New materials have remarkable properties and can be customised

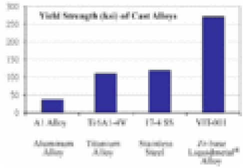

Fig. 1. Liquidmetal Technologies' VIT-001 series alloys have a yield strength that is more than twice that of conventional alloys.

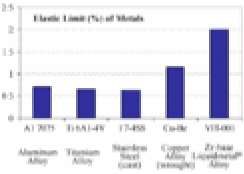

Fig. 2. Liquidmetal Technologies' VIT-001 series alloys have an exceptionally high elastic limit of 2percent.

Fig. 3. Vertu's hand-crafted Ascent Motorsport Limited Edition mobile telephone features a Liquidmetal casing.

Fig.4. The Sandisk 2GB Cruzer Titanium USB Flash drive has a 'crush-resistant' Liquidmetal casing.

Imagine a class of material with twice the strength of stainless steel, an elastic limit more than double that of most metallic alloys, yet it can be processed in ways similar to thermoplastic polymers.

Furthermore, the same class of material can be used to hard-coat metallic components to give exceptional wear resistance and corrosion resistance. If required, the properties can be tailored to enhance fatigue resistance, yield strength, density, elastic modulus, impact resistance, thermal or electrical conductivity, coefficient of thermal expansion or acoustic and damping characteristics.

This versatile class of materials is not based on an exotic element or complex alloy; rather it is what is known as glassy metals. These have been discussed as a theoretical possibility for decades, but only more recently has it been possible to produce them in commercial quantities.

Patents

Numerous patents have also been granted, so the sources of supply are also limited for the time being.

Metals have an amorphous structure while they are in the liquid state, but they normally form crystals as they cool and solidify, often undergoing phase changes as well. Within the crystals there are atomic vacancies that enable dislocations to occur if the material is subjected to a load – which results in the strength of the bulk material always being much lower than the theoretical maximum that the inter-atomic bonds should allow. In addition, grain boundaries between the crystals promote corrosion and other chemical reactions such as oxidation and sulphidation.

Amorphous metals, on the other hand, do not form a crystalline structure; instead they maintain a random, amorphous structure (akin to that in glass) without the vacancies that would cause weaknesses in crystalline metals, and without the grain boundaries that promote chemical reactions.

Glassy metals therefore offer a high yield strength (approaching the theoretical limit), high hardness and wear resistance, a superior strength-to-weight ratio, an increased elastic limit, resistance to corrosion, and exceptional damping and acoustic properties.

If you are sceptical about how much of an impact the molecular

structure can really have on the bulk properties of a material, think about the alternative forms that carbon can adopt – graphite, diamond and carbon nanotubes – and the corresponding material properties.

Yield strength doubled

Liquidmetal Technologies of the USA, which is at the forefront in this field, says that it has produced zirconium-base and titanium-base Liquidmetal alloys (the VIT-001 series) with a yield strength of over 250ksi (1723MPa), which is more than twice the strength of conventional titanium alloys (Fig.1). The same alloys are also claimed to have an exceptionally high elastic limit of 2percent, which is more than double that of aluminium alloys, titanium alloys and cast stainless steel (Fig.2). Note that the material properties are achieved with the material ‘as cast’, with no need for work hardening, heat treatment or other processing.

Compared with conventional metals, the amorphous alloys have a relatively low melting point that is advantageous for two reasons: first, it means that intricate parts can be formed without costly post-finishing processes; and second, various other materials can be added to create composites with tailored material properties.

Because of the astonishing properties of glassy metals, it is not surprising that the applications are extremely diverse. One of the first was in golf clubs, and another is in tennis racquets. Head has used Liquidmetal within its racquets to deliver a claimed 29percent increase in power and a substantial expansion of the ‘sweet spot’. Further applications are either in production or being investigated in the fields of baseball and softball, skiing and snowboarding, cycling, knives, guns, scuba equipment, fishing tackle and boating.

