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Superconducting state parameters of ternary metallic glasses

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Abstract. **The well-known empty core (EMC) model potential of Ashcroft was used to study the theoretical investigation of the superconducting state parameters (SSP) viz. electron–phonon coupling strength λ, Coulomb pseudopotential μ^*, transition temperature T_C, isotope effect exponent α and effective interaction strength N_OV of some ternary metallic glasses. Most recent local field correction function due to Sarkar *et al* is used to study the screening influence on the aforesaid properties. Quadratic T_C equations have been proposed and found successful. Also, the present findings are found to be in qualitative agreement with other such earlier reported data, which confirms the superconducting phase in the ternary superconductors. The pseudo-alloy-atom (PAA) model was applied for the first time instead of Vegard's law.**

Keywords. **Pseudopotential; superconducting state parameters; ternary metallic glasses.**

1. Introduction

During last several years, superconductivity remains a dynamic area of research in the field of the condensed matter physics with continual discoveries of novel materials and with an increasing demand for novel devices for sophisticated technological applications. Stable ternary glasses can be formed on addition of a third element (M) to binary metallic glasses. They are of interest since third element can modify the physical properties of binary metallic glasses and can also be used as a probe to study the host. The influence of the third element on the electronic and electron transport properties of binary metallic glasses have been studied extensively (Mizutani *et al* 1987, 1989; Yamada *et al* 1988; Zehringer *et al* 1988) but its effect on superconducting properties has been given lesser attention. Only few researchers are studied the superconducting properties of ternary metallic glasses using model potential formalism (Chatterjee 1980; Narlikar and Ekbote 1983; Yamada *et al* 1988; Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010). Such study may be of great help in deciding their applications, and the study of the dependence of the transition temperature T_C on the composition of metallic elements is helpful in finding new superconductors with high T_C. The application of pseudopotential to ternary metallic glasses involves the assumption of pseudoions with average properties, which are assumed to replace three types of ions in the ternary systems, and a gas of free electrons is assumed to permeate through them. The electron–pseudoion is accounted by the pseudopotential, and the electron–electron interaction is involved through a dielectric screening function. For successful prediction of the superconducting properties of the alloying systems, the proper selection of the pseudopotential and screening function is very much essential (Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010).

Therefore, in the present paper, we thought it worthwhile to undertake the investigation of the superconducting state parameters (SSP) of $(Ni_{33}Zr_{67})_{1-x}M_x$ (M = Ti, V, Co, Cu) ternary metallic glasses using the well-known McMillan's theory (McMillan 1968). We have incorporated here the well known Ashcroft's empty core (EMC) model potential (Ashcroft 1966) for studying the electron–phonon coupling strength λ, Coulomb pseudopotential μ^*, transition temperature T_C, isotope effect exponent α and effective interaction strength N_OV for the first time using more advanced local field correction function of Sarkar *et al* (1998). Actually, our main aim of the present study was to check the validity of the appropriate local field correction function. Sharma *et al* (2005) used random phase approximation (RPA) form of dielectric screening, while in the present work we have used here more advanced local field correction function due to Sarkar *et al* (1998). In the RPA form of screening, the exchange and correlation effect is not included, while the local field correction functions proposed by Sarkar *et al* (1998) with modified Hartree dielectric function (Harrison 1999) provides useful information about the screening effects on the aforesaid properties correctly.

