IFAM

CELLMET NEWS

Editorial

Dear reader,

The new issue of the CELLMET News reflects the progress in applications of cellular metals in different areas. For instance an unique open-cell copper foam has been developed to cool more efficiently high powered electronics. Additional alloyed nickel based foams for high-temperature applications like diesel soot filtration and a new type of regenerator for Stirling engines based on highly porous fiber structures are covered. Furthermore, a novel lightweight metal composite sheet for structural applications and a high temperature thermal insulation material based on a molybdenum foam are highlighted. Another successful application of an open cell foam as a part of the breather unit for the gearbox of the Gulfstream airplane will be addressed.

These and other applications will be presented and discussed during the CELLMET 2008 Symposium which will be held in Dresden, October 8th to 10th.

I invite you to join the symposium and share your experience in the applications of cellular metals and alloys.

Günter Stephani
Fraunhofer IFAM Dresden and
Chairman CELLMET 2008

CONTENTS

Regenerators from sintered metallic short fibres

The Dresden-based department of the Fraunhofer Institute for Fabrication and Advanced Materials (IFAM) specialises in the development of metallic short fibres and sintered porous structures thereof. The preferred method of crucible melt extraction allows for the production of almost arbitrary metals and alloys. A special deposition method (rotating sieve drum) was developed in order to achieve homogeneous fibre structures. This process results in an anisotropic structure with regard to pressure drop and heat transfer properties. This results in favourable characteristics for the use as heat regenerators in Stirling engines.

In the course of the project inno.zellmet (funded by the German Ministry of Education and Research), such regenerators were developed jointly with Enerlyt Potsdam GmbH, who produces 2- and a 4-cycle Stirling engine

Fig. 1 2-cycle stirling engine

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prototypes. In contrast to conventional diesel and other internal combustion engines, a hot gas engine uses an external heat source to generate mechanical energy. The regenerators periodically transfer heat to or from a working gas. The efficiency of this process determines to a large part the overall efficiency of the Stirling engine. The design freedom of the short fibre structures allows to build a porous morphology that results in an almost ideal linear temperature profile along the direction of the gas flow.

The development of Stirling engines for the use in micro combined heat and power generation (μCHP) has gained momentum and is in the focus of intensified international research and development activities. Additional environmental benefits are derived from the use of CO_2 neutral fuels such as biogas or wood pellets. The Stirling engine of Enerlyt is designed for such applications and field testing has started this year.

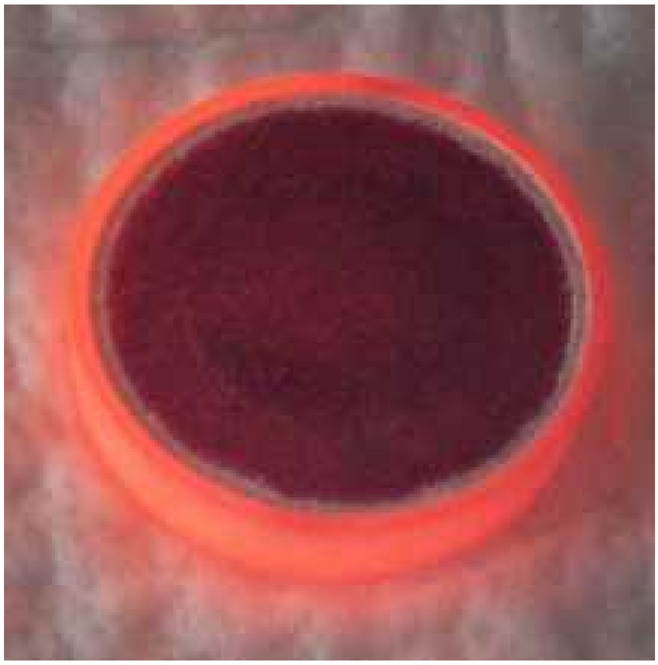

Fig.2 Regenerator at 600°C

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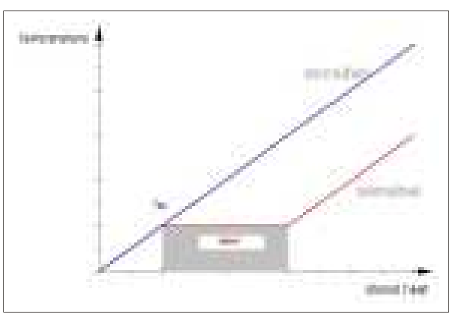
Latent storage device with open-porous metal foam

It is necessary to store heat in order to optimize the production and use of heat. This takes place with the network-independent heat supply or to adjust supply and demand of heat according to time and performance.

