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Specific Heat Study of Ni-Cu Alloys Near The Curie Temperature

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The specific heat of nickel-copper alloys containing 0 .0, 4.6, 9.3, 14.0 and 18.8 at .% Cu has been studied near the Curie temperature. The effective critical exponents of specific heat were analyzed using a simple power law; our results show that the value of the effective critical exponents depends on the concentration of impurities. Higher-order correction techniques are definitely necessary for analyzing the universality and symmetry of the exact critical exponents of specific heat.

INTRODUCTION

RECENTLY the research activities on transport properties near critical points are considerably increased[1-2] The singularities in various thermodynamic quantities near the critical point are described by the critical exponents. Critical exponents have usually served as the common meeting ground between experiments and theories; the power-law analysis of the critical behavior has been widely studied both experimentally and theoretically[3-5]. However, different analyzing technique always produced different results. Up to now, much attention has been drawn to the universality of these critical exponents and some other parameters. Theoretically, systems with the same number of degrees of freedom of the order parameter and.with the same dimensionality should .belong to the same universal class[6]. Experimentally, the thermal, electronic and other background terms besides the singularities are quite difficult to treat accurately.

The critical exponent "β"[7] and the electrical resistivity[8] of nickel-copper alloy system have been studied near the Curie temperature before. The specific heat of nickel copper alloys has been measured by Pawel and Stansbury[9] , however, their experimental data do not allow to do the critical exponent analysis. For pure nickel,-the specific heat near the Curie temperature has been reported by Handler et al[10], they found that $\alpha = 0.0 \pm 0.1$ and $\alpha' = 0.3 \pm 0.1$ for $-3.2 \leqslant \log|\epsilon| \leqslant -1.5$; Connelly et al ” reported that $\alpha = \alpha' = -0.10 \pm 0.03$ for pure single-crystalline Ni; recently, the specific heat of Ni-Cu alloys with the

Cu concentration less than 9.6 wt. % has been studied by Papp[12]. He concluded that if the experimental data is analyzed with higher-order correction terms in the Ni-Cu system, the impurity (Cu) does not alter the critical behavior of the universal parameters. In this study, we report further research works on the critical exponent behavior for the Ni-Cu system with the Cu concentration up to 20 wt.%; and only the results of the effective specific heat critical exponents analyzed by means of the simple power law are discussed here. The studies of using the correction to scaling etc. will be reported later.

EXPERIMENTAL CONSIDERATIONS

Specific heat were measured in the neighborhood of the corresponding magnetic transitions on Ni-Cu alloys containing 0.0, 4.6, 9.3, 14.0 and 18.8 at.% Cu. The samples of these meterials were prepared from the original arc-melted ingots used in the electrical resistivity work described elsewhere! Specific heat data were obtained using a Perkin-Elmer differential scanning calorimeter, DSC-4. A system 4 microcomputer controller was used to program the DSC-4 from an initial temperature to a final temperature. The heating rate used was 6K per minute. The specific heat data of Ni-Cu samples were calibrated by the standard specific heat of sapphire (Fig. 1). This procedure is desired for the minimum achievable accuracy in specific heat determinations.

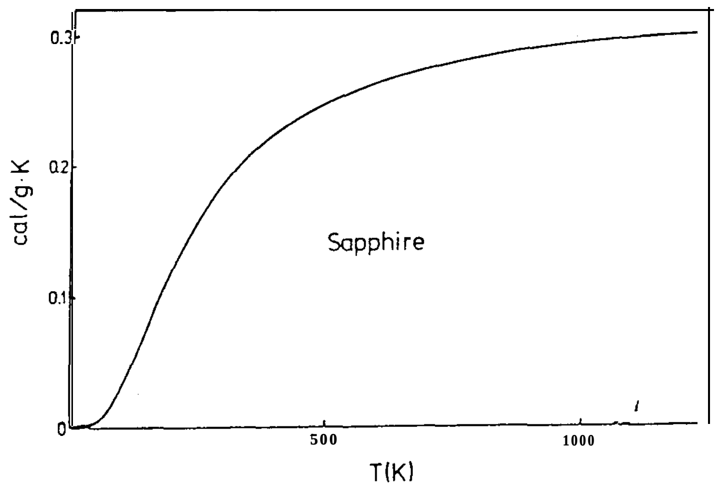

Fig. 1 The specific heat of sapphire used for standard.

Our specific heat data were analyzed with the following simple power-law equations:

$$C(T) = A\epsilon^{-\alpha} \bullet t\ B \qquad T < Tc \tag{1}$$

$$C(T) = A'\epsilon^{-\alpha'} + B' \qquad T > Tc \tag{2}$$

where $\epsilon = |T/T_c - 1|$ is the reduced temperature, T_c is the Curie temperature. A, A', B, B', α and α' are constants.