Also, in the present work, the pseudo-alloy-atom (PAA) model was used for the first time to explain electron–ion interaction for alloying systems instead of

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Vegard's rule (Sharma *et al* 2005). But, it is well established that PAA is more meaningful approach to explain such kind of interactions in binary systems (Vora 2008a, b, c, 2009, 2010). In the PAA approach, a hypothetical monoatomic crystal is supposed to be composed of PAAs, which occupy the lattice sites and from a perfect lattice in the same way as pure metals. In this model, the hypothetical crystal made up of PAA is supposed to have the same properties as the actual disordered alloy material, and the pseudopotential theory is then applied to study various properties of an alloy and an amorphous alloy. The complete miscibility in the glassy alloy systems is considered as a rare case. Therefore, in such ternary systems the atomic matrix elements in the pure states are affected by the characteristics of alloys such as lattice distortion effects and charging effects. In the PAA model, such effects are involved implicitly. In addition to this, it also takes into account the self-consistent treatment implicitly. Hence, we thought it worthwhile to apply PAA model to investigate the SSP of ternary metallic glasses.

2. Computational methodology

In the present investigation for ternary metallic glasses, the electron–phonon coupling strength λ is computed using the relation (Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010):

$$\lambda = \frac{m_b \Omega_O}{4\pi^2 k_F M \langle \omega^2 \rangle} \int_0^{2k_F} q^3 |V(q)|^2 \, dq. \tag{1}$$

Here m_b is the band mass, M the ionic mass, Ω_O the atomic volume, k_F the Fermi wave vector, $V(q)$ the screened pseudopotential and $\langle \omega^2 \rangle$ the averaged square phonon frequency, of the ternary metallic glasses, respectively. The averaged square phonon frequency $\langle \omega^2 \rangle$ is calculated using the relation given by Butler (1977), $\langle \omega^2 \rangle^{1/2} = 0{\cdot}69\theta_D$, where θ_D is the Debye temperature of the ternary metallic glasses. Using $X = q/2k_F$ and $\Omega_O = 3\pi^2 Z/(k_F)^3$, we get (1) in the following form

$$\lambda = \frac{12 m_b Z}{M \langle \omega^2 \rangle} \int_0^1 X^3 |W(X)|^2 \, dX, \tag{2}$$

where Z and $W(X)$ are the valence of the ternary metallic glasses and the PAA screened EMC pseudopotential (Ashcroft 1966) for ternary metallic glasses, respectively. The well-known screened Ashcroft's EMC model potential (Ashcroft 1966) used in the present computations of the SSP of ternary metallic glasses is of the form

$$W(X) = \frac{-\pi Z}{\Omega_O X^2 k_F^2 \varepsilon(X)} \cos(2k_F X r_C). \tag{3}$$

Here r_C is the parameter of the model potential of ternary metallic glasses and $\varepsilon(X)$ the modified Hartree dielectric function (Harrison 1999). Ashcroft's EMC model potential is a simple one parametric model potential (Ashcroft 1966), which has been found successfully for various metallic complexes (Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010). When used with a suitable form of dialectic screening functions, this potential has also been found to yield good results in computing the SSP of $(Ni_{33}Zr_{67})_{1-x}$ M_x (M = Ti, V, Co, Cu) ternary metallic glasses (Sharma *et al* 2005). As such we have decided to employ this well known EMC potential (Ashcroft 1966) in the present work. Here, the parameter of the model potential r_C is adjusted in such a way that the calculated value of T_C agree well with the available experimental value of T_C (Yamada *et al* 1988) as close as possible.

The Coulomb pseudopotential μ^* is given by (Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010)

$$\mu^* = \frac{\frac{m_b}{\pi k_F} \int_0^1 \frac{dX}{\varepsilon(X)}}{1 + \frac{m_b}{\pi k_F} \ln\left(\frac{E_F}{10\theta_D}\right) \int_0^1 \frac{dX}{\varepsilon(X)}}, \tag{4}$$

where E_F is the Fermi energy, m_b the band mass of the electron, θ_D the Debye temperature and $\varepsilon(X)$ the modified Hartree dielectric function, which is written as (Harrison 1999)

$$\varepsilon(X) = 1 + (\varepsilon_H(X) - 1)(1 - f(X)). \tag{5}$$

$\varepsilon_H(X)$ is the static Hartree dielectric function (Harrison 1999) and $f(X)$ the local field correction function. In the present investigation, the local field correction functions due to Sarkar *et al* (1998) are incorporated to see the impact of exchange and correlation effects on the aforesaid properties. The mathematical expression of it is given by

$$f(q) = A_S \left\{ 1 - \left(1 + B_S \left(\frac{q}{k_F} \right)^4 \right) \exp\left(-C_S \left(\frac{q}{k_F} \right)^2 \right) \right\}. \tag{6}$$

Here, A_S, B_S and C_S are the atomic volume dependent parameters. The mathematical expressions of these parameters are narrated in the respective paper (Sarkar *et al* 1998).