Industrial process and waste heat, solar heat, or block-type thermal power stations can be taken into consideration as heat source.

If temperature of the storage medium increases when heat is added, we talk about sensible heat.



The measurable increase of temperature is proportional to the heat stored in the medium (dQ=m•c•dT). The dependency of temperature of most of the storage media can be disregarded. Therefore, the sensibly stored heat quantity changes linearly with the difference of temperature (fig. 1).

Latent storage device means the storage of heat in a medium that experiences a phase change. The material starts to melt during the heat addition and the temperature will not increase in spite of the thermal flux. The

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temperature will not continue to increase sensibly (fig. 1) until the material (PCM: Phase Change Material) has completed the phase change. Due to the phase change it is possible to store heat without a high change of temperature with

- high storage density
- avoidance of temperature peaks or fluctuations for smoothing or buffering

Using H_2O as an example it can be seen that the necessary amount of heat for melting a mass H_2O of ice at 0°C is approximately the same amount of heat to warm up the same mass from 0°C to 80°C. For the phase change of $H_2O_{liquid} \rightarrow H_2O_{steam}$ the fivefold amount of heat is necessary in order to warm up H_2O from 0°C to 100°C. This means that 14 % are stored as sensible heat and 76 % are stored as latent heat in steam.

Medium	Heat conductivity $\left[\frac{W}{m \cdot K}\right]$	
	With metal foam	Without metal foam
H_2O	6.9	0.57
Ice	7.4	2.20
Paraffin RT6	7.0	0.2

Materials are used as PCM for climatisation that go through a phase change from solid-liquid because the volume change is the lowest in this process.

A significant bottleneck with regard to the heat storage is the low heat conductivity of the PCMs. Due to the characteristics of open-porous metal foams they are ideal for the structure of compact latent storage devices in stationary and mobile climate control systems because they

- clearly increase heat conductivity (see table)
- use less than 10 % of the useable total volume
- represent seed crystals and therefore avoid supercooling or overheating
- allow free shape forming to the incorporation conditions

In order to use such property potential, the contact between the metal foam and the heat transferring surface is decisive.

The transformation actually takes place in cold air reservoirs for mobile use and air conditioning of buildings. The cold air reservoir contains approximately 75l of H_2O and its size is 600 x 500 x 250 mm^3 with a cooling capacity of 500 W (fig. 2).

The latent storage devices for the stationary climatisation are designed as open systems that are charged by means of the cool external air during night and discharged by means of the warm air during the day. The construction is carried out as plates and cylinders that are filled with metal foam.

Open-porous metal foams result in a clear improvement of the heat conductivity and dynamics of charge and discharge in latent storage devices. Current trials deal with the heat storage obtained by solar thermal systems.

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Production of large-size flat aluminium foam components

At the Fraunhofer Institute for Machine Tools and Forming Technology a new installation for the production of large-size flat aluminium components as well as plates and sandwiches was started. The installation is an infrared foaming facility which was developed and built together with the company Xerion in Freiberg within a project funded by the Sächsische Aufbaubank (SAB).

The emitter area of the installation has a dimension of 2500 x 1250 mm. This conforms to the so called medium format of plates. So the demand of producing foam components in dimensions "close to the industry" is fulfilled.

The motivation for the construction of the installation was an increase of efficiency and a better controlability of the foaming process. This is achieved by using infrared radiation for heating and by the usage of several emitter modules.

The installation does no longer have the disadvantages of chamber kilns because on the one hand no unnecessary space for the furnace and on the other hand no fireproof cladding has to be heated and cooled down while foaming. So the heating by infrared radiation leads to a good control of the heating process, which is nearly without delay.

