

The cover shows the computer-assisted segmentation of individual pores in the sample of an Al-Cu-Mg alloy foamed without blowing agent by pressure manipulation. Read more about this in the article by L.-P. Lefebvre et al. on page 775.



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Editorial 767

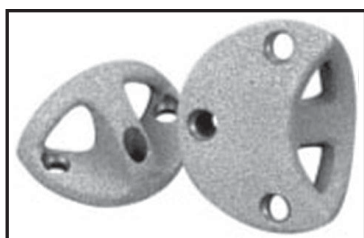
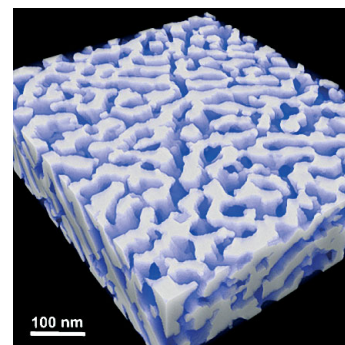
Reviews

Porous Metals and Metallic Foams: Current Status and Recent Developments

L.-P. Lefebvre,* J. Banhart, D. C. Dunand

Porous metals and metallic foams are presently the focus of very active research and development activities. There are currently around 150 institutions working on metallic foams worldwide, most of them focussing on their manufacture and characterisation. Various companies are developing and producing these materials which are now being used in numerous industrial applications such as lightweight structures, biomedical implants, filters, electrodes, catalysts, and heat exchangers. This review summarizes recent developments on these materials, with particular emphasis on research presented at the latest International Conference on Porous Metals and Metallic Foams (MetFoam 2007).

ADV. ENG. MATER. 2008, 10 775 ... 787



A New Era in Porous Metals: Applications in Orthopaedics

B. Levine*

The development of porous metals has revolutionized the field of orthopaedics. Tritanium (Stryker, Mahwah, NJ), Regenerex (Biomet, Warsaw, IN), Trabecular Metal (Zimmer, Warsaw, IN), and Stiktite (Smith and Nephew, Memphis, TN) are currently available for use in orthopaedics. The open-cell structure of these materials allow for: increased porosity (60–80%), low modulus of elasticity, and high frictional characteristics. The paper represents a review of the applications in orthopaedics for these metals.

ADV. ENG. MATER. 2008, 10 788 ... 792

Aluminium Foam Sandwich Panels: Manufacture, Metallurgy and Applications

J. Banhart, H.-W. Seeliger*

Sandwich panels consisting of a highly porous aluminium foam core and aluminium alloy face sheets are manufactured by roll-bonding aluminium alloy sheets to a densified mixture of metal powders and titanium hydride, and foaming the resulting three-layer structure by a thermal treatment. Such sandwich panels are promising alternatives to similar panels manufactured by adhesive bonding and can be forged to shape after foaming or age hardened.

ADV. ENG. MATER. 2008, 10 **793** ... 802



A New Class of High Temperature and Corrosion Resistant Nickel-Based Open-Cell Foams

G. Walther, B. Klöden, T. Büttner, T. Weißgärber, B. Kieback, A. Böhm, D. Naumann, S. Saberi, L. Timberg*

A new powder metallurgical process was developed allowing the transformation of nickel foam into a high temperature corrosion resistant foam. Parameters such as pore size and alloy composition can be varied in a wide range, and, combined with the good workability, make this foam especially promising in high temperature application like diesel particulate filters and catalyst carriers. High-temperature stability is described based on a FeNiCrAl alloy, which shows outstanding durability.

