PROSPECTIVE OF GAS-EUTECTIC POROUS MATERIALS FOR FUEL CELL APPLICATION

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Introduction

Porous materials usually are designed for special properties and they are most often classified by the method of manufacture. Gasar-process and its scientific basis are completely different of well-known technologies so it was distinguished as new class of porous materials [1, 2].

The scientific base of gasar technology [3] was established in National Metallurgical Academy of Ukraine 1979. The first USSR patents (1980 -1985 years) were confidential, as gasars were used in military rocket and spacecraft industries. Thus the information was beyond the reach of the general public until 1989 when the USSR patents were removed from secret list. ***Gasar*** is the word an acronym of Russian expression meaning "***gas-reinforced***." In 1993 it was published US Patent № 5181549 "Method of Manufacturing Porous Articles" and gasar technology was described in detail [3,4]. But the first open information about possibility to obtain ordered porous structures at gas-eutectic solidification was shown up much earlier – 1980 - in Foundry Russian magazine.

Gasar technology fundamentals

Key phenomenon underlying gasar technology is ***gas-eutectic reaction***, which was discovered in metal-hydrogen systems not long ago in National Metallurgical Academy of Ukraine (1971-1979).

The reaction represents simultaneous formation of solid and gas from liquid metal-gas or ceramic-gas solutions and takes place in materials having ***gas-eutectic phase equilibrium.*** There are many Metal-Hydrogen systems (for example the Al-H, Be-H, Cr-H, Cu-H, Fe-H, Mg-H, Mn-H, Mo-H, Ni-H, Ti-H, W-H, Fe-C-H) displaying gas-eutectic equilibria in the melting range.

Basically gas-eutectic reaction can be observed in some Metal-Oxygen (Ag-O; Fe-C-O; Cu-O), Metal-Nitrogen systems (Fe-N; Ni-N; Cu-N; Mn-N) and different kind of ceramics which saturated with hydrogen, nitrogen, oxygen or those mixes [3]. It is possible to use gaseous carbohydrates and gaseous water too. But we believe hydrogen is the best because it can be entirely removed from gasars by heat treatment in vacuum after gasar structure formation.

Gasar's Structure

Porous fuel cell electrode structure is very important for fuel cell productivity and reliability. The structure should give the electrodes high strength and large specific surface area.

Gas-eutectic and usual eutectic reactions have common features. But there are fundamental distinctions, which radically distinguish the reactions. First of all it is high sensitiveness of gas-eutectic reaction to pressure changing. The pressure is very powerful gasar technology parameter and it allows obtaining different kind of structure. Solidification velocity and pouring temperature are much less effect parameters in the technology.

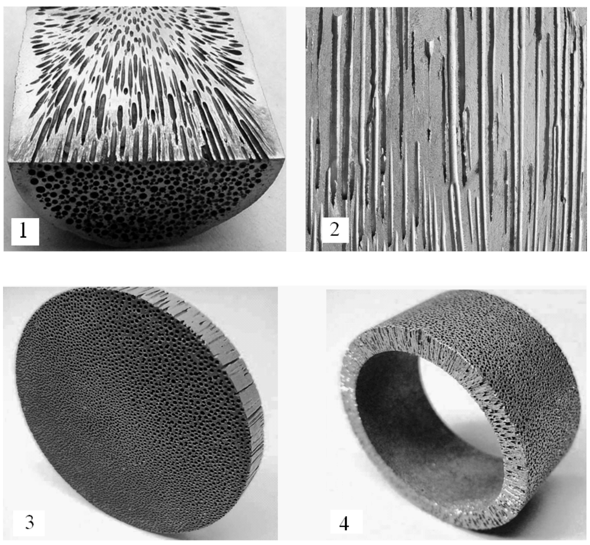

Figure 1. Common pore structure of gasars: 1 – combination of parallel and radial ellipsoidal pores in one sample; 2- parallel cylindrical pores in longitudinal section; 3- parallel ellipsoidal pores; 4 – radial ellipsoidal pores (everywhere pore diameter is about 0.25-0.5 mm).

Second distinction consists in pore nucleation feature. Inception of the bubbles is heterogeneous and always occurs on existing discontinuities in the liquid bulk or at the liquid/solid interface.

Most often ellipsoidal pores are observed in gasars Figure 1. But it is possible to see more complicated shapes (Figure 2).

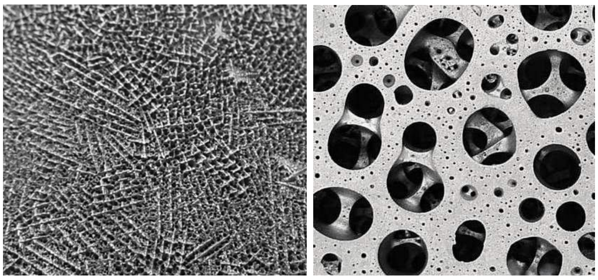

Figure 2. Special pore structure of gasars: left - "inverse dendrite" pore structure; right – arterial pores.

The elongated pores always have simile nature of orientation. The general orientation is directed by heat sink conditions during gas-eutectic solidification. The growth velocity vector is always normal to the solidification front at the pore initiation site. Therefore, any misalignment of pores is associated with local nonplanar areas of the solidification front.

Some distinctive properties of gasars

Most essential advantages of gasars to well known porous metals are: relatively high strength, low cost and high productivity; and diversity of porous structure.

Mechanical tests of gasars have shown that directional pores below 10µm in diameter make them superior in strength to monolithic materials having the same composition. Gasars are well suited for machining and forming, allow hardening by conventional heat treatment, possess unique damping capacity, can be produced with a heat conductivity value lower or greater than the one for the monolithic material and have good capacity to absorb vibrations and sounds.

Because of very low admixture concentration and monolithic matrix gasars have relatively high heat conductivity and electro conductivity.

Prospects

Generally speaking several disadvantages prevent the application of porous metals on wider scale. The majority drawback is the high cost due to the multiple steps involved in the manufacturing process, and the low production rates. There are also difficulties in engineering a desired pore space structure. Problems are posed by the poor corrosion resistance, machinability and weldability, and by the complexity of mechanical joining with similar materials or poreless parts. Clearly, the prospects of porous metals depend on whether these and other disadvantages will be eliminated, be it through improvements in conventional process or by the advent of revolutionary technologies.

Porous metals and ceramics formed by gas-eutectic reaction are particularly promising especially for fuel cell porous electrode application. Among the advantages of gasars over conventional porous materials, are:

- Improved strength and rigidity,
- Ease of fabrication and relatively low cost,
- Flexibility in regard to the permeability,
- Possibility of making various pore space structure,
- Wide range of the pore diameter (from 5µm to 10mm),
- Feasibility of control over pore shape and orientation,
- Good weldability, fabricability, and machinability,
- Unprecedented formability.

References:

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