The heating is achieved nearly completely by radiation. In contrast to convective heating, the temperature difference between emitter and component is proportional to the forth power, the heat transfer by radiation is highly effective. Additionally, infrared emitters can bear significantly higher temperatures than furnaces heated by resistors (about 2400 °C).

To run the installation energy efficient, a scalable emitter field is used for heating the components. The heating is done by 60 emitter modules, which are allocated above and under the component in two layers. The flat components are heated by their largest areas. The infrared emitter modules can be switched on and off according to the area that is to be heated. So the energy supply can be adjusted to the size of the component and the foaming demands.

Within the next weeks precision tuning will be done to achieve an effective and safe operation. It is the aim to produce and supply huge plates and sandwiches with good quality in higher quantities.

Finally, the installation is a further and consequent step to transfer aluminium foam components into existing and novel applications.

We thank the Development Bank of Saxony (Sächsische Aufbaubank SAB) for sponsoring the investigations within the scope of the project 11140/1739.

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Metal foam takes off and flies with Gulfstream G650 business jet to unequaled hights

RECEMAT metal foam package for a breather unit

In CELLMET NEWS II-2007 we have discussed the application of oil mist separators for airplanes. Now we may inform the readers about the airplane such metal foam packages are used for. It is most important people know about applications available and which show to be proven technology.

RECEMAT International strongly promotes the development of new applications with her open cell metal foam.

The G650, the latest business jet of Gulfstream Corp. was launched on March 13, 2008. Rolls-Royce supplies the BR725 jet engines for this airplane. Rolls-Royce has selected Hispano-Suiza, daughter company of the French SAFRAN Group, to develop and produce the gearbox driving the auxiliary rotary equipment. A most essential device driven by the Auxiliary Gearbox (AGB) is the breather unit. The beather unit makes sure the lubrication oil mist in the gearbox is not discharged into the atmosphere. A package of metal foam in the breather unit achieves this. These packages rotate at speeds between 10,000 and 20,000 rpm. Just like in a centrifuge the oil separates from the air.

Hispano-Suiza has selected RECEMAT International as partner for the production and supply of the metal foam packages.

The Gulfstream G650 will start commercial flights in 2012. Production forecast runs up to 2032. At that time it is expected around 1,000 G650 will have been supplied. For RECEMAT International it means delivery of a total of 2,000 metal foam packages.

RECEMAT International also has been selected to supply its metal foam packages for another airplane, with engines from another supplier.

For publications about the research & development sponsored by RECEMAT International please refer to our website: www.recemat.com and click in the left column subjects such as Research, Research Support and/or Publications.

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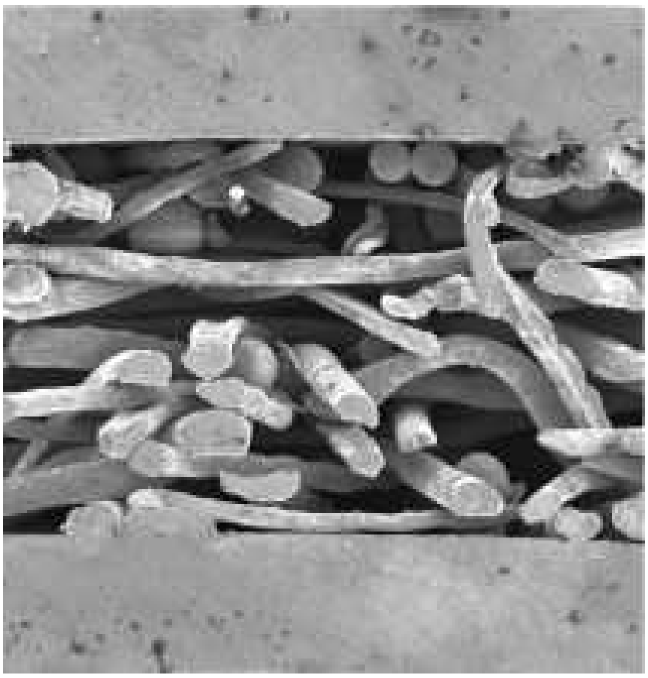
Fibrecore™ – A novel lightweight all metal composite sheet for structural applications

