TABLE II Fracture toughness

Geometry	Material	K_C (MN m$^{-3/2}$)
Surface notch (SN) 15 mm thick	ABS (22.5% rubber)	2.77
Surface notch 15 mm thick	ABS (30% rubber)	3.12
Surface notch 7 mm thick	SAN (matrix)	0.95

shows a crazed zone of ~0.3 mm which approaches the minimum expected in such a system.

When the data from such an experiment are plotted as $\sigma^2 Y^2$ versus $1/a (K^2 = \sigma^2 Y^2 a)$, the resultant straight line has a correlation factor greater than 0.95. The line was determined using a linear regression fit to the data points; each of which represent five specimens. This was true for the two ABS samples of different rubber levels and for notch dimensions of three different sizes.

Data are shown for the ABS materials of one notch dimension. Fig. 3 and Table II show the K_C values. These values are more representative of the plane strain fracture toughness.

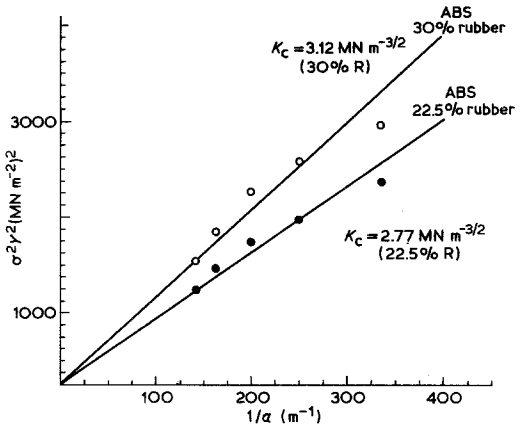

Figure 3 Fracture toughness data.

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High temperature interactions of metal oxides with rhenium in vacuo

Among the high temperature metals, rhenium and tungsten are the only two elements that have melting points over 3000° C. For use as high temperature devices, rhenium has probably more suitable properties than tungsten as the latter become brittle upon heating to a high temperature. Considerable data are available in the literature on the reactions of metal oxides with refractory metals, [1, 2] but there are few published data on the high temperature interactions of rhenium with metal oxides above 2000° C.

A pure rhenium metal boat of 0.0025 cm thickness, 0.4 cm wide and about 2 cm long was placed

Figure 1 Photomicrograph of MgO after interaction with Re at 2450° C for 20 min.

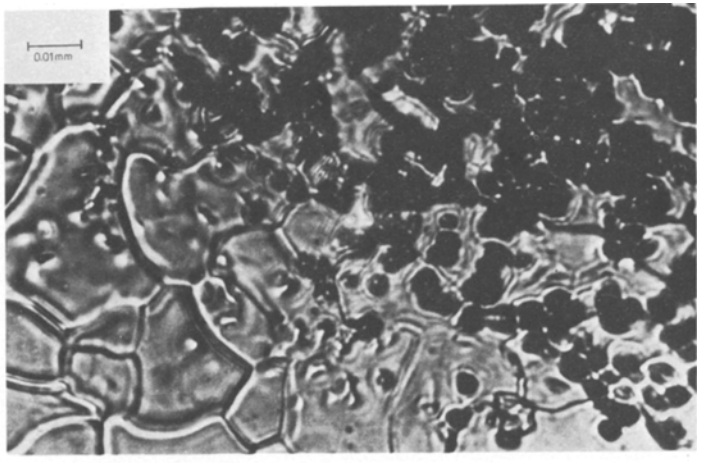

Figure 2 Photomicrograph of TiO_2 after interaction with Re at 2040° C for 26 min.

Figure 3 Photomicrograph of Al_2O_3 after interaction with Re at 2030° C for 20 min.

