The 10-5 and 7.05 x 10-4 cm2 s, also

Thegroup IV-VI transitiond-metal carbides are harder and havethe highest melting temperatures of all known compounds. This leads to theirwide use in tooling, with the capability of operating in extreme conditions, even under significant loading. It is not, however, WCs superior hardness orrefractory properties that make it a more suitable material for tooling thanthe other transition metal carbides. With a melting temperature of around 3060K and a hardness between 18 and 22 GPa at room temperature, WC does not havethe highest melting temperature or hardness when compared to the others 5–8.

It is a combination stability ofWCs hardness over a range of temperatures, its high Young's modulus, which istwice that of the other carbides (~ 700 GPa) and its low thermal expansioncoefficient, which is only half that of the other carbides (~ 5. 5×10-6K-1) 5, 15. DiffusionalPropertiesWheninterpreting deformation at high temperature, it is important to know thecoefficients of diffusion. Self-diffusion of 14C in WC has beenstudied by C P Buhsmer and P H Crayton 16. Data was collected attemperatures between 2238 and 2643 K. It was observed that there are twodiffusion mechanisms, bulk and grain boundary diffusion. An anomalous volumediffusion coefficient was measured between 2.

56 x 10-15 (at 2238 K)and 5. 88 x 10-14 cm2/s (at 2643 K), increasing withtemperature 16. The grain-boundary diffusioncoefficient was measured to be between 5. 10 x 10-5 and 7. 05 x 10-4cm2/s, also increasing with temperature 16. The activation energies for theseprocesses were calculated to be around 368 kJ/mol for the bulk diffusion andbetween 297 and 310 kJ/mol for the grain boundary diffusion 16. These values suggest thatgrain-

boundary diffusion will almost always dominate, which can be rationalisedby considering the ratio of grain boundary diffusion to bulk diffusion, DGB/Dbulk.

At atemperature of 1000 K this ratio is around 103 16. We can therefore calculate atthis temperature, the grain size at which grain boundary diffusion willdominate using the equation: where f is the volume fraction of grain boundaries, which can becalculated using a simple cuboidal grain shape to be approximately: where ? is the width of the grainboundary and d is the average widthof the grain. In the limit of large grain size, (1-f) ? 1, therefore, the grain sizeat which the grain boundary diffusion will exceed bulk can be estimated as: Assuminga grain boundary width of 0. 5 nm, dcritis about 1.

5 µm, i. e. at grain sizes below this, grain boundary diffusionshould dominate, while at larger grain sizes, bulk will. This can then be compared to pure metals and pure oxides. Puremetals tend to have a value of 104-106 whilst pure oxideshave a value close to 1 16–19.

I. e., the dcrit of pure metals is typically 10 µm to 1 nm, whilefor oxides they are estimated to be in the nm range. The comparison of these ratios suggests that the diffusioncharacteristics of WC are an intermediate between pure oxides and pure metals. DeformationMechanisms in CeramicsWhenmaterials are used in high temperature applications, such as in a nuclearfusion reactor, creep can lead to significant deformation.

Creep is thesustained (time dependant) plastic strain resulting from an applied stress, usually seen at temperatures greater than 0. 5 Tm 20. There are three distinct stagesof creep.

The first is primary creep, in which the strain rate begins high butdecreases over time. The strain rate eventually comes to an equilibrium, leading to the secondary creep stage, steady-state creep. The third stage istertiary creep, in which the stain rate increases up until failure. Tertiarycreep is typically only seen when the material is in tension and is due to theformation of voids or onset of necking 20.

Although there are multiplemechanisms of creep in ceramics, many of these are not expected to operate inmonolithic tungsten carbide (for example, viscous flow creep requires thepresence of a liquid phase, and can therefore be excluded in this project). Inpractice, deformation of transition metal carbides tends to be dominated bythree mechanisms (see Figure 2) 21. Therefore, this section willfocus primarily with these: low temperature plasticity, diffusional flow andpower law creep. In addition, it will consider grain boundary sliding.