ADV. ENG. MATER. 2008, 10 **803** ... 811

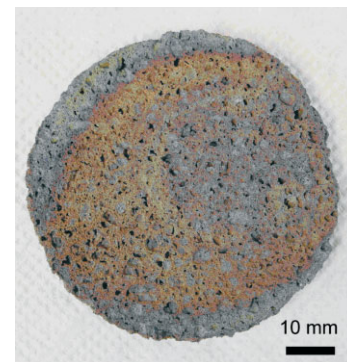
Research News

Characterization of Heat and Momentum Transfer in Sintered Metal Foams

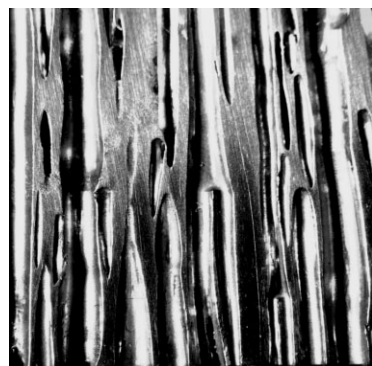
O. Reutter, J. Sauerhering, T. Fend, R. Pitz-Paal, S. Angel*

In this study, metal foams made by the Slip Reaction Foam Sintering (SRFS)-process are investigated concerning their thermophysical and permeability properties. Using the acquired experimental data, a proposal is made for the calculation of the inner surface temperature of the combustion chamber as well as the temperature distribution inside the chamber wall, which consists of a structural element, the metal foam and a thermal barrier coating, equipped with laser drilled micro-holes.

ADV. ENG. MATER. 2008, 10 **812** ... 815



Communications



Fabrication of Lotus-type Porous Metals through Hydride Decomposition

*H. Nakajima**

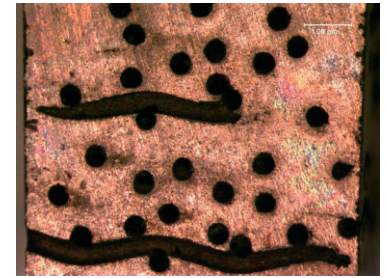
Lotus-type porous metals with aligned long cylindrical pores were fabricated by unidirectional solidification using high-pressure gas (hydrogen) method (PGM) and thermal decomposition method (TDM). The pores are evolved from insoluble gas when the molten metal dissolving the gas is solidified. In the conventional PGM, the hydrogen pressurized in a high-pressure chamber is used as the dissolving gas. However, the use of high-pressure hydrogen is not desirable because of flammable and explosive gas, in particular, for scaling up to mass production of lotus metals. Thus, we propose the thermal decomposition method as an alternative simple fabrication method. The compound containing gas elements is added into the molten metal to fabricate lotus metals. Since the high-pressure gas is not required, TDM is an attractive and alternative method.

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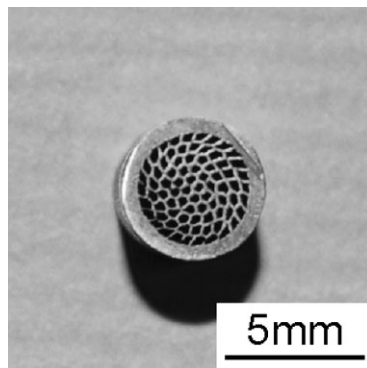
Porous Titanium by Electro-chemical Dissolution of Steel Space-holders

*P. J. Kwok, S. M. Oppenheimer, D. C. Dunand**

Titanium powders are densified together with steel spheres, wires or wire meshes which are subsequently removed by electrochemical dissolution, creating porosity that replicates the steel space-holders. Interdiffusion between steel and titanium is prevented by formation of a TiC diffusion barrier. Without this barrier, a Fe-containing titanium zone adjacent to the space-holder is formed which can be removed electrochemically, thus increasing the size and volume fraction of the pores.



