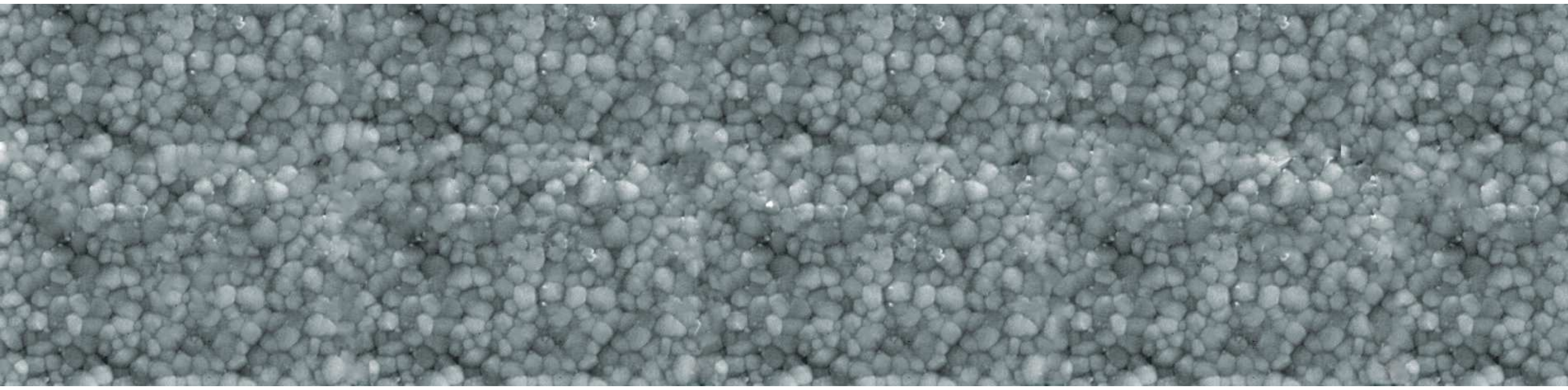
WHAT IS LOW TEMPERATURE DEGRADATION AND HOW DOES IT AFFECT THE PROPERTIES OF YTZP?



OVERVIEW

Low temperature degradation - sometimes referred to as ‘aging’ - is a process whereby a stabilized ceramic loses its strength and other favorable properties when it is used in the presence of moisture, hydrogen or water. Under certain environmental conditions, a harmful crystal transformation can occur which removes the carefully tailored microstructure which endowed the ceramic with its superior properties during manufacturing. Stabilized ceramics such as Yttria-stabilized Tetragonal Zirconia Polycrystal (YTZP) can be prone to low temperature degradation, so understanding the phenomenon is important when choosing among materials. In this paper, we discuss what is known about low temperature degradation and its effect on YTZP, and why modifications or alternatives such as Ceria Stabilized Zirconia (CSZ) should be used instead.

LOW TEMPERATURE DEGRADATION (OR 'AGING')

'Stabilized' zirconia is a family of materials that have been dubbed the 'ceramic analog of steel'. Their exceptionally high strength and fracture toughness is due to the presence of a particular crystal structure called tetragonal zirconia (t-ZrO2)[1]. However, under certain conditions this crystal structure or phase becomes unstable, and the material can lose both its advanced properties and its integrity. When this happens, wear or fracture can result. It is therefore important to understand the environmental usage context, especially when low temperatures are involved, before selecting a ceramic material for a particular application.

The problem of low temperature degradation in YTZP surfaced in the early 1980s when researchers noticed that a humid atmosphere could prompt a weakening phase transformation at the surface of stabilized zirconias at temperatures near 250 degrees C. However continued research appeared to show problems occurring at much lower temperatures: in 1997, the FDA warned against the use of steam sterilization when cleaning zirconia femoral heads for hip implants. Until the turn of the century, researchers concerned themselves mostly with temperatures above room or body temperature, believing that the kinetics of the reaction were negligible above 37 degrees. But in 2001, fracture of hundreds of YTZP femoral heads led to the announcement of a recall. Some argue that these problems were limited to particular batches of YTZP; others say that the same results are likely even with normal processing.

POSSIBLE MECHANISMS OF THE LOW TEMPERATURE DEGRADATION OF YTZP

Thirty years after the initial discovery of the problem, research into the exact nature of low temperature degradation is still ongoing, and for as long as this phenomenon remains only partially understood, the stability of YTZP ceramics in high-stress, moist environments will remain uncertain. Both research and practice have shown that in the presence of water or moisture, the stability of the tetragonal phase t-ZrO2 in YTZP is limited. At even low to moderate temperatures, the tetragonal phase (t-ZrO2) transforms to the monoclinic (m-ZrO2), causing severe wear or failure. It is thought that low temperature degradation begins at the surface of the polycrystal and progresses throughout the material in a 'domino effect' as each expanding grain causes stresses on the surrounding ones, which leads to micro-cracking and continued water penetration; thus the process continues.

Despite continued research, the exact mechanism of low temperature degradation is not fully understood. Early in 2014, researchers identified the presence of no less than three different hydrogen defects. It appears that a complex involving a hydrogen defect and an oxygen vacancy plays an important role. What is certain, however, is that the primary factor is the presence of oxygen vacancies in the Zirconia itself. Water radicals are thought to invade the surface and destabilize the tetragonal phase by sitting in these oxygen vacancies. It is the presence of these oxygen vacancies in YTZP and MSZ that make these particular stabilized zirconia

WHAT THIS MEANS FOR YTZP

YTZP has a fine-grained microstructure that is mostly tetragonal zirconia (t-ZrO_2). Susceptibility to low temperature degradation is why CSZ is a better choice than YTZP or MSZ for structural ceramic, in the presence of moisture.

Of course, material selection will always depend on not just one consideration (such as the avoidance of low temperature degradation) but the full application specification/structure-property relationship. However, in general, for high stress, high temperature applications, Magnesia Stabilized Zirconia (MSZ) can be useful. To protect against low temperature degradation, Ceria-Stabilized Zirconia (CSZ) is often chosen instead. Alternatively, YTZP can be manipulated to increase resistance to low temperature degradation, either through doping or the use of surface treatments.

YTZP RELATED SERVICES**

- Powder Preparation
- Forming
- Green Machining
- Firing
- Grinding and Cleaning
- Glazing / Coating
- Metalizing and Plating
- Metrology