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MELTING BEHAVIOUR OF NICKEL-CHROMIUM-SILICON ALLOYS

E. LUGSCHEIDER, O. KNOTEK and K. KLÖHN
Institut für Werkstoffkunde der Rhein.-Westf. Technischen Hochschule Aachen, Aachen (G.F.R.)

ABSTRACT

With regard to developing low melting Ni-Cr-Si alloys used as joint materials in high temperature brazing technics, especially in reactor technique, the melting behaviour of nickel-rich Ni-Cr-Si alloys was investigated systematically by differential thermal analysis. The dependence of the liquidus temperatures on alloying concentration ranges from 0 to 28 at.-% Si and 0 to 60 at.-% Cr shows a ternary eutectic melting temperature minimum of 1077°C at 20 at.-% Cr and 21.3 at.-% Si. The melting behaviour of the alloys in the indicated concentration range will be characterized in a reaction scheme. The dependence on temperature of the solubility of Si and Cr in Ni will be discussed.

INTRODUCTION

Branches of industry in which nickel base alloys are used as high temperature filler metals for joining high stressed parts are nuclear-, aircraft-, space-, energy-, and chemical engineering. An essential criterion for the application of these alloys, which are besides one exception either alloyed with phosphorus or boron, is their the processing influencing melting characteristic.

In nuclear industries are boron-containing filler metals because of their high neutron absorption mostly unusable. For these industries is nowadays only one Ni-Cr-Si alloy (BNi-5) available (ref. 1). The filler metal BNi-5 has a very high liquidus temperature of 1135°C which causes a heavy thermal strain of the base metal. Therefore it was made an attempt to develop lower melting boron-free nickel base alloys. It was necessary to investigate systematically the melting behaviour of Ni-Cr-Si alloys by differential thermal analysis[+)] in concentration ranges which are of interest in brazing technique.

[+] DTA unit of Netzsch-Gerätebau-GmbH, Selb/Bay., heating and cooling rate 5°C per min., temperature range 25°C...1550°C, argon inert gas atmosphere, sample weight approx. 1g.

RESULTS

Liquidus temperatures of nickel-chromium-silicon alloys

The melting behaviour of Ni-Cr-Si alloys which are interesting in brazing technique is mostly influenced by the eutectic reactions Melt $\rightleftharpoons$ α(Ni)+Ni_3Si and Melt $\rightleftharpoons$ α(Ni)+β(Cr) of the boundary systems. These transformations which ensue in the system Ni-Si at 21.2 at.-% Si and 1150 °C (refs. 2-3) and in the system Ni-Cr at 54 at.-% Cr and 1345°C (refs. 2-3) could be proved by many own investigations.

The liquidus behaviour of ternary alloys in areas of high nickel contents shows Fig. 1. Obviously it is shown by the isoliquidus graphs in a 50°C distance that coming from the boundary systems both Cr and Si lower the liquidus temperature with increasing content. The influence of Si is stronger as it can be seen in the graph. At 20 at.-% (20.5 wt.-%) Cr, 21.3 at.-% (11.8 wt.-%) Si and a temperature of 1077°C exists a ternary eutectic. This fact is for high temperature brazing technique very important because it shows that by changing slightly the composition of the high temperature filler metal BNi-5, new, about 58°C lower melting filler metals with the same good brazing abilities are producable.

On the basis of the DTA results it is tried to characterize the melting behaviour of ternary alloys in the investigated concentration range in a reaction scheme (Fig. 2). Starting with the nonvariant reactions of the boundary systems (E_I, P_I, E_{II}) run the melting grooves - that are the lines of intersection of the planes of primary crystallisation - into the ternary eutectic (E_{III}). Before reaching this ternary eutectic further four-phase reactions of peritectic character (P_{II}-P_{IV}) happen.

