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Categorizing the embrittling residuals in engineering alloys by Auger electron spectroscopy*

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Residual elements may affect adversely the performance of engineering alloys essentially through an ability to concentrate at grain boundaries and other interfaces during thermal treatment: at equilibrium, impurity species can concentrate to grain boundaries by factors as high as 10000 times above the bulk level. In general, there is an associated reduction in grain boundary cohesion which may lead to certain well known forms of intergranular failure in metallurgical components.

In order to identify the most commonly occurring residuals responsible for such failures in material of commercial purity and for various service conditions, an evaluation was carried out on a wide range of commercial engineering alloys which had exhibited forms of intergranular failure in service, and in addition, data from laboratory melts were used. For each alloy, fresh grain boundary surfaces were exposed *in situ* by fracture in tension or by impact, and then analysed by both Auger electron spectroscopy and scanning electron microscopy. The results have been assessed according to several behaviour categories: (i) high temperature (for example creep embrittlement and stress relief cracking); (ii) low temperature (for example temper brittleness) and (iii) reaction with an aggressive environment (for example intergranular stress corrosion cracking).

For any form of intergranular failure induced by segregating residuals, a level of response to the embrittling species can be defined by an engineering parameter, the relative fragility, which is the product of three terms: the bulk residual content, c; the grain boundary enrichment factor, β; and the intrinsic embrittling sensitivity, σ.

The parameter σ refers to the decohesion micromechanism and the extent to which it is altered by the local chemical environment: this will be different for each of the above behaviour categories. The enrichment factor, β, depends on alloy type and temperature and it is probably the most decisive factor in the above relation. The aim of the present work has been to measure β for all the cases considered.

It is shown that for each of the above categories, there exists a different hierarchy of β values for a number of common embrittling species. This approach gives a quantitative determination of the relative fragility, which may be used as a general screening parameter for identifying the most probable embrittling agents in a given metallurgical situation, and the fragility index, which denotes the quality of a cast of steel in relation to one of the above behaviour categories.

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