Fibrecore™ is a lightweight, high stiffness metallic sandwich material, designed as a steel or metal sheet replacement. Fabricated entirely from stainless steel, with thin faceplates and a novel melt spun fibre core, it has an overall thickness of around 2mm and an areal density below that of a titanium sheet of the same thickness. Assembled at room temperature, prior to high temperature vacuum diffusion bonding, it can be machined, formed and welded using conventional metal fabrication techniques. Fibrecore™ is manufactured in two stages. The standard product is prepared by evenly depositing a layer of melt spun stainless steel fibres onto a sheet of stainless steel. A second sheet of 304 is placed on top of the metallic fibre layer and the resulting assembly is diffusion bonded under vacuum or an inert/reducing atmosphere.



Fibrecore™ melt spun fibrous network between two thin faceplates

Fibrecore™ fibres are manufactured using Fibretech's melt overflow process. Melt overflow is a highly efficient and cost-effective method of manufacturing metallic fibres, with diameters of 50μm – 500μm and lengths of 1.5mm – 50mm. The core architecture can be controlled via the initial fibre aspect ratio and the consolidation conditions.

Sandwich panels with low density cores are known to exhibit high bending stiffness. For the same areal density, the beam stiffness of Fibrecore™ is about 300% higher than titanium sheet and nearly 800% higher than steel sheet. For a Fibrecore sheet with a thickness of 2 mm, its beam stiffness is 40% higher than titanium sheet, more than 200% higher than aluminium sheet and only 18% less than steel sheet. Finally, and perhaps most importantly, for the same beam stiffness, Fibrecore™ is 15% lighter than titanium sheet and 50% lighter than steel sheet.

Fibrecore™ has good energy absorption charac-teristics and can withstand a 70 J impact from a 9.5mm diameter steel ball bearing at 200 m/s. Multi-layer Fibrecore™ offers even higher levels of performance, with 20-layer material being capable of resisting impacts of up to 1000 J. When used in conjunction with disruptive layer technology, multi-layer Fibrecore™ also provides effective protection against high-velocity ballistic projectiles.

The range of potential applications for Fibrecore™ is correspondingly wide. It is currently being evaluated for automotive, rail transport construction and defence applications, including vehicle body panels and crumple zones, railway carriage cladding, building cladding and decking, marine decking and transport containers, exhaust system noise reduction, low cost heat exchangers and lightweight personal protection.

10 Layer Fibrecore after impact testing with a 9.5 mm diameter steel ball bearing and a velocity of 200 m/s

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Hybrid foams – combination of foams of the material classes polymer, metal and ceramic

At the beginning of this year five Fraunhofer Institutes (ICT, IFAM, IKTS, ISC, and IWM) have started to develop a new foam material grade: multi-functional Hybrid Foams. The aim is to achieve new properties and new property combinations, respectively, to expand application fields of foamed materials.

Hybrid foams are defined as the combination of two mono material foams of different material classes (polymer, metal, and ceramic). The foams are connected on a macroscopic level. Depending on the structure the hybrid foams will be divided in two types:

1. Interpenetrating hybrid foams:
The foamed Materials are in a co-continuous state

2. Particulate hybrid foams:
One foamed material is embedded in a second foamed matrix

The processing of the hybrid foams will be carried out by polymeric manufacturing technologies, a sintering process and a special aluminium foam process (APM-technology). In addition to the material development it will be worked out a numerical tool for the application-oriented material optimization and calculating the properties of the hybrid foam. The capability will be shown with three model application in the fields of mechanical energy absorption, high temperature noise insulation, and construction elements with a high stiffness.

This joint project has started at the beginning of this year and will end by January 2011.

