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Towards ductile bio-ceramics: Zirconia-based composites with transformation-induced plasticity

40 years ago, Garvie and co-workers reported that the transformation of metastable tetragonal zirconia grains towards the monoclinic symmetry could give rise to a powerful strengthening mechanism. Their results even led them to consider zirconia systems as analogues of certain steels. This seminal paper created an extraordinary excitement in the ceramic community and is still the subject of extensive research, debates and controversies. It has to be admitted that transformation toughening is widely used in a series of zirconia materials and leads to an increase in strength when compared to non-transformable ceramics (zirconia exhibits the highest strength of oxide ceramics), but the translation into tough, strong and sufficiently stable materials is not fully addressed. For most industrial applications, indeed, zirconia ceramics fail by cracking at low strains and with a much larger scatter in the strength values than metals and statistical approaches of failure are required. Also, the common yttria stabilized zirconia ceramic may suffer aging in some particular conditions. In our latest research, conducted in the framework of two European projects (FP7 - LONGLIFE and H2020 – FTI -SISCERA), we have developed a new class of ceria doped zirconia-based composites that can reach high biaxial strength and high toughness associated with a significant strain to failure, and do not exhibit aging. Moreover, the mechanical behaviour law is, in some extent, analogue to a metal with a significant amount of transformation-induced plasticity, high strain (for a ceramic) and almost no dispersion in strength data. Such zirconia composites could open new avenues in applications where the advantages of ceramics were dampened by their failure properties. They are currently under industrial development for dental implant applications.