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STRUCTURE AND MORPHOLOGY OF THE COPPER METAL FOAM

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Abstract

Metal foam is a solid metal cellular structure that has a significant number of gas-filled pores. The primary classification of metal foams is based on whether they have closed or open cells, which mostly determines the application area. Since the open-cell foams permit water to pass through their pores and trap pollutants there, they are suitable for usage for the waste water treatment. This paper gives an overview of the literature data on the structure, morphology and potential application of copper metal foams.
***Keywords**: metal foams, morphology, copper foams*

1. INTRODUCTION

Advances in science have made it possible to obtain the foam materials. Over the past ten years, there has been a significant increase in the study of this class of materials' characteristics and production techniques. The combination of metal characteristics and porous structure offers an incredibly wide variety of applications. Highly porous materials are known for their high rigidity and low specific gravity and as a result, they are frequently utilized in construction. Due to their geometric properties, they have potential applications as the heat exchangers, chemical reactors and filters. Another area of interest is the biomedical applications [1].

Possessing the specific properties, such as the exceptional strength and energy absorption capacity, make the metal foams a unique structural material, used in a variety of applications. These applications include the vapor cooling of rocket nozzles, making the heat shields for aircraft and protective structures for satellites or aircraft engine casings. In all these situations, the foam materials are exposed to different temperatures, especially high ones. They must ensure the smooth functioning of equipment without malfunctions in the conditions of high temperatures. Given that the influence of high temperature can significantly affect the mechanical properties of metal foams, it is necessary to evaluate the safety of equipment. However, this is considered as a disadvantage in the application of metal foams, because the testing at high temperatures is expensive, time-consuming and requires the complex experimental procedures. This paper provides an overview of the existing literature data on the structure, morphology and potential application of copper metal foams [2].

2. MORPHOLOGY OF METAL FOAMS

Cellular materials are common in everyday life and widely used in a variety of industrial sectors, such as insulation, damping, building, and filtration. Metal foams are lightweight cellular materials that are inspired by the nature; examples of such structures include wood, bone, and sea sponges. While the process of foaming materials such as polymers, ceramics and glass is well known and established, the foaming of metals and alloys presents a challenge. Over the last four decades, different methods for producing the porous metal structures and metal foaming have been discovered. However, the primary issues were the economic unprofitability and obtaining low-quality foam materials. Fortunately, the new technologies for producing metal foams have been introduced within the previous decade.

The term "foam" has no universally accepted definition. There is a difference between the liquid and solid foams. Solid metal foams are typically referred to as the metal foams. A fine dispersion of gas bubbles within a liquid is called the liquid foam. A frozen liquid foam, often referred to as a solid foam, is created by cooling the liquid foam below the melting point of a particular substance. The term "solid foam" mostly describes substances that were formerly liquid. On the other hand, the other porous metal forms, such as the sintered metal powder, that have never been in liquid form can also be referred to as a "foam". These structures have similarities with the real metal foams in their irregular structure and high porosity (40-90% of volume) [3].

Metal foams can have cells that are closed, partially closed, partially open, or open and each of these configurations has the unique properties. Production methods, as well as the structure of the foam, determine their properties and thus the areas of application. An open-cell foam is a metal foam that contains only the edges of present pores, allowing the pores to link through the open surfaces (Figure 1a). On the other hand, similar to a kitchen sponge, the closed-pore foam consists of the pores that are isolated from the nearby ones (Figure 1b) [4].

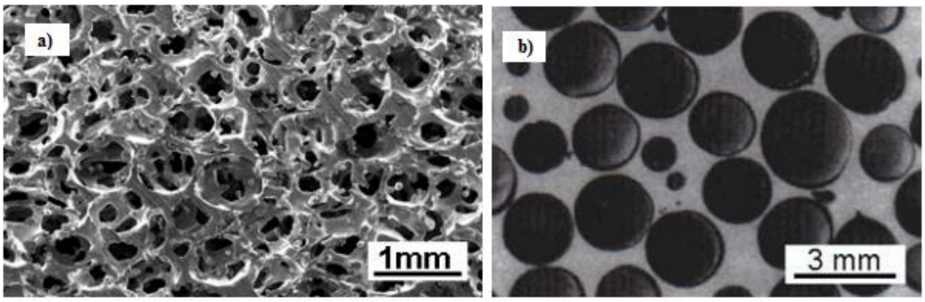

Figure 1. *Three-dimensional foam with (a) open pores (b) closed pores [4]*

Copper foams can be developed using the powder metallurgy technique, applying the potassium carbonate particles as the space holders. Two types of the formed pore structures are the macropores and micropores. The macro-pores can be described as the spherical-shaped pores that had the size of potassium carbonate particles, while the micro-pores were detected in the pore struts and walls. These micro-pores form the open-pore structure and connectivity of the macro-pores, resulting in foams with a significant pore connectivity. Figure 2a depicts the homogeneous distribution of linked pores in the Fe(Al) foams in a compressed specimen. Following the leaching process, these holes resemble the size and form the space holders (NaCl particles), as it can be seen in Figure 2b. This indicates that the final shape of pores may be controlled using the different types of space holders of varying sizes. The use of polyester resin as a binder can provide a sufficient strength to avoid a compact deformation and collapse, while also reducing the base metal corrosion and dissolution during the leaching process. Figure 5c shows the pore structure following sintering, when the resin is removed [5].