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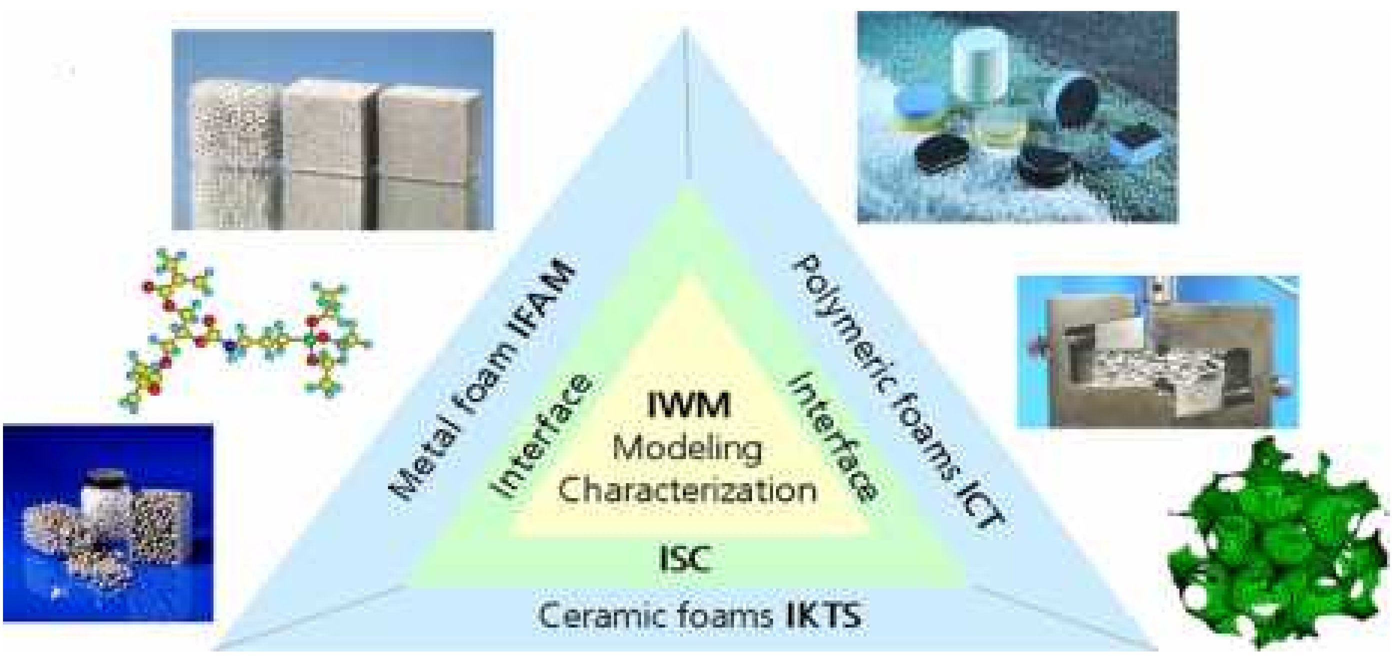

Nickel-based foams for high-temperature applications

A number of nickel-based (e.g. Inconel®) and iron-based (e.g. Incoloy® or Fecralloy®) alloys have been successfully developed for applications at high service temperatures and in corrosive environments. Applications such as diesel particulate filters, heat exchangers, and catalyst supports require open-cell porous structures with tailored material properties. Both requirements can be met at the same time by high tempe-rature and corrosion resistant metallic alloy foams of the above mentioned materials.

VALE INCO is the worlds largest producer of Nickel foam, i.e., over 4,000,000 m² per year are produced, mainly for the battery market. However, this foam has only limited high temperature stability. The concept of tailoring the properties of this commercially available foam (INCOFOAM®) in order to make it stable at extremely high tempe-ratures could possibly offer a wide range of new applications. Therefore, in cooperation between VALE INCO and the Fraunhofer IFAM Dresden a technology was developed, which transforms the commercially available Ni foam (INCOFOAM®) into an alloyed foam with high temperature stability (INCOFOAM®HighTemp).