After evaluating λ and μ^*, the transition temperature T_C and isotope effect exponent α are investigated from the McMillan's formula (McMillan 1968; Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010)

$$T_C = \frac{\theta_D}{1{\cdot}45} \exp\left[\frac{-1{\cdot}04(1+\lambda)}{\lambda - \mu^*(1 + 0{\cdot}62\lambda)} \right], \tag{7}$$

Table 1. Input parameters and other constants ternary metallic glasses.

Superconductors	Z	r_C (au)	Ω_O (au)^3	M (amu)	θ_D (K)
$(Ni_{33}Zr_{67})_1Ti_0$	3·34	1·4584	129·73	80·49	343·47
$(Ni_{33}Zr_{67})_{0.95}Ti_{0.05}$	3·37	1·4450	129·19	78·86	347·30
$(Ni_{33}Zr_{67})_{0.90}Ti_{0.10}$	3·41	1·4244	128·62	77·23	351·12
$(Ni_{33}Zr_{67})_{0.85}Ti_{0.15}$	3·44	1·4087	128·05	75·60	354·95
$(Ni_{33}Zr_{67})_{0.80}Ti_{0.20}$	3·47	1·3920	127·48	73·97	358·78
$(Ni_{33}Zr_{67})_{0.75}Ti_{0.25}$	3·51	1·3728	126·92	72·34	362·60
$(Ni_{33}Zr_{67})_1V_0$	3·34	1·4584	129·76	80·49	343·47
$(Ni_{33}Zr_{67})_{0.95}V_{0.05}$	3·42	1·3988	127·95	79·01	345·30
$(Ni_{33}Zr_{67})_{0.90}V_{0.10}$	3·51	1·3457	126·14	77·54	347·12
$(Ni_{33}Zr_{67})_{0.85}V_{0.15}$	3·59	1·2918	124·33	76·06	348·95
$(Ni_{33}Zr_{67})_1Co_0$	3·34	1·4584	129·76	80·49	343·47
$(Ni_{33}Zr_{67})_{0.95}Co_{0.05}$	3·27	1·4572	126·09	79·41	348·55
$(Ni_{33}Zr_{67})_{0.90}Co_{0.10}$	3·21	1·4626	124·21	78·33	353·62
$(Ni_{33}Zr_{67})_1Cu_0$	3·34	1·4584	129·76	80·49	343·47
$(Ni_{33}Zr_{67})_{0.95}Cu_{0.05}$	3·22	1·4756	127·26	79·64	343·45
$(Ni_{33}Zr_{67})_{0.90}Cu_{0.10}$	3·11	1·4852	124·75	78·80	343·42
$(Ni_{33}Zr_{67})_{0.85}Cu_{0.15}$	2·99	1·5060	122·25	77·95	343·40