Solidus temperatures of nickel-chromium-silicon alloys

The space of the Ni-Cr-Si solid solution is fixed by four characteristic temperatures (Fig. 3). That is to say the melting point of Ni (1453°C), the binary eutectic temperatures of the boundary system Ni-Cr (1345°C) and Ni-Si (1150°C) as well as the ternary eutectic temperature (1077°C). The isosolidus lines give an impression of the significant dependence of the temperature of the solid solubility of Cr and Si in the nickel solid solution. Especially the decreases of the solubility below the ternary eutectic temperature, where the nickel solid solution is balanced with the ternary π-phase (refs. 5-6) too, is of great interest for the brazing technique. Ni-Cr-Si filler metals have to be in concentration areas which are far away from the concentration area of the nickel solid solution because of the demand of a low liquidus temperature. The structure of Ni-Cr-Si filler metals contents besides silicides predominantly solid solutions which are characterized with regard to concentration in Fig. 3. The exact information of the solid solubility in the Ni-Cr-Si solid solution area dependent on the temperature makes it possible to estimate the real temperature constitution of a filler metal alloy in a brazed joint. This constitution is dependent on the brazing temperature, a diffusion treatment temperature, and cooling conditions. If this constitution of a filler metal alloy is well known it is possible to make a statement about the real solubility of silicon respectively about the brittle hard phase part of the silicides. By optimization of the temperature cycle of the brazing- and heat treatment process these brittle silicide hard phases can be minimized.

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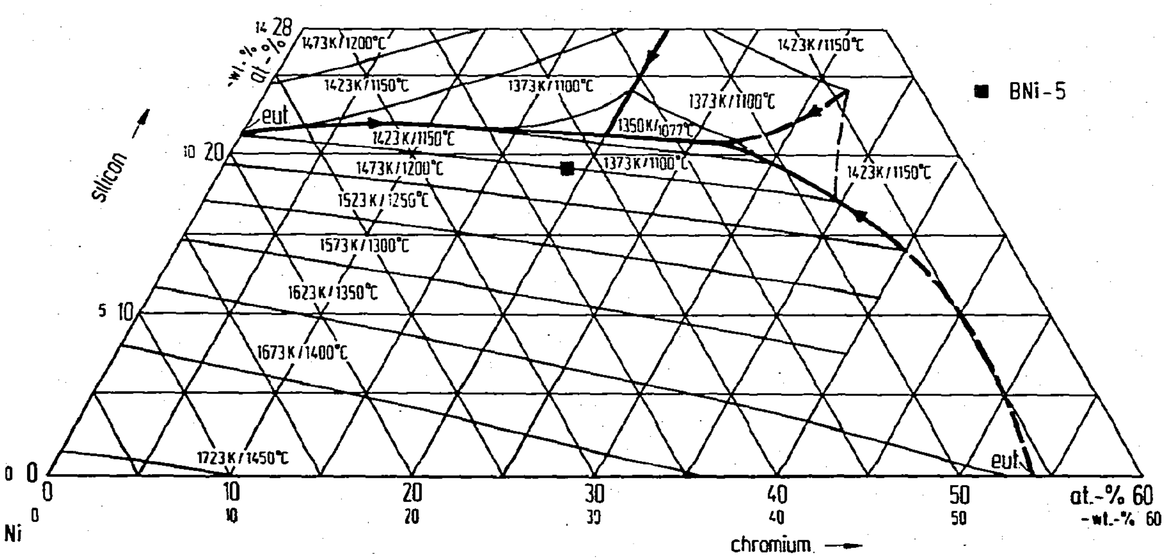

Fig. 1. Liquidus temperatures of nickel-rich nickel-chromium-silicon alloys (ref. 4).