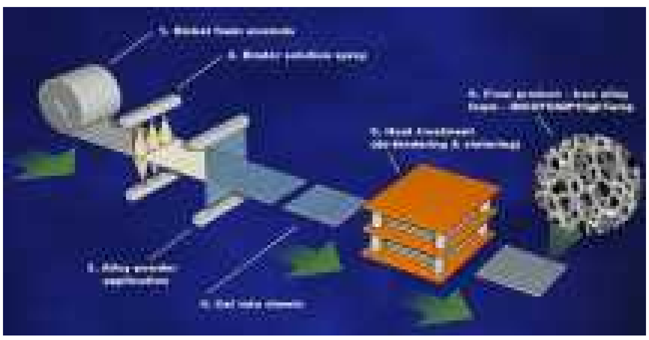

Fig. 1 Manufacturing process for alloyed Ni-based foam

The main features of this powder metallurgical process are the coating of the Ni foam with a binder by a spraying process and afterwards with a specified metal powder (Fig. 1). The following heat treatment includes a debindering and sintering step. During the transient liquid phase sintering process elements from the powder diffuse rapidly into the foam struts and ensure a homogeneous alloy foam composition. In terms of production capacity, upscaling has taken place: a pilot plant has been built near Munich with an output of about 100,000 m²/year.

The foam draws its excellent high temperature properties from the ability to protect itself against corrosion by the formation of metal oxide layers. This can happen either in service or prior to it (i.e. by pre-oxidation). For the currently targeted applications in the automotive sector, namely diesel particulate filters (DPF) and diesel oxidation catalyst (DOC), pre-oxidation is necessary. At IFAM a process was developed which ensures that only the protective metal oxide alumina is formed (Fig. 2). Because the foam material is easy to shape all sorts of prototypes can be manufactured (Fig. 3). In these tests, the foam showed an excellent soot filtration performance and proved to be a very good choice as a catalyst carrier.

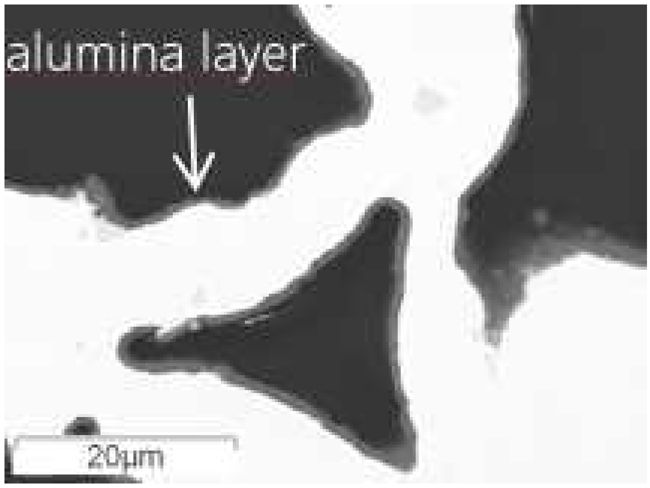

Fig. 2: protective alumina layer formed by pre-oxidation on the foam strut surface

Fig. 3: DPF prototype

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Efficient two-phase electronics cooling with Metafoam's boiling surfaces

A hermal management of electronics components and systems – a 4.5 B$ market – has became a major challenge. By increasing the density of transistors, manufacturers have been able to give constant performance improvements. However, those powerful microprocessors generate higher heat fluxes which need to be quickly dissipated or else they will impact the lifespan, reliability and, ironically, the performance of the products.

Fig. 1 Metafoam's Copper Foam Boiling Surface

Metafoam® Technologies has developed electronics cooling solutions using its unique open-cell copper foam to cool more efficiently high powered electronics. Those boiling surfaces find use in two-phase thermosyphons (also called heat pumps or wickless heat pipes).

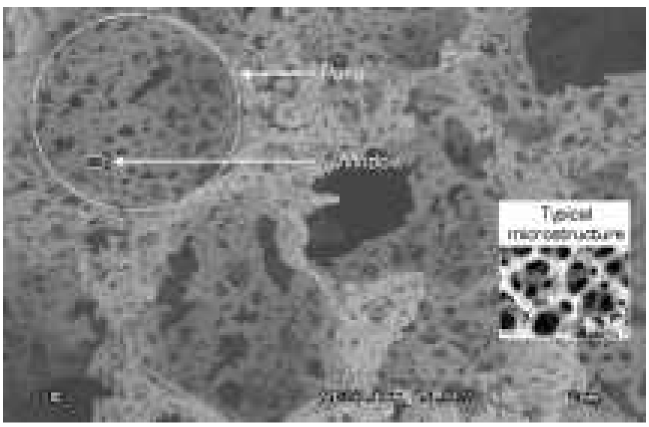

Fig. 2 Metafoam's lace-type foam

Phase-change boiling related methods – with the appropriate boiling surface – are a proven way to remove high heat density. Particularly, thermosyphons can handle higher heat fluxes than heat pipes with the same diameter. Metafoam's innovative nucleate pool boiling surface can dissipate up to 80 W/cm² and therefore more than 515 W for a typical 1 in² die. This is respectively 1.7 and 2.4 times more than sintered copper particles and plain copper surface. Therefore, Metafoam's material can cool servers

