# Sintered metallic fibers in electrochemical applications

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## Introduction

An electrode is a crucial component in electrochemical devices with significant impact on performance. Many electrochemical applications benefit from an increased electrode surface area while other applications require electrodes that provide channels for guiding reactants to catalytic centers and for the removal of products. Well-known examples of electrodes used in fuel cells are carbon paper and carbon cloth. Metallic porous structures like foam, mesh, sintered powder and sintered fiber, are selected when high corrosion resistance and high conductivity are desired. This paper focusses on the use of electrodes made of sintered metallic fibers. Material properties, such as compression and roughness, are analyzed through ex-situ analysis. In-situ analysis helps to understand the effect of the electrode composition on electrochemical performance. Sintered titanium fibers as gas diffusion electrode in proton exchange membrane (PEM) water electrolyzers is highlighted as case study.

## Bekaert's product portfolio

Bekaert's proprietary production process allows the development of sintered metallic fibers. These 3D structures are homogeneous and allow tuning in terms of pore size, surface area and permeability. Sintered metallic fibers are available in a wide range of porosities, i.e. 50% to 90%. Note that sintered powders are generally available between 30% and 60%. Bekaert's available alloys include AISI 316L, AISI 430, titanium and nickel. Bekaert offers finishing services that facilitate assembly and reduce total cost of ownership for cell manufacturers, e.g. (i) sizing by advanced cutting methods, (ii) co-sintering fibers and flow field into one single component and (iii) applying protective coatings.

## Compression of sintered metallic fibers

Electrodes need to withstand compression forces during stack assembly and operation. The effect of pressure (0.5 – 8MPa) on the thickness of sintered fibers has been tested in a Zwick Z010 test apparatus. Sintered metallic fibers were found to mainly deform elastically in this pressure range. They have lower permanent deformation compared to sintered metallic powders.

### Roughness of sintered metallic fibers

In some applications, electrodes need to be sufficiently smooth to avoid structural damage to other components, e.g. to prevent damage to the membrane in PEM electrolysis. A Taylor Hobson profilometer has been used to quantify the roughness of the surface of sintered metallic fibers, which strongly depends on porosity and fiber diameter. Average roughness as low as 2µm has been measured, indicating that sintered metallic fibers can effectively protect other components.

### Electrochemical performance of sintered metallic fibers

The effect of electrode composition on electrochemical performance has been evaluated in collaboration with cell manufacturers and/or external institutes.

Researchers at Fraunhofer ISE have developed an electrolysis test bench to assess the performance of sintered titanium fiber based gas diffusion electrodes in PEM electrolysis. Polarization curves were acquired at current densities between 0.05 and 5 A $cm^{-2}$ for pressures 0.1 – 3 MPa, temperatures 313 – 353 K. Tested gas diffusion electrodes included sintered titanium powder and sintered titanium fibers with varying porosity and fiber diameter. High porosity sintered titanium fibers showed the best performance when used in the electrochemical cell, irrespective of the set pressure and temperature. For example, at 333 K and 3 MPa, the current density when using high porous sintered titanium fibers as gas diffusion electrode was 1.5 and 5 A $cm^{-2}$ at 2 and 3 V respectively. At the same operating conditions, the current density when using low porous sintered titanium powders as gas diffusion electrode was 1.25 and 3.5 A $cm^{-2}$ at 2 and 3 V respectively. Consequently, an electrolyzer using high porous sintered titanium fibers achieves the same hydrogen output as an electrolyzer using low porous sintered titanium powders at reduced active area, ~15% reduction at 2 V and ~30% reduction at 3 V.

### Conclusion and outlook

Sintered metallic fibers are high performing (gas diffusion) electrodes. They withstand compression forces and their smooth surface is able to protect fragile membranes. The flexibility in porosity and fiber diameter allows tuning its properties in terms of surface area and/or mass transport properties.

In the case of PEM water electrolysis, a clear improvement in electrochemical performance is observed when using high porous sintered titanium fibers as gas diffusion electrode instead of low porous sintered titanium powders.