ADVANCED ENGINEERING MATERIALS

CVD Technique for Inco Nickel Foam Production

By *Vladimir Paserin*,* *Sam Marcuson*, *Jun Shu*, and *David S. Wilkinson*

In this paper, the capability of the CVD technique to produce uniform foams of different properties, with cell size ranging from ~ 450 to ~ 3200 μm, porosity from ~ 70 to ~ 98 %, and nominal thickness up to 3 mm is presented. In addition to the established application as a battery electrode material, some other potential capabilities and applications are explored.

1. Introduction

INCOFOAM® nickel foam – high purity nickel foam produced in a wide porosity range (~ 70 % to 98 % by vol.) and based on the structure of reticulated polymer foams has been available for several years. In 2000, a new, large scale commercial production facility was commissioned at the Inco UK refinery in Clydach, near Swansea, Wales. A wide range of porosities and pore sizes, limited only by the availability of polyurethane foams, presents unique opportunities for custom-tailored properties to serve a variety of applications. Hybrid electric vehicles (HEV) for example, have attracted great public interest due to their energy savings and environmental benefit. High-quality Ni foam is used as the electrode material in HEV batteries. Applications of Ni foam in fuel cells and electrolyzers are under development. While rechargeable battery electrodes remain the dominant application at present, the material is finding its way into a host of new applications. This paper presents the industrial scale CVD process developed at Inco and its benefits in delivering high quality uniform Ni foam products. Applications of Ni foam in various fields are discussed based on INCOFOAM® nickel foam properties.

2. INCOFOAM® Production Process

To produce nickel foam, nickel metal is coated onto reticulated polymer substrates such as polyurethane foam and sintered afterwards to remove the polymer substrate in a controlled atmosphere at high temperature. In general, nickel coating can be applied by a variety of processes such as sputtering, electroplating and chemical vapor deposition (CVD)[1]. For mass production of continuous foam, electroplating and CVD are the main processes in the industry. The production process at Inco is based on CVD of nickel tetracarbonyl ($Ni(CO)_4$) onto open-cell polyurethane substrate.[2]

$Ni(CO)_4$ was first synthesized in 1888 by Carl Langer and Ludwig Mond and since 1902 has been used commercially for the refining of nickel and the production of nickel powders and other special products. It has a boiling point of 43 °C and is readily decomposed into elemental nickel and CO upon heating to 150–200 °C via the following reaction:

$$Ni(CO)_4 \Rightarrow Ni + 4\,CO$$

The low decomposition temperature allows nickel deposition on temperature-sensitive materials, such as PU foam.

The commercial plating units at Inco semi-continuously produce coils of battery-grade foams approximately 2000 m long, 1 m wide and 1.3–3 mm thick in a single batch. The plating unit is essentially a cold-wall CVD reactor with a spool-to-spool winding mechanism designed to transport spooled, porous substrates through a series of deposition chambers under tightly controlled process conditions. The amount of nickel plated onto the substrate depends on plating gas composition, substrate temperature, substrate surface

[*] *V. Paserin, S. Marcuson, J. Shu*
Inco Technical Services Limited
Sheridan Park, 2060 Flavelle Blvd.
Mississauga, Ontario, Canada L5K 1Z9
E-mail: paserin@inco.com
David S. Wilkinson
McMaster Centre for Automotive Materials
McMaster University
Hamilton, Ontario, Canada L8S 4L7

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