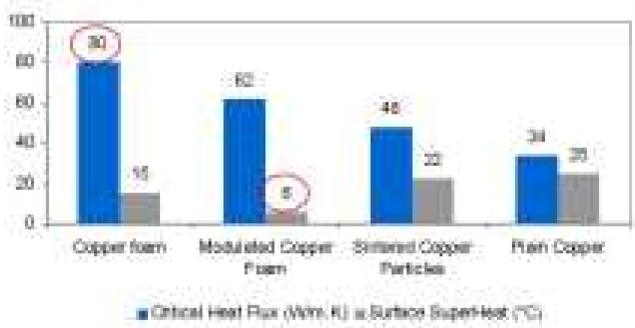

Fig. 3 Performance Reached by Copper Foam Boiling Surfaces

Such a good performance can be reached thanks to the unique microstructure of Metafoam's lace-type metal foam. As shown in Figure 2, each pore is interconnected by small openings called windows. This double porosity leads to a very high specific surface area (20,000 m^2/m^3 on average) and a strong capillary force that wicks the coolant toward the heat source for quick and efficient evaporation. A patent pending bonding technique also reduces the thermal resistance at the interface of the copper foam and the copper plate.

Typically, the main performance objective for pool boiling is to reach a high critical heat flux (CHF) while maintaining a low surface superheat (SSH). CHF is the maximum heat flux that can be handled by a boiling surface before performance drops (similar to dryout for a heat pipe). SSH is the difference between surface temperature of the heat source and fluid saturation temperature. By optimizing both parameters with its innovative material, Metafoam can thus offer a greatly enhanced solution.

As shown in Figure 3, Metafoam's material can reach both the highest CHF and the lowest SSH and thus answer various electronics cooling needs.

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Molybdenum foams for heat insulation in industrial furnaces

Because of its high temperature strength molybdenum frequently is used in kiln engineering. E.g., hot plates, heating element support and shielding plates are manufactured out of molybdenum. Since the price of molybdenum rose by a factor of 7 within the last 5 years, material costs became critical for manufacturer of industrial furnaces.

Consequently, H.C.Starck Hermsdorf GmbH in cooperation with the Fraunhofer Institutes IKTS and IFAM-DD developed a lightweight molybdenum foam for heat insulation applications. It is well known that cellular metals exhibit extremely low heat conductivities of about 1-5 % of the basic material. Thus, network-like structures with porosities up to 95 % and cell sizes of 0.8-1.2 mm where synthesized. The foams where prepared using a powder metallurgical replication technique. Within this preparation route, a polyurethane (PU) sponge is coated by a powder metallurgical slurry. Subsequently the PU template is thermally debinded and sintered.

In first tests, the heat insulation capability of the new material was tested in an industrial vacuum furnace. To this end the molybdenum foam was laminated by a thin molybdenum foil. In comparison to conventional shielding plates, the temperatures at the cold zones only show differences of about 2 % when the molybdenum foam heat insulation was used. At the same time, the mass of the heat insulation was reduced by factor of 4.