RESULTS AND DISCUSSION

Fig. 2 shows the specific heat data of five Ni-Cu samples near their Curie temperature. However, owing to the rounding effect of the transition, our data near the maximum point were excluded. As a quantitative measure of this rounding, we chose the temperature interval about 1K in which our data were excluded from the fitting analysis. Within this temperature range, the Curie temperature was chosen by the criterion of the best fitting. The values of T_c are 629.9K, 578.0K, 526.7K, 475.5K and 424.6K for Ni-Cu alloys containing 0.0, 4.6, 9.3, 14.0 and 18.8 at .% Cu, respectively. This is not the same value of Tc determined. by different method[7,8]; however, the difference is small. As shown in Fig. 3 and Table I, it is evident that Tc decreases linearly with a slope of 10.9K per at .% of Cu.

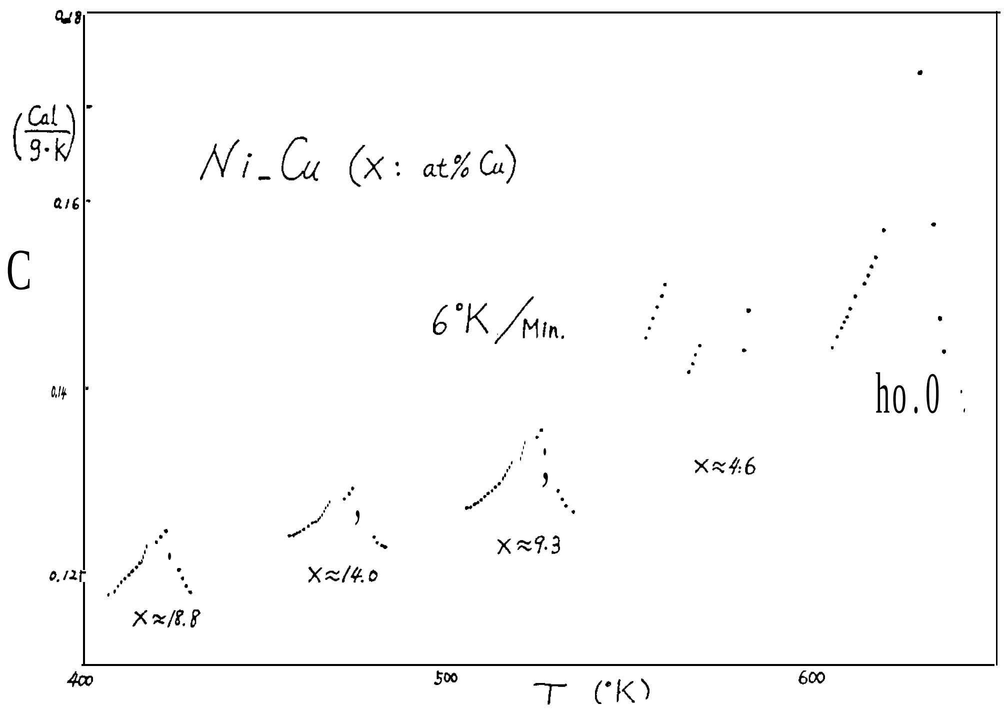

Fig. 2 the specific heat of Ni-Cu samples near the Curie temperature.

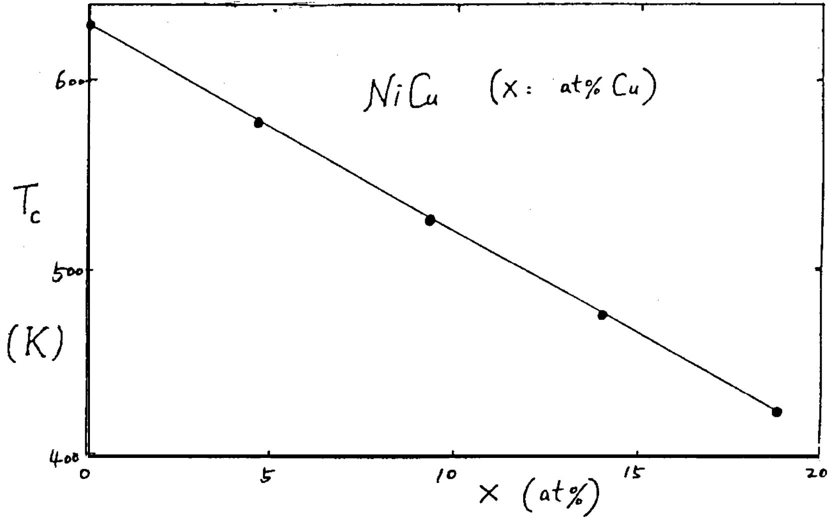

Fig. 3 The Curie temperature as a function of Cu concentration for all the Ni-Cu samples.

