (c) Double (sample and reference) configuration with twin direct pressure transducers.