H.C.Starck

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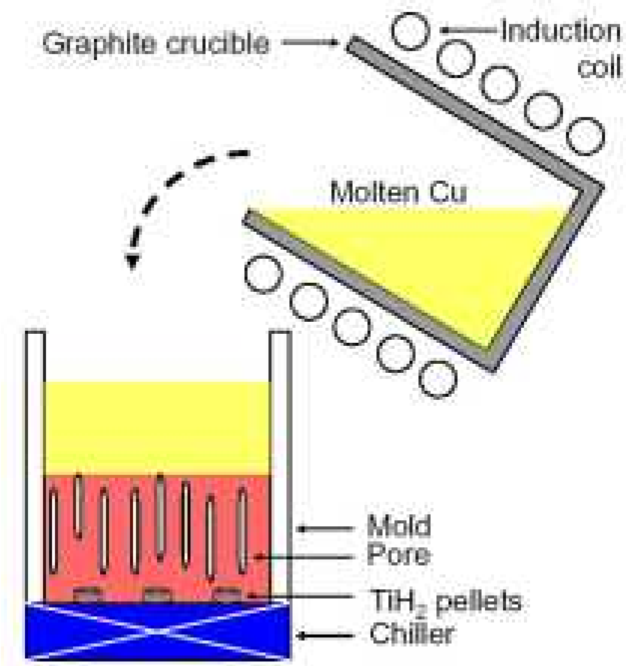
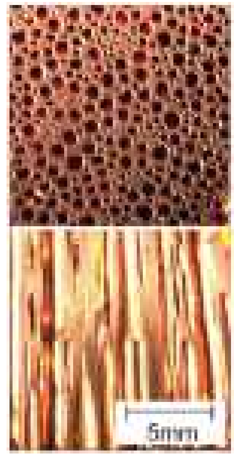
Fabrication of lotus-type porous metals through thermal decomposition of compounds containing gas elements

So far lotus-type porous metals with aligned long cylindrical pores have been fabricated by unidirectional solidification using high-pressure gas (hydrogen) method (PGM). 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, expensive high pressure chamber and laborious handling of the high pressure, in particular, for scaling up to mass production of lotus metals.

In order to overcome this shortcoming, Nakajima group of Osaka University in Japan invented a new technique called as the thermal decomposition method (TDM) as an alternative simple fabrication method.



The compound containing gas elements (for example, hydrides or nitrides) is added into the molten metal to fabricate lotus metals. The compound is decomposed into gas atoms (hydrogen or nitrogen) in the melt, and the gas pores are evolved from the insoluble gas in the solidification process. Simultaneously the compound containing metallic element may serve as the nucleation sites for the pore formation. Thus, the uniformity of pore size and porosity in the lotus metals fabricated by TDM is much superior to that by PGM.



Since this TDM is simple, safe and cheap method compared with the conventional PGM, mass production of lotus metals through TDM is possible.

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2nd CELLMET-Symposium is in preparation

The second International Symposium on Cellular Metals for Structural and Functional Applications will be held October 8th – 10th, 2008 in Dresden, Germany. Already numerous papers were received by the organising committee. A first review of the paper abstracts reveals a broad range of very interesting applications related investigations including automotive, machine tool, aviation, biomedical, acoustics, environmental, and process engineering. Furthermore, papers dealing with new results in manufacturing, machining, coating, and joining of cellular metals and alloys have been received.

Several companies will show their metal foam products during the exhibition/show case.

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Fig: The Dresden Frauenkirche (Church of our Lady)
Photo: Christoph Münch (www.dresden.de)

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Well known international experts in cellular metals will give keynote lectures.

The second flyer is in preparation and will provide more detailed information about the keynote lectures, the different sessions and the time schedule.

CELLMET 2008

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or visit the conference website
www.cellmet.de

The first CELLMET-Awards will be launched during the CELLMET 2008

As already mentioned in the CELLMET-News II-2007 the first CELLMET Awards will be granted during the CELLMET 2008 Symposium.

The aim of the CELLMET Awards is to promote and push cellular metals and alloys especially in the field of application. Two award categories are open for submissions:

- The application award (full serial part based on cellular metals)
- The demonstrator award (prototype/demonstrator based on cellular metals)

Each category winner will earn € 1,500 and a specially designed trophy. Applicants have to provide more information about their cellular metal serial parts, prototypes and demonstrators. More information is available in the last CELLMET News (II-2007) or at www.cellmet.de

We expect your application not later than July 31th, 2008.

The CELLMET Awards will be sponsored by:

RECEMAT open cell material engineering INTERNATIONAL BV — ALU light

CELLMET *NEWS* Impressum

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