Substitution of Non-Engineered Materials from Ceramic Cores used in Investment Casting

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The ceramic cores used in the investment casting of turbine components are required to maintain dimensional stability and resist creep at the casting temperature of the alloy used. It has been proposed that a new ceramic formulation is to be developed, improving high temperature performance and eliminating potentially unreliable non-engineered materials from the matrix.

An engineered material is considered to be one that is highly processed by a manufacturer, resulting in increased control of physical and chemical properties. Non-engineered materials, however, are usually considered to be those from natural sources with minimal beneficiation. Trace elements and impurities will always be present, but in engineered materials the increased processing provides more opportunity to remove and control them. Non-engineered materials are not as reliable; not only are the trace elements present in much higher quantities, but they are more likely to vary in composition between sources. Zircon is perhaps the most widely used non-engineered material in the technical ceramics industry. Table 1 shows a selection of trace elements found in zircon compared to fused silica, an engineered component that forms the basis of most ceramic core formulations.

Table 1: Some trace elements found in standard and higher purity fused silicas and zircons (ppm)

	Al_2O_3	Fe_2O_3	TiO_2
Fused Silica	1700	350	250
Zircon	11500	400	2700
High Purity Fused Silica	140	200	15
High Purity Zircon	2400	200	1300

The presence of small amounts (<1 wt%) of additives is known to have a significant impact on the performance of the ceramic material. Metallic oxides, for example, may promote sintering or cristobalite formation. Such processes may improve the final properties of the ceramic, but must be controlled to ensure that excessive changes, which may have a detrimental impact, do not occur. SEM micrographs like those in Figure 1 can be used to examine the results of these processes at grain boundaries. One such example would be the rounded edges seen on some grains in this Figure; these indicate the presence of a liquid phase during the firing of the ceramic. This work is further enhanced through the use of EDS for chemical analysis.

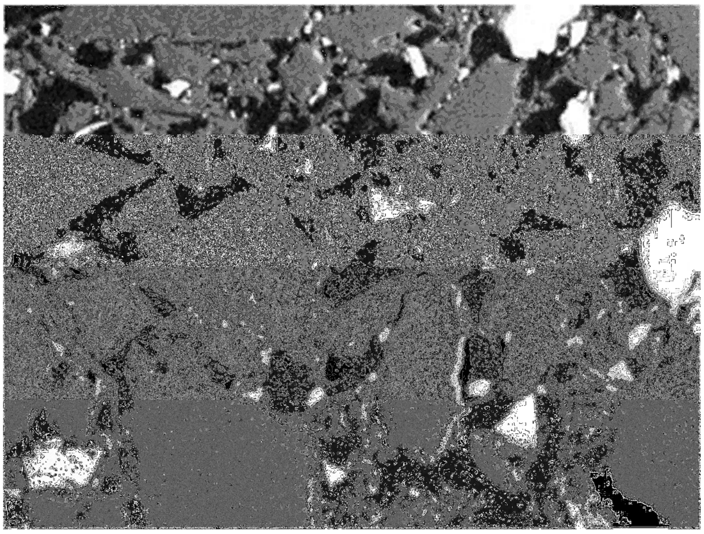

Figure 1: Backscattered SEM micrograph of a typical core ceramic. The grey areas are silica grains, the white areas are zircon grains, and the black areas are pores formed between them (x500 magnification, image approx. 250 µm across) [1]

Given their potential impact, it is preferable to control what trace elements are present. The use of non-engineered materials, however, makes this more difficult. The previously mentioned example, zircon, is unfortunately required; its presence is not entirely understood, but removal from the matrix is detrimental to high temperature performance. Whilst some work has been done to address this [1], one of the main conclusions drawn was that trace elements act as contaminants, masking or modifying the true function of zircon.

It is therefore proposed that a synthetic, purer zircon be produced, allowing an investigation of its function without inherent contamination. Whilst it is possible to form zircon from a high temperature melt of silica and zirconia [2], sol-gel methods exist that allow synthesis at less extreme conditions [3]. If such a synthetic product were to be produced in sufficient quantities, basic ceramic formulations can be made to compare both engineered and non-engineered zircon. This would allow determination of the effects of zircon and the inherent contamination.

It is hoped that accurately determining the function of zircon would allow a more reliable engineered material to be substituted in its place. Even if such a material requires the presence of trace elements to achieve the desired effect, direct introduction and control is far more preferable than relying upon the traces present in a natural mineral.

References

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