Providing an alternative to titanium for joint implants

Proof of Principal projects take steps towards using Zirconia in the high value added biomedical industry.

Dynamic Ceramic was one of the collaborating companies in the ACORN programme, which was facilitated by Chemistry Innovation; the case study looks at the two follow-up 'Proof of Principal' projects (PoP)

Background

Yttria stabilised zirconia (YSZ) is well known for its strength, hardness and toughness. Known as ceramic steel, this material offers the traditional ceramic benefits of hardness, wear resistance and corrosion resistance, without the characteristic ceramic property of absolute brittleness.
Two Proof of Principle projects have taken significant steps to enable the use of Zirconia in the high value added biomedical industry where its strength would offer a viable alternative to titanium for joint implants.

The Need

YSZ is used in a wide variety of applications including catalysts, fuel cells and refractory lining. A major drawback however is that in the presence of water or water vapour it undergoes a structural change from tetragonal to monoclinic leading to a deterioration in properties. One of the major application areas adversely affected by the hydrothermal degradation of zirconia is the biomedical industry.
Dynamic Ceramic worked with Loughborough University on two proof of principle projects. These projects took significant steps in addressing the hydrothermal degradation of zirconia. The first project looked at hydrothermal resistance of **nanostructured zirconia** to demonstrate that this provided a potential solution. Because the material is not readily available in sufficient quantities the second project focused on scale –up in order to manufacture large ceramic components.

Challenges

Dynamic Ceramic, although a specialist in advanced ceramic manufacturing, do not have the capability to undergo the synthesis and characterisation of raw materials—they worked with Loughborough university who are pre-eminent in the field.

The Solution

The first project demonstrated that Nanoparticle Zirconia provided the desired hydrothermal resistance. It studied the grain size dependant variation in ageing properties of zirconia ceramics with < 100 nm grain size. Currently the worldwide market for joint replacement is around $5.1bn

Ageing studies were performed for nano zirconia ceramics with different yttria content and compared with that of a commercial (Tosoh) yttria stabilised zirconia. The results are shown in figure 1, which clearly demonstrates the efficacy of nanostructured zirconia, with little or no loss in hardness detected over an extended period.

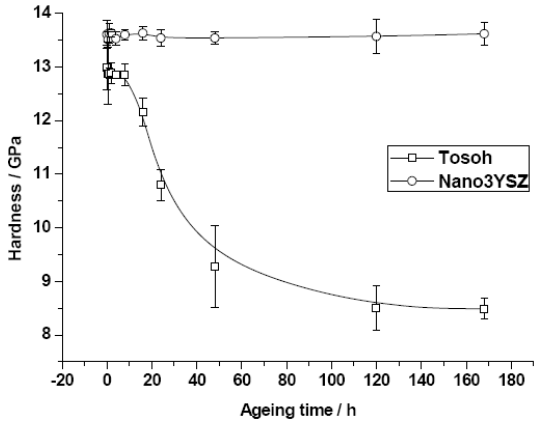

Figure 1 Effect of Hydrothermal Ageing on Hardness for Nano3YSZ and Tosoh at 140°C

In order to exploit this it was necessary to manufacture larger components than were currently available. In the second project Loughborough produced ~ 1kg of YSZ nanopowder based on its patented spray freeze drying process, allowing Dynamic Ceramic to conduct a series of pressing trials to make large components (~50 – 60 mm).

Successes

Market potential

This project has taken the first steps towards the development of a viable alternative to titanium for joint implants

These promising findings provided Dynamic Ceramic with sufficient information to push forward in this field and they are currently engaged with a number of Technology Strategy Board projects, aiming to scale up materials identified in the two studies.

The hydrothermal resistant material will also find applications in valve seals and dental ceramics.