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Solidification of Selected As-Cast Ni-Ru-Y Samples

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The Ni-Ru-Y system is being studied as a companion system to Al-Ru-Y for a potential new coating material. It is of interest because ruthenium has been shown to increase the corrosion resistance of stainless steels [1] and titanium alloys [2], and yttrium has been used in coating Ni-based alloys [3]. The Ni-Ru and Ni-Y binary phase diagrams are well established, but the reactions in Ru-Y are uncertain, although the phases are established [4]. The Ni-Y phase diagram is very complex with many phases [4]. No literature was found on the ternary system.

The samples were made by arc-melting the 99.9% pure elemental components, and titanium was used as an oxygen-getter. They were then sectioned, as near as possible into halves, mounted, and prepared for metallography. Analyses were undertaken using pure element standards in a Philips XL 30 ESEM equipped with an EDAX Phoenix EDS system.

Some of the alloys had small particles of Y_2O_3, which were assumed to be present before or in an early stage of melting, despite taking precautions (keeping the Y in alcohol). Since the oxide particles were in minor proportion, and have a very high melting point (2458^{o}C [4]), they were ignored in the interpretation of the microstructures, despite the fact that they were sometimes nucleation sites. This was justified because attempts to interpret them as (Y), which then oxidised subsequently, gave impossible sequences of solidification reactions.

The Ni_{38}:Ru_{42}:Y_{20} (at. %) sample had primary (Ru), with ~10 at. % Ni. Next were two peritectic reactions forming the ~YRu_2 (actually of composition ~$Y_{24}Ru_{46}Ni_{30}$) and ~$Y_{20}Ru_{22}Ni_{58}$ phases respectively (Fig. 1). The ~YRu_2 phase was identified by its morphology and also from the smooth boundary formed around binary ~YRu_2 when the phase compositions from different samples were plotted on ternary paper.

Nominal Ni_{69}:Ru_{16}:Y_{15} was mostly a phase of composition ~$Y_{16}Ru_{13}Ni_{71}$ with small amounts of a eutectic comprising ~$Y_{16}Ru_{13}Ni_{71}$ and (Ru). At this stage, it is not known whether the major phase is a true ternary phase, or an extension of one of several Ni-Y phases in that region.

There were some oxide particles in the Ni_{19}:Ru_{46}:Y_{35} alloy, and the true primary phase was cored ~YRu_2 (the most Ru-rich composition being $Y_{33}Ru_{55}Ni_{12}$), with minor amounts of an interdendritic phase of ~$Y_{51}Ru_{15}Ni_{34}$. The overall composition did not lie on the tie-line because only the centres of the dendrites were analysed, and the dendrite edges had a higher nickel content.

The nominal Ni_{24}:Ru_{26}:Y_{50} alloy also had primary ~YRu_2 (with actual composition $Y_{33}Ru_{48}Ni_{19}$) in a eutectic of overall composition Ni_{27}:Ru_{18}:Y_{55}. The two components of the eutectic were ~YRu_2, with a slightly different composition from the primary phase (and hence slightly different contrast) and a grey phase. Both of these phases were too small to analyse accurately, without collecting X-rays from the neighbouring phases. However, the composition of the darker component can be extrapolated back towards the Ni-Y binary, directly away from the primary phase composition, so the phase is probably~Y_3Ni. The solidification temperatures of this and the preceding alloy must have been fairly different, because the tie-lines cross. In an isothermal section, the tie-lines are forbidden to cross, but since these are as-cast samples, if the solidification ranges are different, then the tie-lines can cross, as long as they lie at a fairly low angle to each other.

The last alloy in the sequence, Ni_{41}:Ru_{16}:Y_{43}, also had dendrites of ~YRu_2, with 33 at. % Ni (Fig. 2). The primary phase was the darker phase inside the dendrites, and this was too small to analyse accurately. However, the approximate composition could be derived by considering the offset of the overall composition against the tie-line joining the two analysed phase compositions, and the contrasts. Thus, the composition is likely to lie near the grey phase of the Ni_{19}:Ru_{46}:Y_{35} sample, at ~$Y_{51}Ru_{15}Ni_{34}$. Most of the sample was ~NiY (with 6 at. % Ru).

Analysis of the as-cast samples of the Ni-Ru-Y system has shown that the (Ru) phase extends to at least ~25 at. % Ni in the ternary, but with little yttrium. The ~YRu_2 phase extends well into the ternary, at least to 33 at. % Ni. It was identified by its morphology and the fact that the compositions formed a smooth boundary when plotted on ternary paper. The other phases, nearer the Ni-Y binary, are difficult to determine without more samples, and structure determination. This has to be undertaken in later work.

References

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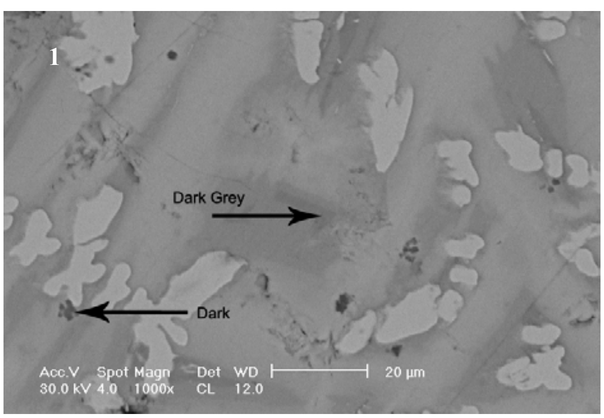

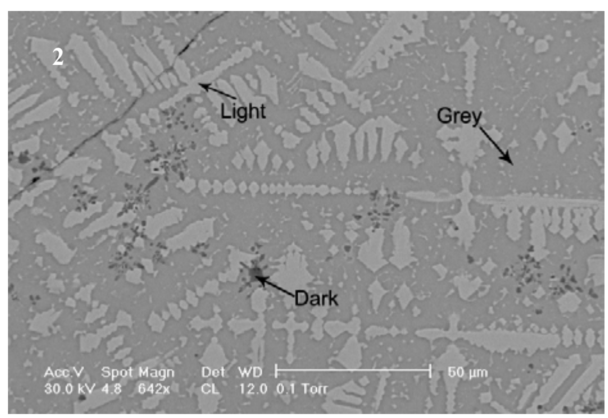

Fig. 1. Backscatter image of the Ni_{38}:Ru_{42}:Y_{20} (at. %) sample showing (Ru) dendrites (light), with ~YRu_2 (of composition ~$Y_{24}Ru_{46}Ni_{30}$) (medium), ~$Y_{20}Ru_{22}Ni_{58}$ (dark grey) and Y_2O_3 (dark).
Fig. 2. Backscatter image of the Ni_{41}:Ru_{16}:Y_{43} sample showing ~YRu_2 dendrites (light) with darker centres (~$Y_{51}Ru_{15}Ni_{34}$) in a ~NiY (with 6 at. % Ru) matrix (grey), with very dark Y_2O_3 particles.