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Received 31 July and accepted 20 September 1978.

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Four cobalt-base silicide eutectics

Directionally-solidified Co- and Ni-base eutectic alloys have been studied for high-temperature structural applications such as turbine blades or vanes [1, 2]. Eutectics containing carbide fibres have received considerable attention, but several authors [3, 4] have noted that silicide phases would be expected to have better oxidation resistance. In this note, we report the identification and characterization of four aligned Co-base eutectics reinforced with ternary silicides. This work was an extension of earlier work on Co–Si aligned composites [5].

Initial compositions studied were (at.%), 70Co–20M–10Si, where M = W, Mo, Ti, or Nb. Samples about 2.3 cm diameter and 12 cm long were directionally solidified under argon at $0.64\,\mathrm{cm\,h^{-1}}$ under a temperature gradient of $100^\circ\,\mathrm{C\,cm^{-1}}$. Transverse sections of the final portions to freeze were studied metallographically, and average compositions of the eutectic portions of the microstructure were determined by electron microprobe. New heats were made of these compositions, and directionally solidified under the same conditions. In each case, dendrite-free aligned eutectic structures were obtained over most of the sample length. It was concluded that these compositions were at or near eutectic composition. In at.%, these compositions were: 79.2Co–12.6W–8.2Si, 77.8Co–12.3Mo–9.9Si, 76.3Co–17.4Ti–6.3Si, and 82.1Co–10.0Nb–7.9Si.

Transverse microstructures are shown in Fig. 1. The silicide phases were rods in the W (Fig. 1a) and Mo (Fig. 1b) eutectics and lamellae in the Ti (Fig. 1c) and Nb (Fig. 1d) eutectics. A cellular structure disturbed the alignment in the W alloy, and portions of the Ti alloy contained a small volume fraction of isolated carbide particles. Debye–Scherrer X-ray analysis and microprobe measurements indicated that the silicide phase was the hexagonal Laves λ_1-phase ($MgZn_2$ structure) in the W, Mo, and Ti alloys, but was probably the cubic G-phase ($Mg_6Cu_{16}Si_7$ structure, denoted T in the Russian literature) in the Nb alloy. The established phase diagrams show that the Co solid solution is in equilibrium with the λ_1 phase in the Co–W–Si [6] and Co–Mo–Si [7] systems, and is in equilibrium with both the λ_1 phase and the G phase in the Co–Ti–Si [8] and Co–Nb–Si [9] systems.

