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Solidification of Selected Al-Ru-Y Samples

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The Al-Ru-Y system is of interest because RuAl has excellent properties for spark plugs [1] and yttrium has been used in coating Ni-based alloys [2]. Thus, the Al-Ru-Y system might provide a potential new coating material. The Al-Ru and Al-Y binary phase diagrams are well established, but the reactions in Ru-Y are more speculative, although the phases themselves are known [3]. Six phases on the YRu_2 – YAl_2 transus had been reported [4]. Earlier work on the Al-Ru-Y system [5] showed mainly limited extension of the binary phases into the ternary, and located four of the phases on the YRu_2 – YAl_2 transus.

Samples were made by arc-melting 99.9% pure elemental components together, using titanium as an oxygen-getter. They were then halved, mounted, and prepared for metallography. Analysis was undertaken, using elemental standards, in a JSM-840 SEM with a LINK AN10000 EDS system.

Some of the alloys had small particles of Y_2O_3, assumed to be present before or in an early stage of melting, despite taking precautions. Since these were in minor proportion, and have a very high melting point (2458^{o}C [3]), and despite the fact that they were sometimes obviously acting as nucleation sites, they were ignored in the interpretation of the microstructures. Interpreting them as (Y), which had oxidised subsequently, gave an impossible sequence of solidification reactions.

The Al_{15}:Ru_{70}:Y_{15} (at. %) sample, which had small particles of (Ru) and RuAl (with negligible Al), was mostly a ternary eutectic. The ternary eutectic comprised (Ru), RuAl and ~YRu_2 and its overall composition was Al_{14}:Ru_{71}:Y_{15}.

Two phases on the YRu_2 – YAl_2 transus were found in the Al_{15}:Ru_{70}:Y_{15} sample: ~$Y_{33}Ru_{56}Al_{11}$ and ~$Y_{33}Ru_{47}Al_{20}$.

The Al_{17}:Ru_{39}:Y_{44} sample had a small proportion of the oxide particles, and comprised primary ~Y_5Ru_2 (with about 2 at. % Al). There was then a peritectic reaction forming ~$Y_{34}Ru_{43}Al_{23}$, and subsequently ~$Y_{34}Ru_{47}Al_{19}$.

The Al_{12}:Ru_{11}:Y_{77} sample comprised angular primary crystals of a ternary phase, ~$Y_{75}Ru_9Al_{16}$, surrounded by a ~$Y_{75}Ru_9Al_{16}$ + Y_3Ru eutectic, as shown in Fig. 1.

The nominal Al_{35}:Ru_{42}:Y_{23} alloy also had oxide particles. The primary phase was RuAl which was cored (but without Y). The next two reactions were peritectic, forming cored ~$Y_{34}Ru_{40}Al_{26}$ and ~$Y_{34}Ru_{33}Al_{33}$. The latter two phases were also seen in the Al_{31}:Ru_{33}:Y_{36} sample, together with primary ~$Y_{50}Ru_{27}Al_{23}$, which is assumed to be a ternary phase.

As well as containing yttrium oxide, the Al_{39}:Ru_{19}:Y_{42} sample comprised a primary phase which lay on the YRu_2 – YAl_2 transus, ~$Y_{35}Ru_{22}Al_{43}$, and a ternary phase, ~$Y_{68}Ru_{12}Al_{20}$.

The Al_{69}:Ru_{14}:Y_{17} samples had dendrites of ~$RuAl_2$ (with ~10 at. % Y) surrounded by coarse needles of a ternary phase of composition ~$Y_{11}Ru_{16}Al_{73}$ with the last phase to solidify being YAl_3 (Fig. 2). The ternary nature of the ~$Y_{11}Ru_{16}Al_{73}$ phase was confirmed by the Al_{79}:Ru_{14}:Y_7 sample. This had primary ~Ru_4Al_{13} surrounded by ~$Y_{11}Ru_{16}Al_{73}$, then (Al).

The investigation of the Al-Ru-Y system revealed problems with oxidation of Y, although the particles were small. A ternary eutectic of (Ru) + RuAl + ~YRu_2 was found, and the congruent melting of Y_5Ru_2 was confirmed. Ternary phases of compositions ~$Y_{50}Ru_{27}Al_{23}$ and ~$Y_{75}Ru_9Al_{16}$, have been found, and on the YRu_2 – YAl_2 transus, the phases: ~$Y_{33}Ru_{56}Al_{11}$, ~$Y_{33}Ru_{47}Al_{20}$ ~$Y_{34}Ru_{43}Al_{23}$, ~$Y_{34}Ru_{33}Al_{33}$ and ~$Y_{35}Ru_{22}Al_{43}$.

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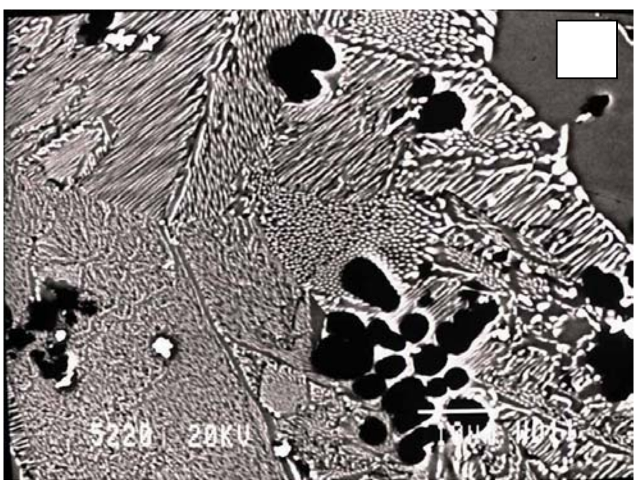

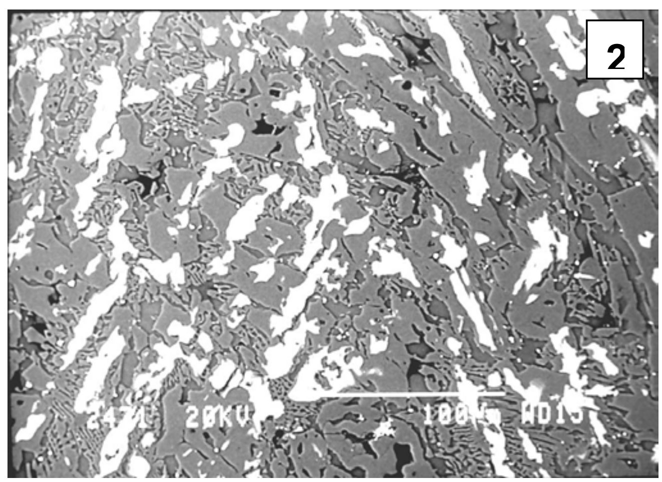

Fig. 1. Backscatter image of the Al_{12}:Ru_{11}:Y_{77} sample showing dark Y_2O_3 particles, ~$Y_{75}Ru_9Al_{16}$ (medium), in a ~$Y_{75}Ru_9Al_{16}$ + Y_3Ru (light) eutectic.
Fig. 2. Backscatter image of the Al_{69}:Ru_{14}:Y_{17} sample showing ~$RuAl_2$ dendrites (light) with coarse needles of ~Ru_4Al_{13} (medium) and YAl_3 (dark).

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