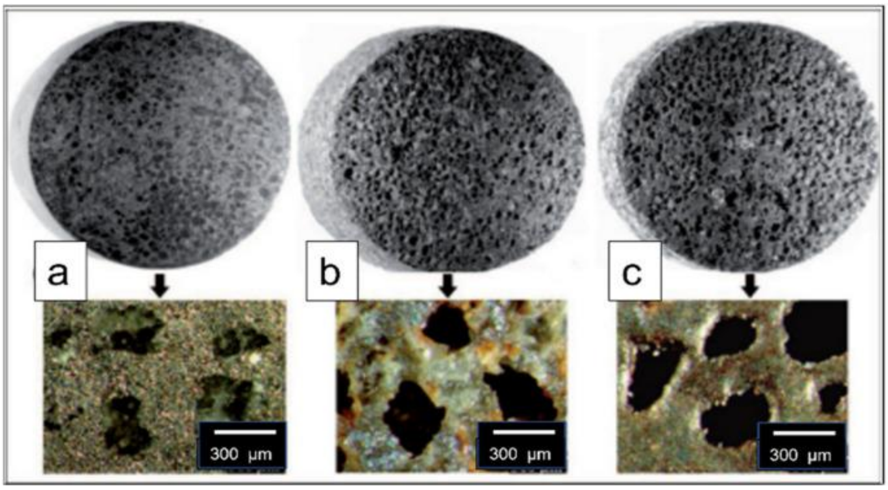

Figure 2. *(a) Compacted; (b) Leached; (c) Sintered Fe(Al) foams [5]*

The open structures allow media to pass through them and are particularly relevant in the heat conduction processes, as well as in the water and air filtration. On the other hand, the closed-pore structures are used for the energy absorption. Although metal foams offer a high potential and wide application, in the last few years, the new areas of application have appeared which may not all be commercially relevant. Some of the leading manufacturers of metal foams include companies such as Alulight (Austria), Cimat (Canada), Aluinvent (Hungary), M-pore (Germany), Recemat (Netherlands) and Ekkentis (Switzerland) [4].

2.1 Properties of Metal Foams

The same techniques, used for fully solid bodies, are also applied to determine the physical, mechanical and thermal characteristics of the foam materials. Understanding the mechanical and physical characteristics of the metal foams is essential since they have an immediate impact on their application. The density and cellular structure (open or closed) of the metal foams have a direct impact on their mechanical and physical characteristics. The cellular structure results in a low weight and high strength. The existence of primary cells ensures that the voltage is maintained at a low or nearly constant level enabling the absorption of energy at a low voltage level. Additionally, the cellular structures can also help in absorbing the sound energy, but one condition must be met, that is, the cells must be connected to each other so that there is no friction loss when the gas passes from one cell to another. The low thermal conductivity of cellular architecture makes it an excellent choice for thermal insulation; nevertheless, the vast interior surface area and high thermal conductivity of the cell wall material make it an excellent choice for heat exchange. The low density of metal foams is their key characteristic. As an illustration, consider the density of Al foam, which varies from 0.1 to 0.4 g/cm^3 (the standard density of Al is 2.7 g/cm^3). The Young's modulus values increase rapidly with increasing density of the metal foam. Metal foams have good mechanical and physical properties, which greatly expands the area of their application [6].

2.1.1 Mechanical properties

The mechanical properties of foams are often characterized using the pressure test data. All foams show a universal deformation behavior, regardless of the material they are made of. Stiffness, also known as the Jung's modulus of elasticity, is a significant mechanical property used in constructions. As previously stated, the primary characteristics are the foam density and structure. Mechanical characteristics are primarily determined by density, but they are also influenced by the quality of the cell structure relating to the connections and roundness of the cells.

The thermal characteristics of foams were studied extensively. In most situations, the melting point, coefficient of thermal expansion and surface specific heat of the foams are the same as those of the materials used to make them. Thermal conductivity and diffusion are two parameters that are always substantially less than the original material values.

Mechanical vibration damping is the use of internal friction in a material to change vibration energy into heat. In this way, the excessive noise and vibrations are reduced and converted into heat. One of the most essential qualities of porous metals is their ability to absorb sound, making them suitable for use in the construction of residential buildings and musical instruments. To reduce the intensity of sound inside a closed space, different mechanisms are applied depending on the place where the sound comes from. If the sound is coming from inside, the sound absorption is required, which is why the porous materials are an excellent choice. The only condition that must be met for the sound absorption to occur is that the cells must be connected to each other. If the sound is coming from outside, the porous materials, when combined with other materials, can help to isolate it.

The mechanical properties of metal foams can be improved and adjusted depending on the desired application by the mechanisms such as hardening, changing the alloy composition, grain refinement and heat treatments [6,7].

3. CONCLUSION

Metal foams offer the unique properties, including stiffness, light weight, and the most important feature of metal foams is their low density. Foam structures can be made to generate either closed-cell or open-cell foams, depending on the applications. Effect of reinforcements and fabrication procedures on the microstructure of foams, as well as defining their mechanical behavior can be achieved by the microstructural studies. The porosities in these foams are determined by the foaming agents and space-holder particles, while the metal foam characteristics and foaming behavior are heavily influenced by the manufacturing procedures used. They can efficiently be used as the structural components in the automobile parts such as the ships and aerospace transportation, as well as the sound dampers, filters and electrodes. However, the improvement is attainable by identification the disadvantages and developing practical solutions for the improved performance under a variety of working conditions and production methods. Due to their great strength and low weight, the metal foams are used in many different industries; however, a large-scale production is limited by the high cost of fabrication procedures. Therefore, cutting the manufacturing costs should also be the main goal of the future process development.

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