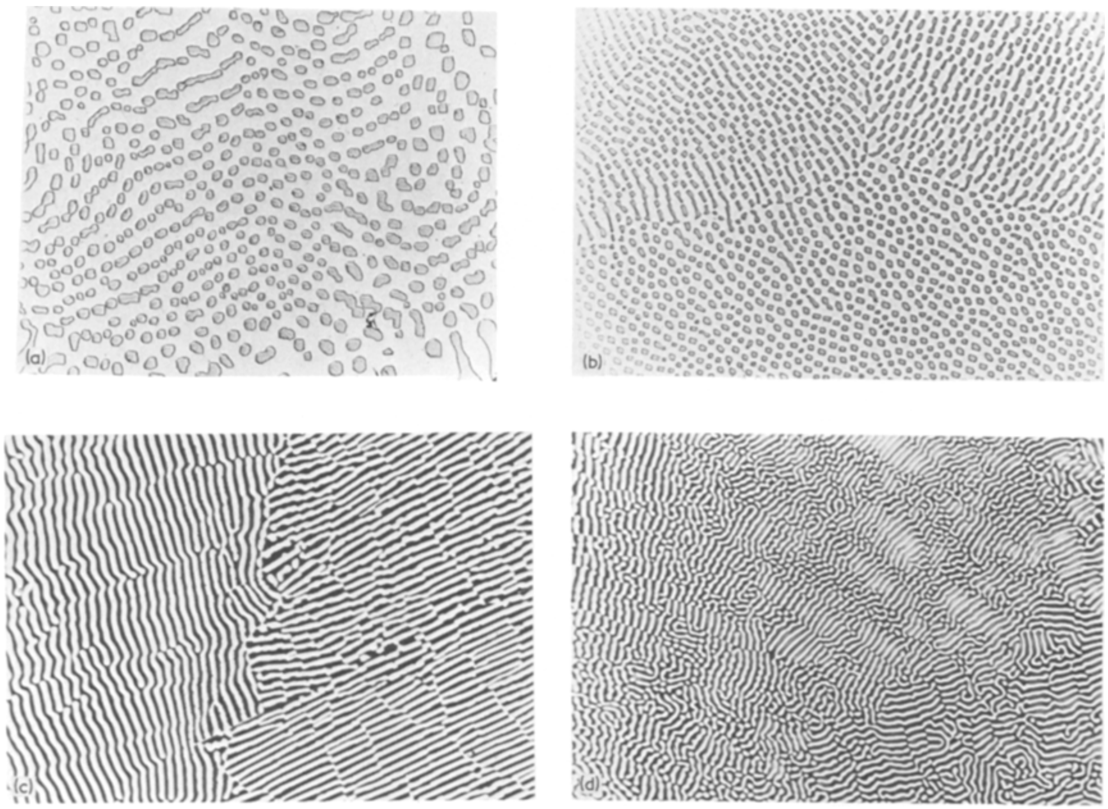

Figure 1 Transverse microstructures of directionally-solidified Co-base silicide eutectics (a) Co–W–Si, (b) Co–Mo–Si, (c) Co–Ti–Si, (d) Co–Nb–Si, × 300.

Tensile specimens, ground to produce a gauge diameter of 0.254 cm and a gauge length of 1.59 cm, were strained at 4×10^{-2} min^{-1} in air at room temperature and under vacuum at 900 and 1000° C. Results are shown in Table I. Although tensile strengths were high, particularly for the Mo alloy at room temperature, only the W alloy showed room-temperature ductility. Samples of each alloy were also subjected to cyclic oxidation tests to 1100° C and severe hot-corrosion tests simulating engine environments. All four alloys were found to be significantly inferior to standard Cr-bearing Co alloys, such as MAR-M509, in oxidation and hot-corrosion resistance.

There has been little prior study of silicide-reinforced eutectics. Sprenger and co-workers have studied a Cu–Zr–Si eutectic [10] containing E-phase silicide and a Ni–Mo–Si eutectic [3] containing λ_1-phase silicide. Haour *et al.* [4] located eutectic compositions in various Fe-, Co-, and Ni-base ternary systems, including Co–Ti–Si and Co–Nb–Si. Eutectic composition was not reported for Co–Ti–Si, but that reported for Co–Nb–Si differed significantly from that found here.

The present results indicate high tensile strengths, accompanied by extreme brittleness and inadequate resistance to cyclic oxidation and hot corrosion. Additions of Cr would be expected to improve the oxidation and corrosion resistance, as confirmed by the reported effects of Cr additions in Co–Mo–Si wear-resistant "Tribaloy" materials [11]. As regards ductility, the presence of λ_1 Laves phase had earlier been reported to embrittle a Co-base superalloy [12]. However, present results on the Co–W–Si eutectic and earlier results on the Cu–Zr–Si [10] and Ni–Mo–Si [3] eutectics indicate that adequate room-temperature elongations are possible with silicide-reinforced

TABLE I Tensile properties

Alloy	Temperature (° C)	0.1% yield stress (10^3 psi)	Ultimate tensile strength (10^3 psi)	Elongation (%)
Co–W–Si	room	122	157	9.3
	900	40.3	42.1	35
	1000	28.9	30.4	38
Co–Mo–Si	room	280	280	0
	900	107	107	0
	1000	74.2	75.5	0.8
Co–Ti–Si	room	108	108	0
	900	54.4	54.4	32
	1000	26.5	26.5	34
Co–Nb–Si	room	157	157	0
	900	108	108	0
	1000	69.9	71.1	47

eutectics. Probably a rod morphology is necessary, perhaps with a lower volume fraction of silicide than contained in the present Co–Mo–Si alloy.

Acknowledgements

Alloys were prepared under the direction of W. F. Moore and directionally solidified by G. Stebbins. Metallography was done by C. Rodd, microprobe analysis by M. D. McConnell, X-ray analysis by A. M. Davis, tensile tests by P. L. Dupree, and oxidation and hot-corrosion tests through M. R. Jackson and J. R. Rairden.

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Received 15 August and accepted 2 October 1978

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Some physical properties of hot-pressed CaF_2

Alkali halides heated to high temperatures and pressed under high pressure were termed hot-pressed. In their physical appearance, as well as in some of their physical properties, the hot-pressed samples resemble single crystals of the same material. Attempts are being made to use these samples in place of single crystals. The aim of the present study is to show that in some important physical properties the hot-pressed samples differ considerably from the single crystals. In this communication we report measurements of the dielectric constant (K) and loss ($\tan\delta$) for hot-pressed CaF_2 in the frequency range 10^2 to 10^6 Hz and in the temperature range 30 to 450° C. The optical absorption data of these samples before and after irradiation and thermoluminescence are also presented.

The samples used in the present work were donated by Professor A. Smakula. The density of these samples is reported to be 3.179 27 g cm^{-3} and lattice parameter 5.463 65 Å (these values are 3.179 34 g cm^{-3} and 5.463 42 Å, respectively, for CaF_2 single crystals [1]).