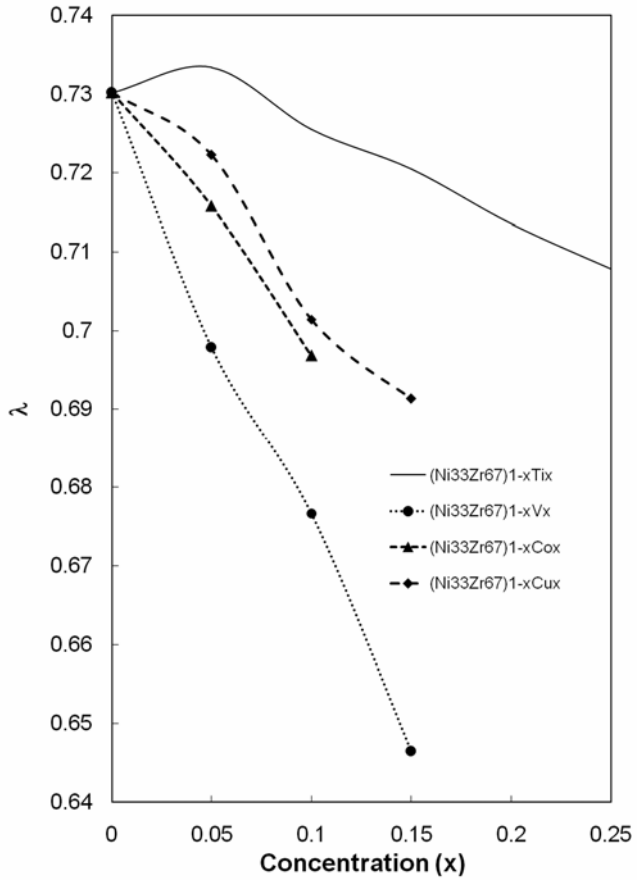

Figure 1. Electron–phonon coupling strength (λ) of ternary metallic glasses.

$$\alpha = \frac{1}{2}\left[1-\left(\mu^* \ln\frac{\theta_D}{1{\cdot}45T_C}\right)^2 \frac{1+0{\cdot}62\lambda}{1{\cdot}04(1+\lambda)}\right]. \quad (8)$$

The expression for the effective interaction strength N_OV is studied using (Sharma *et al* 2005; Vora 2008a, b, c, 2009, 2010)

$$N_OV = \frac{\lambda-\mu^*}{1+\frac{10}{11}\lambda}, \quad (9)$$

3. Results and discussion

The values of the input parameters for the $(Ni_{33}Zr_{67})_{1-x}M_x$ (M = Ti, V, Co, Cu) ternary metallic glasses under investigation are assembled in table 1, which is calculated using PAA model (Vora 2008a, b, c, 2009, 2010). To determine the input parameters and various constants for PAA model (Vora 2008a, b, c, 2009, 2010), the following definitions for ternary metallic glasses $(A_xB_y)_{1-z}C_z$ ($x + y + z = 1$) are adopted:

$$Z = (1-z)(x(Z_A) + y(Z_B)) + z(Z_C), \quad (10)$$

$$M = (1-z)(x(M_A) + y(M_B)) + z(M_C), \quad (11)$$

$$\Omega_O = (1-z)(x(\Omega_{O_A}) + y(\Omega_{O_B})) + z(\Omega_{O_C}), \quad (12)$$

$$r_C = (1-z)(x(r_{C_A}) + y(r_{C_B})) + z(r_{C_C}), \quad (13)$$

$$\theta_D = (1-z)(x(\theta_{D_A}) + y(\theta_{D_B})) + z(\theta_{D_C}), \quad (14)$$

where x, y and z are the concentration factors of the A, B and C pure metallic components ternary metallic glasses. The input parameters of the pure metallic components are taken from the literature (Sharma *et al* 2005).

The presently calculated results of the superconducting state parameters (SSP) of $(Ni_{33}Zr_{67})_{1-x}M_x$ (M = Ti, V, Co, Cu) ternary metallic glasses are tabulated in table 2 with

Table 2. Superconducting state parameters of ternary metallic glasses.

