PERGAMON

Current Opinion in Solid State and Materials Science 5 (2001) 281–282

Current Opinion in
Solid State &
Materials Science

Editorial Overview

Ceramics, composites and intergrowths

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The articles in this section focus on aspects of research relevant to power generation and transmission. Specifically, they deal with recent developments in: monolithic ceramics and ceramic composites for use in gas tubine engines; ceramic electrolytes and electrodes for solid oxide fuel cells; and growth of high temperature superconductors using liquid phase epitaxy.

There has been renewed interest within the power generation industry in continuous fiber-reinforced ceramic composites (CFCCs) with all-oxide constituents. The industry has been under increased pressure to reduce NO_x emissions from gas turbine engines whilst keeping up with market demands for increased power output and efficiency. These goals can be achieved in part through reductions in the amount of film cooling of combustor liners and turbine airfoils with attendant increases in temperature. In current gas turbine engines, many of the superalloy-based components are operating at or near their upper use temperature, even with the benefits imparted by the use of thermal barrier coatings, thereby precluding significant temperature elevations with these alloys. To meet future environmental and performance standards, it is anticipated that the targeted temperature elevations in turbine components will be accomplished through the use of CFCCs. The all-oxide systems have attracted significant attention within this industry in the past few years because of their superior resistance to oxidation under typical turbine engine conditions relative to that of the non-oxide systems (e.g. SiC/SiC). Marshall and Davis review these developments, with specific emphasis on the long-term high temperature stability of a new class of porous-matrix CFCCs, methods for coating oxide fibers with La monazite, and emerging oxide fibers with improved microstructural stability in combination with high strength and creep resistance.

Silicon nitride has clearly achieved the status of being the most mature high temperature structural ceramic. Indeed, it has been used in auxiliary power units in aircrafts and is on the verge of insertion into larger turbines. The main challenges involve achieving acceptable combinations of strength, fracture toughness and creep resistance. Wiederhorn and Ferber provide an update on the strategies that have been used to address these challenges. On the issue of creep, the emphasis has been on the use of rare earth oxides as sintering aids (especially Lu_2O_3) and the associated improvements in creep rates and rupture times. To achieve high toughness and strength, new schemes have been implemented for producing microstructures with grains that are of high aspect ratio (through the use of large single crystal seeds for example) and are preferentially aligned (accomplished through tape casting). The authors also point out the problem of chemical attack by oxygen and water in gas turbine combustion gases: one that has recently emerged as being potentially the largest impediment to the large scale use of silicon nitride in combustor applications. In the light of this problem, coupled with the poor resistance of silicon nitride to impact damage by foreign objects, coatings with the requiste mechanical and chemical characteristics are suggested as fruitful areas of future research.

Following upon the latter theme, the mechanisms of oxidation and corrosion of both monolithic ceramics and ceramic composites are addressed in the subsequent article by Jacobson, Opila and Lee. One of the main issues with the composites is the internal oxidation of the fiber coatings (typically pyrocarbon or boron nitride) when matrix cracks are present. A more debilitating mechanism that is pervasive in silicon-containing ceramics (both as monoliths and as composites) is the formation of volatile reaction products in the presence of water vapor, which leads to rapid material recession, especially at the high gas velocitites that are typical in gas turbine environments. Water vapor can still be severely detrimental in stagnant environments through a mechanism that involves the formation of porous (non-protective) oxide layers, again with high recession rates. Recent efforts are directed toward the development of coatings that are resistant to these forms of chemical attack yet are compatible with the underlying ceramics.

Fuel cells have been around for a long time and some types are commercially available. They offer high electri-

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1359-0286/01/$ – see front matter
PII: S1359-0286(01)00020-1

cal efficiencies and low emissions; in particular, negligible NOx. The desire to reduce polluting emissions has led recently to a great upsurge in interest in fuel cells for application in centralised electricity generation, in industrial and domestic co-generation and in transport. The solid oxide fuel cell (SOFC) is the least developed of the fuel cell types, but offers the greatest potential both in terms of energy efficiency and acceptable cost. The article by Huijsmans describes recent progress and future challenges in the development of ceramics for SOFCs. An important aspect of this is the clear demonstration that optimisation of the microstructure of the materials is just as important as their compositions. The recent claims for direct operation with methane are also important, because if this can be achieved reliably the operation of the fuel cell on natural gas would be greatly simplified. Finally the prospects for cost reduction through lowering the operating temperature are now close to realisation. The next few years will be crucial for the commercial success of the SOFC.

Electrical power transmission and distribution are also important for strategies based on large scale centralised generation. The high T_c oxide superconductors have been seen as a possible way of reducing transmission losses since their discovery in the late 1980s. However, this promise is still to be realised and cost reduction is again the key to exploitation, whilst maintaining the required targets for critical current density and critical field. In their article, Qi and McManus-Driscoll describe how liquid phase epitaxy (LPE) is developing into a promising cheap technique for producing highly oriented superconducting oxide layers on textured metal tape substrates. Future development will be required to increase the critical current density and use low cost substrates. This article was written before the discovery of superconducting MgB_2 and so the possible impact of this new ceramic is not considered here.