While the sport and leisure industries are in pursuit of performance improvements, designers of consumer electronics continually seek to create products that are smaller and lighter. Glassy metals are therefore attractive because of their high strength (typically 2.5 times greater than titanium alloy) and hardness (1.5 times harder than stainless steel). Consequently lightweight casings can be manufactured with thin walls and high strength to protect the internal components. Resistance to scratching and corrosion are also benefits in this market.

Vertu, which supplies hand-crafted mobile telephones for the luxury market, last year launched the Ascent Motorsport Limited Edition with a Liquidmetal casing (Fig.3). While the price tag on this product (E4595) inevitably restricts its market appeal, lower-priced electronic products are also taking advantage of Liquidmetal alloys. For example, the Sandisk 2GB Cruzer Titanium USB Flash drive (around E90) benefits from a ‘crush-resistant’ Liquidmetal casing (Fig.4), and the same company's flagship MP3 players, the Sansa e200 series, feature a scratch-resistant Liquidmetal back (Fig.5).

Many mobile telephones today incorporate hinges, but conventional metals, such as zinc, magnesium, stainless steel and titanium, have inherent design and performance limitations, especially with respect to longevity and shock resistance. Liquidmetal Technologies, however, says that its alloys’ superior yield strength and elasticity resist deformation and provide exceptional durability. In addition, structural parts made from Liquidmetal alloys can be net-shape formed to thinner profiles while maintaining superior strength, resulting in more space to accommodate consumer demands for new technology.

Medical applications

Away from electronics, manufacturers of medical devices are finding applications for biocompatible glassy metals. Particular advantages here include superior wear resistance, exceptional component strength, improved manufacturability and control of surface texture during the casting process. Some of the products already utilising glassy metals include reconstructive devices, fracture fixations and spinal implants.

In addition, glassy metals can be used for surgical instruments, as they can be ground to a sharper edge than steel, they are less expensive than diamond, and sharp edges do not degrade with use in the same way as steel.

Not surprisingly, the defence industry is also taking a keen interest in the possibilities presented by glassy metals. Liquidmetal Technologies has been awarded a series of multi-year, multi-million-dollar contracts by the USA Department of Defense, and the company’s technologies are currently being developed for use within a kinetic energy penetrator (KEP) rod. The KEP is a key component for an armour-piercing ammunition system that currently utilises depleted uranium (DU) because of its density and self-sharpening characteristic.

Ballistic tests have shown that the Liquidmetal tungsten composite KEP exhibits self-sharpening similar to the DU KEP. As a result, the Department of Defense is working closely with Liquidmetal Technologies to develop a new class of effective and environmentally benign KEP rods.

So far we have discussed the use of glassy metals for the production of net-shape components, but Liquidmetal Technologies has also developed processes for applying glassy metals as coatings.

Typically the coatings bond extremely well to the substrate, withstand repeated thermal cycling, maintain high hardness at elevated temperatures, exhibit excellent thermal conductivity and are highly resistant to corrosion.

Liquidmetal-Armacor Coatings are alloy steels that are applied by twin-wire arc spraying or a thermal spray technique known as high-velocity-oxygen-fuel (HVOF). Depending on the grade specified, the coatings are suitable for use within the oil, power, pulp and paper, and glass industries.

In addition, applications have been found in diesel engines, fans, non-slip flooring, process equipment, metalworking tooling, mining machinery, agricultural equipment and steel mill rolls. Compared with electroplated chromium, the coatings offer improved resistance to corrosion, wear and impact damage.

Because of the nature of glassy metals and the ways in which they are processed, deciding whether or not to utilise them in new designs or product upgrades is far more than a question of comparing the cost-per-kilogram with that of conventional materials. Designing with glassy metals opens up a wide range of possibilities for enhancing product performance, but the advice of the material supplier should be sought in order to maximise the benefits. Nevertheless, the opportunities are truly exciting.