

Cooling down

Porous copper is being used in thermal management devices to provide a more cost-effective solution.

Electronic devices and systems incorporating microprocessors and integrated circuits are becoming ever smaller, breaking the barriers of Moore's Law. These new devices have to dissipate large amounts of heat to prevent electronic devices from failure. Applying the principles of thermal management, using heatsinks, heatpipes or active cooling devices, removes excessive heat. Current thermal management devices, however, are either inefficient or too expensive. Consequently, there is a demand for them to be more efficient and cost-effective.

A multidisciplinary consortium has been carrying out a £630k project, supported by the Technology Strategy Board, over the past two years to develop thermal management products from Lost Carbonate Sintering (LCS) porous copper. The consortium is led by C-Tech Innovations Ltd in Chester and composed of the University of Liverpool, Ashington-based Thermacore Europe Ltd, Vacua-Therm Sales Ltd in Hamilton, and Ecka Granules (UK) in Birmingham.

'The world market for thermal management products approaches US\$6.7bn a year,' says John Collins of C-Tech Innovation. 'Lost Carbonate Sintering is a world-leading technology for manufacturing open-cell micro-porous metals. It offers significant

advantages over competing technologies, combining low production cost and accurate control over the pore structure... It will reduce product weights for better heat transfer performance and reduce the production time and energy consumption.'

MIXING IT UP

Porous metals are currently produced using a range of techniques – melt-gas injection, melt foaming or infiltration, powder foaming, investment casting, metal deposition, metal gas eutectic method and sintering hollow metal spheres. They all have disadvantages, says Dr Yuyuan Zhao of the University of Liverpool's Department of Engineering.

'Some produce only closed cell materials,' he says, while others involve expensive materials or are only suitable for metals with low melting points. Techniques that can be used with a wider range of metals and their alloys are generally more expensive. 'There are relatively low-cost methods, but they offer poor control over the size and distribution of the pores, or the porosity range obtainable is very narrow. Investment casting produces the highest quality metal foams and offers more controllability, but it's extremely expensive.' While researching metallic powder production technologies, Zhao combined non-metal particles with

metal particles and removed the former to create porous metal solids where the pore size and shape were tightly controlled.

'We mixed metal particles with soluble non-metal particles... for instance, salt crystals and powdered aluminium, potassium carbonate and powdered copper, and compacted the resulting mix,' Zhao recalls. 'We then sintered it – heating it enough to make the metal particles in the mix adhere to each other without melting. Finally, we cooled the mix and dissolved the non-metal particles in water.'

The university has patented Zhao's LCS process, which works particularly well for copper. 'In principle, it will work with any metal or metal alloy,' he says.

'Ideally the diameter of the metal particles should be between five and 500 microns but if a pore size greater than this was appropriate for a particular application, you could use particles up to 1.5mm in diameter. They can be any shape, but spherical particles are compacted and sintered more readily.' The porosity of the resulting materials is 50-85%. The regularity and quality of the foams can be seen in the images right, top and bottom.

ADDING AND SUBTRACTING

The removable additive can be one or more of a range of widely available and cheap carbonates like calcium, magnesium, potassium or sodium carbonate. 'The precise choice will be

influenced by the melting point, the size of the particles and their solubility in liquids,' explains Zhao. The decision regarding the shape of the particulates is influenced by the end application and the functionality required.

Potassium carbonate works particularly well as a removable agent. It has a relatively high melting point (891°C) and is highly soluble in water, thus it can be removed rapidly. When it melts it decomposes into a gas and an ash. This opens up another route for its removal. The dissolution route retains the perfect shapes of the porous copper components, but can be slow. The decomposition route is faster and cleaner with a slight compromise in geometry. Depending on the specifications of the final products, one or both of these routes will guarantee efficient production of high quality products.

