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# On the stacking-fault densities of ternary copper alloys

S C Chatterjee

*Department of Physics, Co-operative College, Jamshedpur, Bihar*

AND

M P Gupta

*Department of Physics,, Ranchi University, Ranchi, Bihar*

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An additive-relationship has been observed to hold for stacking-fault-parameter (SFP, $\alpha$) of the alpha-phase ternary copper alloys represented by,

$$\log \alpha = K\Sigma(p\,|\Delta Z|) + \log \alpha_0$$

where the slope of the line $K \simeq 0.11$ and the SFP of the pure solvent (copper), $\alpha_0 = 3.3 \times 10^{-3}$

## 1 Introduction

Although the binary systems have been extensively studied since the theoretical discussion on SFP of fcc metals and alloys by Paterson (1952), the ternary alloys seem to have claimed much less attention. Cu-Ge-Si appears to be the first ternary alloy investigated in recent times (Folley *et al* 1963).

In the present work it is shown that starting from the data on corresponding binary alloys, it is possible to compute the value of the SFP ($\alpha$) in such ternary systems where the solutes do not interact with each other. The existence of any interaction between the solutes in a ternary alloy can be ascertained by determining its lattice-parameter (Stirling & Raynor 1955).

Following Delchouzee & Deruyttere (1967), the SFP of a binary system is given by,

$$\alpha = \alpha_0 \exp Kp|\Delta Z|$$

so that assuming an additive law to hold for the SFP of a ternary system, one may write,

$$\alpha = \alpha_0 \exp(K p_1)|\Delta Z_1| + \alpha_0 \exp(K p_2)|\Delta Z_2|,$$

where $K$ is a constant for an alloy series, $\alpha_0$ denotes the SFP of the pure solvent, $p_1$ and $p_2$ are the solute concentrations in at. %, $|\Delta Z_1|$ and $|\Delta Z_2|$ are the valency-

differences between the solute and the solvent in the two relevant binary systems respectively

Then, $$\log\left(\frac{\alpha}{\alpha_0}\right) = K(p_1|\Delta Z_1| + p_2|\Delta Z_2$$

Hence finally,

$$\log \alpha = K\Sigma(p\ |\Delta Z|) + \log \alpha_0$$

## 2. Experimental Procedure

The compositions of the ternary alloys (prepared from spectroscopically pure metals) were selected so as to confine them to the primary solid-solution-range, judging from the available phase-diagrams of copper-aluminium-tin (Leach & Raynor 1954) and copper-aluminium-indium (Stirling & Raynor 1955)

The Debye-Scherrer (D-S) patterns were obtained for all the alloys, from annealed fine-filings, using $CuK_\alpha$-radiation The recording-film was in the Straumanis-mounting inside a Philips powder camera The lattice-parameter (LP) was finally determined from the Nelson & Riley (1945) extrapolation. The D-S patterns also confirmed the fcc structure of all the alloys The additive relationship in respect of the LP of the ternary alloys was verified using the authors, data (Chatterjee & Gupta 1975) for LP of the corresponding binary systems (Cu-Al, Cu In and Cu-Sn).

For the estimation of the SFP filings from alloys were prepared at room-temperature, sieved through a 300-mesh and pressed into stainless steel holders of the diffractometer The line-profiles of both (111) and (200) diffraction-peaks for the filings, were recorded by point-counting at intervals of 0 05° in $2\theta$ for the general background decreasing to 0 01° in $2\theta$ near the maxima of the peaks, where $\theta$ is the Bragg-angle The background intensity was carefully fixed

To find the peak-position for the $K_{\alpha_1}$-component, the method of Papoulis (1955) was employed The $K_{\alpha_1}$ peak position (in $2\theta$) for each sample (filings) was determined for both the *as-filed and annealed* states The change $\Delta(2\theta_{200} - 2\theta_{111})$ produced by cold-work (filing) in the separation $(2\theta_{200} - 2\theta_{111})$ of the peaks of an annealed sample could now be calculated Employing Warren's relation (Warren 1959), $\alpha$ was thus estimated for each alloy

## 3 Observations

Figure 1 shows the semilog plots of $\alpha$ against the factor $\Sigma(p.\ \Delta Z)$. The plot approximates to a straight line with a small scatter in the points

The values of the SFP of copper, the pure solvent, $(\alpha_0)$ is found by extrapolation to be $3\,3 \times 10^{-3}$ which agrees well with the accepted value.

The value of the slope of the line, determined from the from the plot, is $K = 0.1059$ for the copper-based alloys which is in agreement with the value ($K = 0.10$) reported earlier by Delehouzee & Deruyttere (1967)

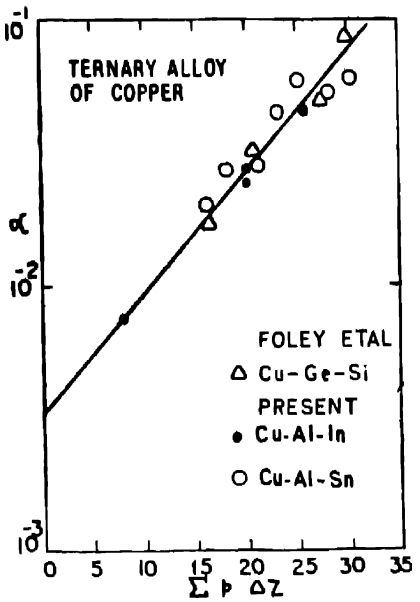


Fig 1. Semilog plot of the SFP ($\alpha$) vs $\Sigma(p\ \Delta Z)$ for the ternary copper alloys.

## 4. Discussion

In the present work, for the estimation of SFP, only the (111) and (200) pair of reflections have been used Now, it had been observed earlier by (Chatterjee 1972), that by assuming an additive law, the value of the LP of each alloy could be computed fairly accurately starting from the LP of the corresponding binary systems This indicates that in the selected alloys the solute atoms which produce the lattice expansion in the parent matrix do not exert between themselves any appreciable solute/solute interaction It was therefore felt that it may be possible to find a similar additive-law applicable to the SFP of the alpha-phase ternary alloys of copper The straight line obtained in figure 1 justifies this assumption to a fair extent The scatter evident in data points of the Cu-Al-Sn series of alloys, may however, be due to several factors such as the atomic-size-factor (Chatterjee *et al* 1973), solute-segregation at the faults (Suzuki 1952), solute/dislocation interaction (Gallagher 1970) etc., which tend to render the value of $\alpha$ apparent

The application of the suggested empirical relation to the results of Foley *et al* (1963) for the Cu-Ge-Si system (figure 1) shows a complete

agreement. Even so, the introduction of terms arising out of the solute/solute interaction into the relation would much widen its range of application. This, however, requires a further probe.

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