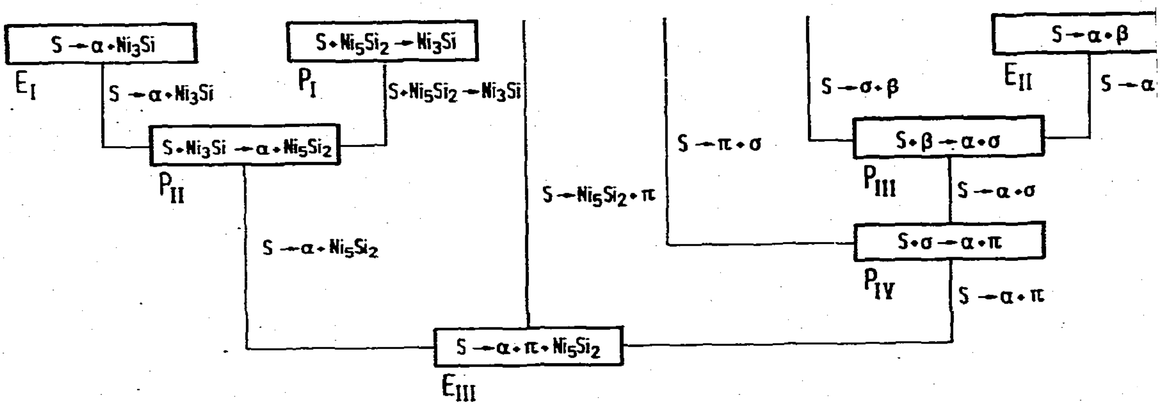

Fig. 2. Reaction scheme of the melting reactions in the nickel-rich part of the system nickel-chromium-silicon.

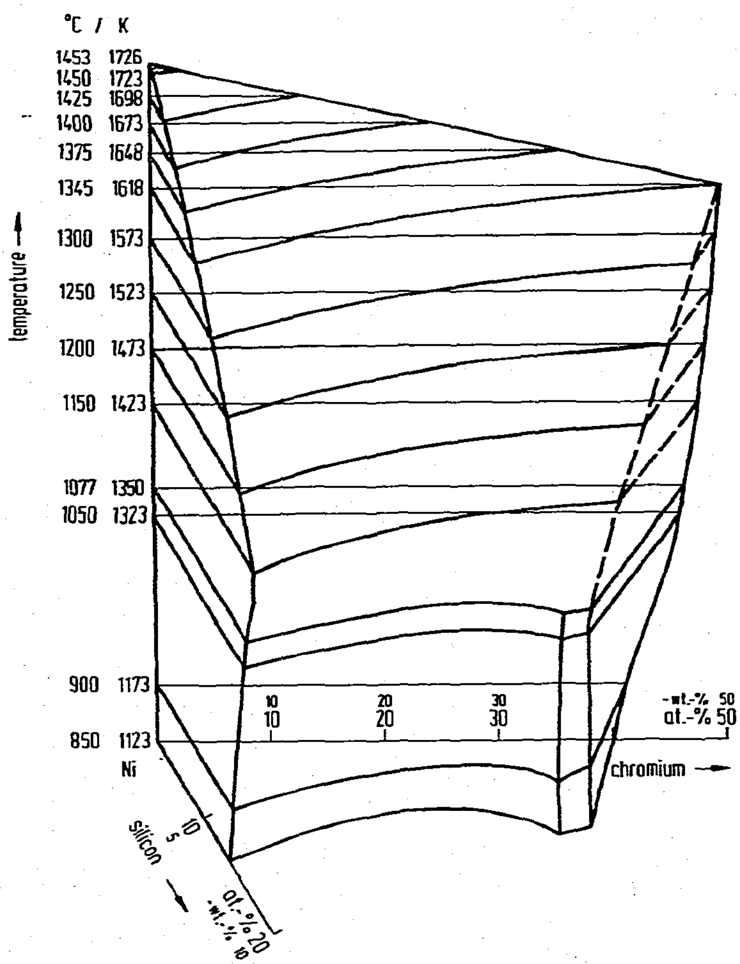

Fig. 3. Dependence of temperature of the solid solubility of chromium and silicon in nickel.