HEAT EXCHANGE

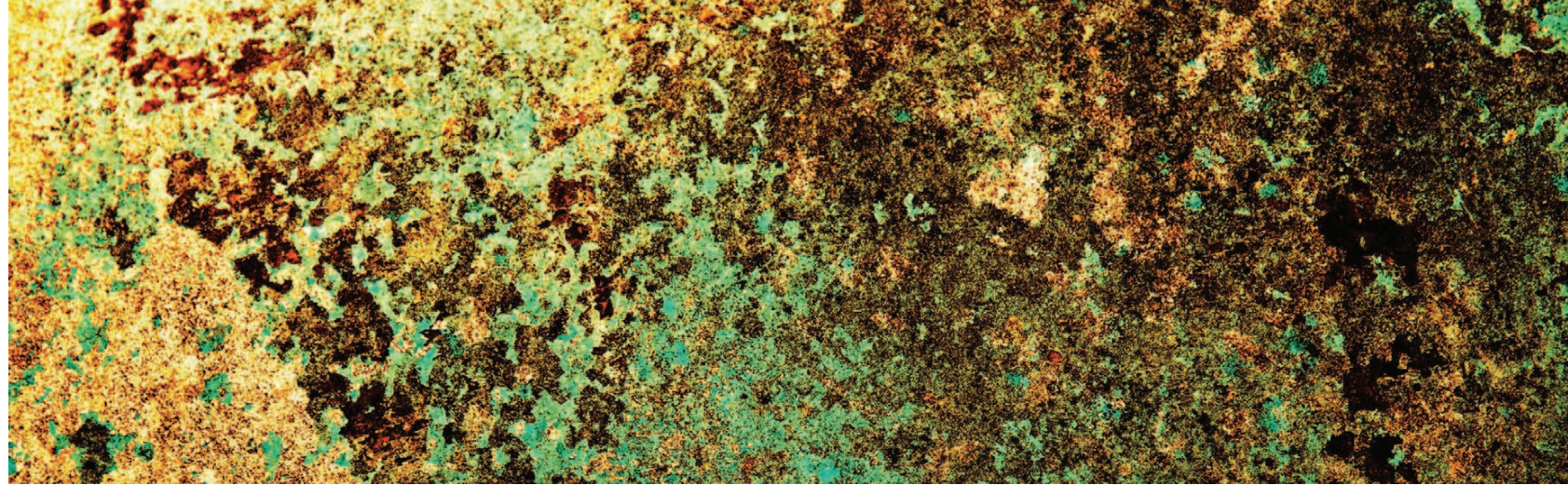
The optimum material for heat transfer or exchange is open-celled with a high ratio of pores to material, through which a coolant can be passed. Most commercial heat dissipation products, like heat pipes, use sintered copper, which has limited ranges of porosity and pore size. Porous copper produced by LCS can have a wide range of porosity and well

controlled pore shape and size. It has a much greater surface area than the same volume of sintered copper, which significantly improves heat transfer due to the increase of surface area in contact with the coolant.

'The LCS porous copper can remove heat at a rate of 1MW/m² while maintaining the component temperature below 85°C. The heat transfer coefficient was found to be as high as 140kW/m²K,' observes David Mullen of Thermacore.

'This material... achieves similar performance as micro-channel heat sinks cooled by two-phase flow with a water flow rate 10 times lower... With this material we can produce lighter, more efficient heat exchangers for applications like radiators, refrigerators, air conditioners... and computers, which become increasingly prone to overheating as they miniaturise.' The graph, right, shows the typical heat transfer characteristics of an LCS copper foam as a function of porosity and water flow rate, with maximum performance at around 65% porosity.

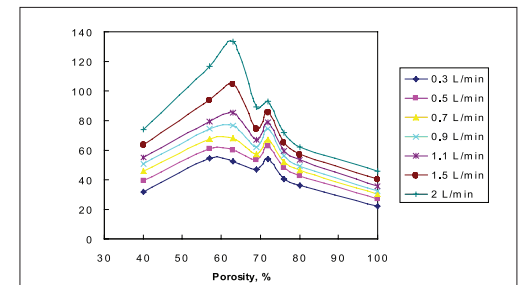
Outside the applications area of electronics' cooling, the consortium has already received interest in porous nickel components for heat engine applications, as catalyst supports and in fuel cells.



A 10cm diameter porous copper disc manufactured by the LCS process



Heat transfer coefficient of porous copper made by the LCS process. The pore size was nominally 700microns



Microstructure of porous copper made using LCS