By differentiating Eqs. (1) and (2) and taking logarithms, a series of linear fits were made by computer; and by varying the Tc as a parameter in the linear fitting, we obtained the best fitting of log $\frac{\Delta c}{\Delta T}$ versue loge. Figs. 4 and 5 plot the log $\frac{\Delta c}{\Delta T}$ versus loge-for all the Ni-Cu samples in the temperature range

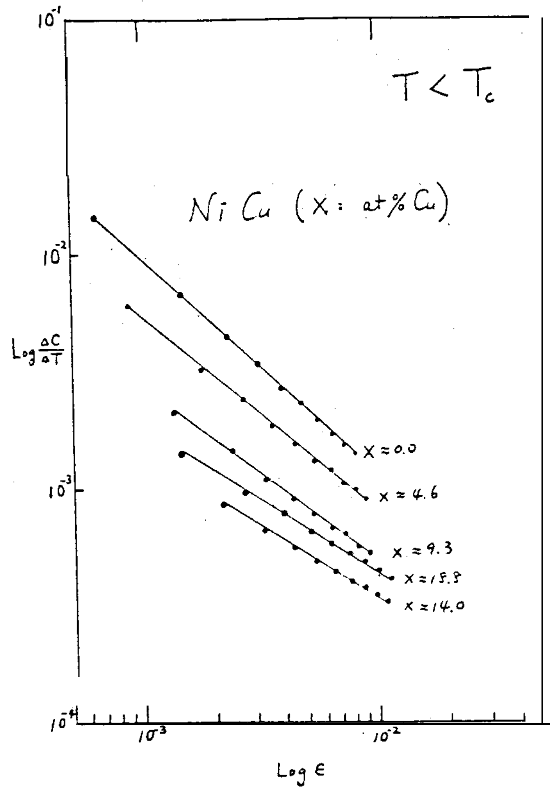

Fig:4 Log $\frac{\Delta c}{\Delta T}$ vs. loge in the temperature range of T < Tc for all the Ni-Cu samples.

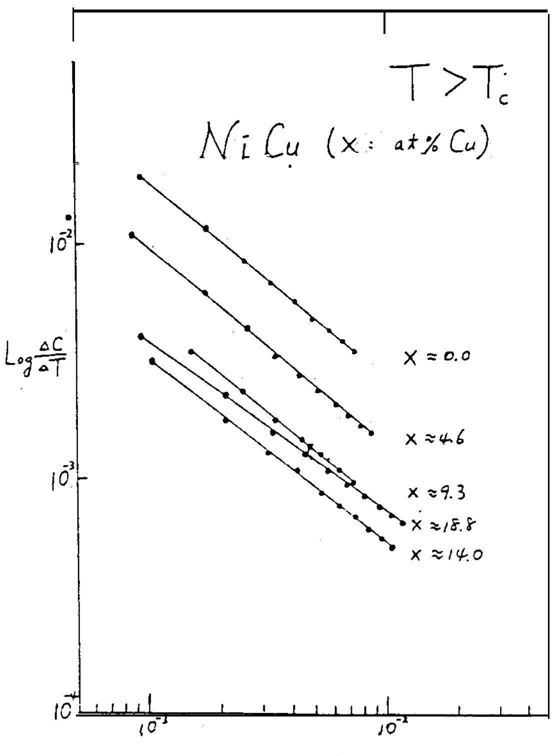

Fig. 5 Log $\frac{\Delta c}{\Delta T}$ vs. Loge in the temperature range of T > Tc for all the Ni-Cu samples.

of T < Tc and T > Tc, respectively. The slope of these curves determines the critical exponents α and α'. The values of α and α' as well as T_c are summarized in Table I. Our data shows that $\alpha \neq \alpha'$ for all the

Table I: The Curie temperatures and critical exponents determined experimentally for Ni-Cusamples.

Sample	T_c(K)	α	α'
Ni	629.9	-0.08	-0.16
Ni-4.6 at .% Cu	578.0	-0.16	-0.16
Ni-9.3 at.% Cu	526.7	-0.24	-0.17
Ni-14.0 at.% Cu	475.5	-0.38	-0.21
Ni-18.8 at.% Cu	424.6	-0.36	-0.27

samples except Ni4.6 at.% Cu sample. The values of α and α' varies significantly with the concentration of Cu. This means that we did not excluded the effects besides the magnetic contribution. The specific heat, C, measured is exact the specific heat at constant pressure, C_p, which can be presented by:

$$C_p = C_m + CL + C_e + V\beta^2 T/K \tag{3}$$

where C_m is the magnetic contribution at constant volume, CL is the lattice contribution, C_e is the normal electronic term and the last ' term is the lattice dilation term resulting from the lattice expansion (where V is the molar valume, β is the volume thermal expansivity, and K is the isothermal compressibility). After differentiating with the temperature, the temperature dependent terms besides the magnetic contribution are not excluded.

Further analyses basing on the higher-order correction are definitely necessary for analyzing the universality and symmetry of the exact critical exponents. Those works will be reported later.

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