The Role of Interparticle Forces in the Preparation of Non-Oxide Ceramic Dense Materials and High Porosity Foams

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Non-oxide ceramics represent the best candidate materials to be used in extreme applications, such as components for hypersonic vehicles, personal armour devices and cathodes for aluminium smelting and lithium air batteries. However, most of these applications require either a very complex geometry or very high and intricate porosity which cannot be achieved or designed using the current state-of-the-art for these type of compounds (hot pressing dry powders). The colloidal powder processing approach seems the natural answer to this problem, since it allowed for the preparation of near-net-shaped pieces and to control the porosity while minimizing defects and flaws through the preparation of ceramic powder suspensions. But this approach is not exempt of difficulties. Most of these powders (borides and carbides) have particle sizes which fall out of the colloidal range and exhibit an “altered” chemistry in terms of oxygen and carbon percentages and other impurities as a consequence of their manufacturing process. This fact combined with higher powder densities and their irregular particle shape, makes the control of the interparticle forces in suspensions a real challenge.

We present two cases studies. The first one comprises the preparation of dense ultra high temperature ceramics for leading edges in hypersonic vehicles. The choice of a water-based or a solvent-based formulation for the processing of zirconium diboride (ZrB_2) had a strong effect on the interparticle forces and therefore in the particle packing. The best particle packing lead to sintered densities of 93% showing an extraordinary behaviour in testing conditions around above 3000^{o}C. The second case study involves the preparation of high porosity titanium diboride (TiB_2) foams for lithium air batteries applications. The combination of the particle stabilized foams and gelcasting concepts produced foams with bubble-like porosities above 85%. The non-oxide nature of the powder allowed the preparation of foams with no need for surfactant addition, due to the interaction of one of the gelcasting additives with the TiB_2 surface. In both cases, the relation between the non-oxide material, the processing method and particle interactions and how this relation determines the final properties of the bulk material is discussed.