Standard Operating Procedure

(SOP)

Measurement of Sintered Density of SOEC Materials

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Rev 1

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Revision History

This page documents the revisions over time to the SOP. The most recent iteration should be listed in the row space, with consecutive versions following.

Date of Revision	Page(s)/Section(s) Revised	Revision Explanation
03/08/2019	All	First Release

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3. Procedures

a. Scope and Applicability

Measurement of the density of sintered materials can provide useful information regarding the suitability of a given processing or fabrication approach to achieve the level of density/porosity required for a given material application.

b. Summary of Method

Density of a sintered specimen can be evaluated in several ways. For bulk specimens, the Archimedes (or saturated-suspended weight) method generally provides the most accurate results, particularly for specimens that are irregular in shape.

c. Definitions

SOEC: Solid Oxide Electrolysis Cell

d. Health & Safety Warning

e. Cautions

f. Interferences

g. Personnel Qualifications / Responsibilities

h. Equipment and Supplies

Balance
Fluid of known density
Apparatus for determining weight of a specimen suspended in the fluid
Test specimen to be evaluated

i. Step by Step Procedure

- Specimen Preparation – The specimen to be measured should be clean and dry prior to beginning the procedure.

- Measurements of Specimen Weight – Three weight measurements are required. First, the dry weight of the specimen (Wd) is obtained using a balance. The saturated weight (Wsat) is obtained by re-weighing the specimen after it has been fully saturated with a fluid such as water, alcohol, or kerosene. To enhance filling of open porosity in the specimen, application of a vacuum while the sample is immersed in the chosen fluid. Note that surface liquid should be wiped off prior to

measuring the weight of the saturated specimen. Finally, the weight of the specimen while suspended in fluid (Wsusp) is obtained. Commercial "density kits" are available for standard balances to conveniently allow for determination of suspended weights.

- Calculation of Specimen Density – The bulk density of the specimen is calculated using the following equation:

$$p = \frac{(W_d)(p_f)}{W_{sat} - W_{susp}}$$

where p is the specimen bulk density (typically expressed in g/cc, although any units may be used as long as they are applied consistently), W_d, W_{sat}, and W_{susp} are as defined above, and p_f is the density of the selected fluid at the temperature at which the measurements were taken.

The density of sintered specimens is frequently expressed as relative (or fractional) density, p_f, which can be obtained simply by dividing the bulk density of the specimen by the theoretical (i.e., pore-free) density of the material:

$$p_f = \frac{p}{p_t}$$

The term $(1-p_f)$ corresponds to the fractional porosity in the specimen.

4. Quality Control and Quality Assurance Section

Best results are achieved by performing multiple measurements on a given specimen, followed by averaging of the results. If the goal is to determine the average density obtained using a specific set of processing parameters, measurements on multiple nominally identical test specimens (each prepared using that specific set of processing parameters) should be performed.

5. Reference Section
Not applicable