ADV. ENG. MATER. 2008, 10 **820** ... 825



High-Strength Porous Copper by Cold-Extrusion

H. Utsunomiya, H. Koh, J. Miyamoto, T. Sakai*

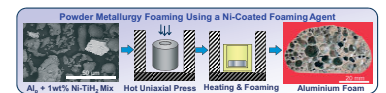
The authors propose a method to fabricate porous metals with high strength in this paper. Pieces of matrix metal and space-holder metal are deformed together by bulk forming for solid-phase bonding. From the bonded composite, only the space-holder metal is removed. If the deformation and the removal are conducted at cold or warm region, 'wrought' high-strength porous metal can be obtained. In this study, using aluminum as space holder, two types of porous copper with one-dimensional pores, i.e., lotus-type and honeycomb-type rods, have been successfully fabricated by cold extrusion followed by chemical leaching. Both the porous coppers fabricated show higher specific yield strength than a conventional porous metal.

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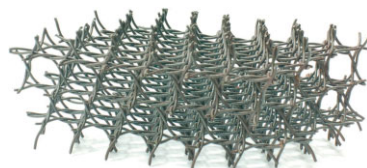
Production of Aluminum Foams with Ni-coated TiH₂ Powder

*P. M. Proa-Flores, R. A. L. Drew**

Aluminum foams produced from Ni-coated TiH₂ display higher final densities than those produced with-out the Ni diffusion barrier; however, resulting foams display rounded pores and a narrower pore size distribution. The 1–2 μm Ni-coating layer is produced by an electroless technique, and is strong enough to remain attached to TiH₂ after the mixing and compaction step in the powder metallurgical foaming process.



ADV. ENG. MATER. 2008, 10 **830** ... 834



High Strength-per-Weight Cellular Metals Fabricated of Wires

*Byung-Kon Lee, Ki-Ju Kang**

In pursuit of high specific strength cellular metals, the authors have examined compressive strength of Wire-woven Bulk Kagome (WBK) specimens composed of two different wires, i.e., aluminum alloy wires and spring steel wires. Compression tests give the strength of 1.8 MPa at a density of 0.096 Mg/m³ for the former and 7.1 MPa at 0.271 Mg/m³ for the latter. These two WBK specimens outperform most competitors of metal foams with respect to specific strength. In comparison with other Periodic Cellular Metals (PCMs), even though the relative density of the two WBK specimens is substantially lower, their compressive strength and energy absorptions are comparable to those of the square honeycomb and the pyramidal core, which are known as ones of the best PCMs.

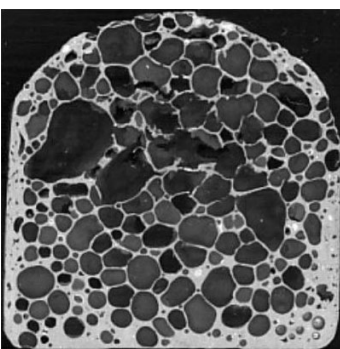
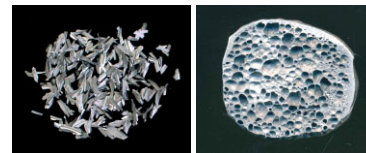
ADV. ENG. MATER. 2008, 10 **835** ... 839

Foaming Behavior of Aluminum Precursor Produced from Machined Chip Waste

N. Kanetake,* M. Kobashi, S. Tsuda

New technology was developed to produce aluminum foams from low cost machined chip wastes instead of aluminum powder. The foamable precursors were fabricated from machined chip wastes with various shapes and alloy elements by compressive torsion processing and they are successfully foamed like those from aluminum powder. The precursors produced from mixed chip wastes of different shapes or different alloy elements can be also successfully foamed.

ADV. ENG. MATER. 2008, 10 840 ... 844



The Effect of TiH₂ Particle Size on the Morphology of Al-Foam Produced by PM Process

A. Ibrahim, C. Körner,* R. F. Singer

The usage of different TiH₂ particle sizes is an approach to adapt the onset of gas evolution temperature of gas blowing agent and improvement of the macrostructure of foamed aluminum. The higher foam expansion and coarser gas bubbles foam structure are corresponding to the coarser particle sizes TiH₂ while the finer macrostructure and lower mean material thickness and quite lower maximum expansion fate the finer grade of TiH₂.