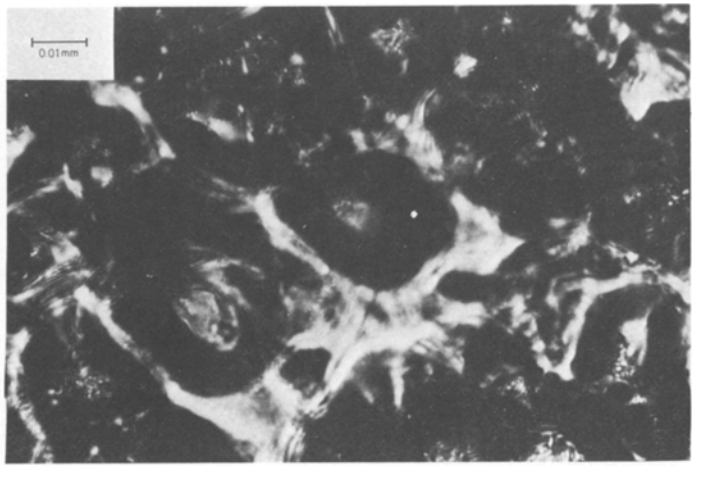

Figure 4 Photomicrograph of ZrO_2 after interaction with Re at 2040° C for 21 min.

in a vacuum system operated in the 10^{-5} Torr range. On the bottom of the boat, a metal oxide prepared from pressed CP grade metal oxide powder was put in close contact with the rhenium. The boat was heated by resistance heating with d.c. current running through it. After a short period of low temperature outgassing, the sample was slowly brought to the final temperature for times ranging from 20 min to 1 h. Temperature readings were taken by a pyroscope looking through the quartz window of the vacuum system while raising the current. The pyroscope readings for each experiment were calibrated against the melting points of some pure metals, e.g. Ni, V, Co, Nb and Mo, set-up on the sample apparatus in the vacuum system.

The results of metal oxides in contact with rhenium heated at different temperatures have been obtained from the microscopic examinations with 300 ×, 600 ×, and 1500 × magnifications respectively; while the photomicrographs were taken at 400 × magnification. All photomicrographs were taken normal to the surfaces of the samples, and some enlarged pictures of them are shown in Figs. 1 to 4. From these photomicrographs, the grain sizes of these metal oxides show increasing order from fine MgO grains to large ZrO_2 grains after interaction with rhenium. Microscopic examination of the cross-sections perpendicular to the sample surfaces was also carried out. Penetration of all four metal oxides along the grain boundaries of rhenium were found for annealing temperature higher than 1500° C. The surfaces of the metal oxides in contact with the rhenium exhibited black contaminations of rhenium when examined in the microscope. The other side of the metal oxides showed no contamination by rhenium in most cases, but a few small samples heated to temperature higher than 2000° C showed migration of rhenium by surface diffusion from the contact surfaces around the edges to the upper sides. The penetration of rhenium into metal oxides was found only few atomic layers below the surfaces of interaction temperatures below 2000° C for all four oxides. The results are summarized in Table I.

No metal oxides except TiO_2 were found in rhenium when the reaction temperature was at the melting point of rhenium. This fact could be due to the total evaporation of the oxides at such high temperatures.

TABLE I The interactions of metal oxides with rhenium

Metal oxide	Testing temperature (° C)	Result
Al_2O_3	1710, 1860, 2000, 2030	Reaction
	1260	No reaction
MgO	1580, 2040, 2260, 2450	Reaction
	1190	No reaction
TiO_2	1510, 1680, 2040	Reaction
	1230	No reaction
ZrO_2	1230, 2040, 2090	Reaction
	1075	Weak reaction

The errors in the temperature measurements of these experiments are estimated from the error in the melting point of the calibrating metal and the statistical errors in the pyroscopic readings. Errors of ± 60° C for temperatures ranging from 1000 to 1500° C, and ± 100° C for temperatures ranging from 1500 to 2500° C have been estimated.

It is practicable to use rhenium as a crucible or heating element and these metal oxides as substrates or liners for high temperature work in the range of this investigation. When using resistance heating of rhenium and applying these oxides as insulators, the surface contamination of rhenium on the oxides and the high temperature insulation properties of these metal oxides [3, 4] must be considered.

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