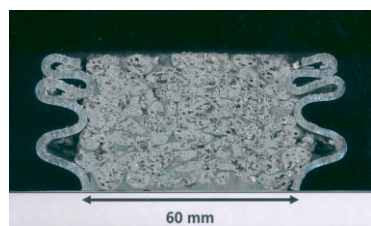
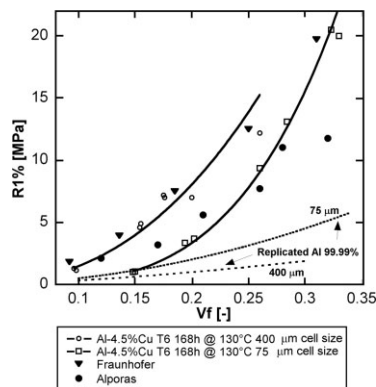
ADV. ENG. MATER. 2008, 10 845 ... 848

Age-hardening Response of Replicated Microcellular Al-4.5%Cu

Y. Conde, A. Mortensen*

We study the response to age hardening of Al-4.5%Cu replicated foams having 75 and 400 μm diameter cells and of relative density between 0.1 and 0.32, to show that the age-hardening response can depend on the cell size and morphology, and that open-celled replicated high-strength aluminium alloy foams can be made as strong as commercial closed-celled aluminium foams despite their inferior mesostructural features.

ADV. ENG. MATER. 2008, 10 849 ... 852



Mechanics of Aluminum Foam-Polymer Hybrid

K. Stöbener,* J. Baumeister, G. Rausch, M. Busse

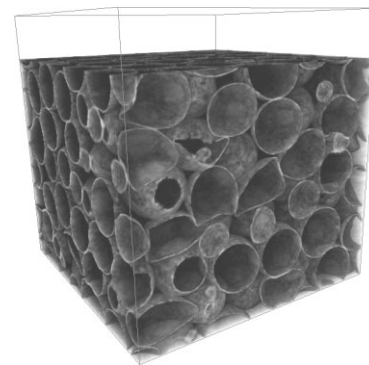
Aluminium foam – polymer hybrids set-up from small volume spherical aluminium foam elements joined by adhesive bonding were subjected to uniaxial compressive loads. Deformation patterns are displayed and discussed. The influence of foam element volume and density as well as strength of polymer joints on the hybrid's mechanical properties are outlined. A simplifying model for prediction of the hybrid's deformation properties is developed and discussed.

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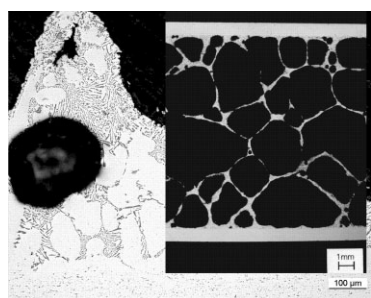
Mechanical Behaviour of Metallic Hollow Spheres Foam

A. Fallet,* P. Lhuissier, L. Salvo, Y. Bréchet

Structural and mechanical characterization of stainless steel hollow spheres foams has been investigated by X-ray tomography. In-situ compression tests enable to study the main deformation mechanisms that govern the plasticity of the foam. FEM calculations of the compression of a pair of connected spheres have been performed in order to identify the conditions under which either mechanism is operative. Then a macroscopic phenomenological model for the compressive behaviour has been developed. It describes the overall behaviour of the material following damage progression. The model gives a description of an equivalent homogeneous material without losing information on irreversible mechanisms occurring at the level of the mesostructure.



ADV. ENG. MATER. 2008, 10 858 ... 862



Influence of Core and Face Sheet Materials on Quasi-Static Mechanical Properties and Failure in Aluminium Foam Sandwich

D. Lehmkus,* M. Busse, Y. Chen, H. Bomas, H.-W. Zoch

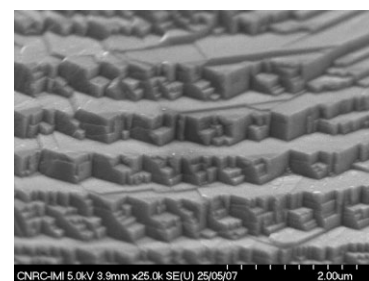
Aluminium foam sandwich (AFS) with metallurgical bonding between face sheets and core has high potential for lightweight design. The present paper studies failure mechanisms and mechanical characteristics under quasi-static bending load to support safe dimensioning of parts. For this purpose, failure charts are provided based on a weakest-link approach which incorporates local material properties and reflects scatter of sandwich properties.

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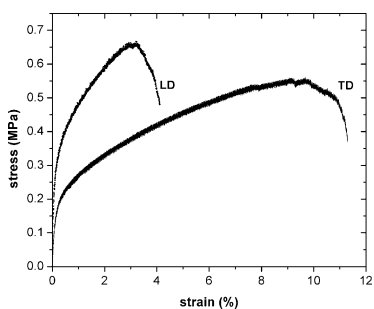
Effect of Oxygen Concentration and Distribution on the Compression Properties on Titanium Foams

L.-P. Lefebvre, E. Baril*

The effect of oxygen in solution and surface oxide on the properties of titanium foams under compression is discussed in this report. The authors present a simple method to discriminate the amount of oxygen coming from the oxide and from the solid solution. Oxygen in solution has an impact on the hardness, yield strength and ductility while surface oxide has little impact on the compression properties within the concentration evaluated.



ADV. ENG. MATER. 2008, 10 868 ... 876



The Influence of Cell Shape Anisotropy on the Tensile Behavior of Open Cell Aluminum Foam

E. Amsterdam, H. van Hoorn, J. Th. M. De Hosson,* P. R. Onck

Tensile tests have been performed on annealed (AN) and heat treated (HT) Duocel open cell aluminum foam (20 PPI) samples for relative densities ranging between 3 and 13%. The long axis of the cell was oriented longitudinal (LD) or transverse (TD) to the loading direction to observe the effect of the cell shape anisotropy on the tensile behavior. During the tensile tests the evolution of damage was monitored by measuring the electrical resistance. All changes in the tensile behavior between orientations, such as the flow stress, peak stress and peak strain, can be explained by both the cell shape anisotropy and the change in damage evolution.

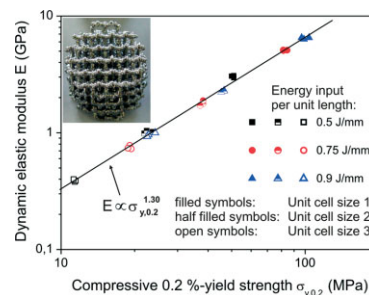
ADV. ENG. MATER. 2008, 10 877 ... 881

Selective Electron Beam Melting of Cellular Titanium: Mechanical Properties

P. Heintl, C. Körner, R. F. Singer*

Cellular titanium seems to be a promising material for medical implant applications due to an elastic modulus comparable with human bone and an interconnected porosity which facilitates bone ingrowth. This paper reports the mechanical properties of non-stochastic cellular Ti-6Al-4V structures fabricated by Selective Electron Beam Melting depending on different unit cell sizes and varying energy input per unit length of the electron beam.

ADV. ENG. MATER. 2008, 10 **882** ... 888



Experimental Demonstration of Entrance/Exit Effects on the Permeability Measurements of Porous Materials

E. Baril, A. Mostafid, L.-P. Lefebvre, M. Medraj*

The pressure drops were measured on metallic foams having uniform structure and different thicknesses, densities and pore sizes. Results indicated that entrance/exit effects can be a significant contributor to the pressure drop when the thickness of the specimens is small. Above a critical thickness, the contribution of the entrance effect on the total pressure drop becomes insignificant and classical models can be applied.

ADV. ENG. MATER. 2008, 10 **889** ... 894