Amorphous superconductors	SSP	Present	Others (Sharma *et al* 2005)	Experiment (Yamada *et al* 1988)
$(Ni_{33}Zr_{67})_1Ti_0$	λ	0·5671	0·553	–
	μ^*	0·1519	0·14	–
	T_C (K)	2·6805	2·6734	2·68
	α	0·3080	0·341	–
	N_OV	0·2753	0·275	–
$(Ni_{33}Zr_{67})_{0·95}Ti_{0·05}$	λ	0·5703	0·558	–
	μ^*	0·1517	0·142	–
	T_C (K)	2·7302	2·7438	2·73
	α	0·3091	0·338	–
	N_OV	0·2757	0·276	–
$(Ni_{33}Zr_{67})_{0·90}Ti_{0·10}$	λ	0·5659	0·558	–
	μ^*	0·1514	0·143	–
	T_C (K)	2·6727	2·6948	2·67
	α	0·3069	0·332	–
	N_OV	0·2737	0·275	–
$(Ni_{33}Zr_{67})_{0·85}Ti_{0·15}$	λ	0·5633	0·558	–
	μ^*	0·1512	0·145	–
	T_C (K)	2·6517	2·6552	2·65
	α	0·3057	0·327	–
	N_OV	0·2725	0·274	–
$(Ni_{33}Zr_{67})_{0·80}Ti_{0·20}$	λ	0·5595	0·557	–
	μ^*	0·1510	0·146	–
	T_C (K)	2·6010	2·6137	2·60
	α	0·3035	0·322	–
	N_OV	0·2707	0·273	–
$(Ni_{33}Zr_{67})_{0·75}Ti_{0·25}$	λ	0·5569	0·557	–
	μ^*	0·1508	0·147	–
	T_C (K)	2·5821	2·5902	2·58
	α	0·3025	0·317	–
	N_OV	0·2696	0·272	–
$(Ni_{33}Zr_{67})_1V_0$	λ	0·5671	0·553	–
	μ^*	0·1519	0·14	–
	T_C (K)	2·6805	2·6734	2·68
	α	0·3080	0·341	–
	N_OV	0·2753	0·275	–
$(Ni_{33}Zr_{67})_{0·95}V_{0·05}$	λ	0·5471	0·545	–
	μ^*	0·1508	0·146	–
	T_C (K)	2·2523	2·2505	2·25
	α	0·2945	0·311	–
	N_OV	0·2647	0·266	–
$(Ni_{33}Zr_{67})_{0·90}V_{0·10}$	λ	0·5358	0·538	–
	μ^*	0·1496	0·151	–
	T_C (K)	2·0804	1·9498	2·08
	α	0·2899	0·285	–
	N_OV	0·2597	0·260	–
$(Ni_{33}Zr_{67})_{0·85}V_{0·15}$	λ	0·5185	0·534	–
	μ^*	0·1485	0·154	–
	T_C (K)	1·7911	1·7836	1·79
	α	0·2784	0·266	–
	N_OV	0·2515	0·256	–
$(Ni_{33}Zr_{67})_1Co_0$	λ	0·5671	0·553	–
	μ^*	0·1519	0·14	–
	T_C (K)	2·6805	2·6734	2·68
	α	0·3080	0·341	–
	N_OV	0·2753	0·275	–
$(Ni_{33}Zr_{67})_{0·95}Co_{0·05}$	λ	0·5556	0·541	–
	μ^*	0·1520	0·141	–
	T_C (K)	2·4024	2·4148	2·40
	α	0·2965	0·330	–
	N_OV	0·2682	0·268	–

(*Contd…*)

Table 2. (*Contd...*)

Amorphous superconductors	SSP	Present	Others (Sharma *et al* 2005)	Experiment (Yamada *et al* 1988)
$(Ni_{33}Zr_{67})_{0.90}Co_{0.10}$	λ	0·5404	0·527	–
	μ^*	0·1524	0·142	–
	T_C (K)	2·1004	2·1103	2·10
	α	0·2812	0·316	–
	N_OV	0·2602	0·260	–
$(Ni_{33}Zr_{67})_1Cu_0$	λ	0·5671	0·553	–
	μ^*	0·1519	0·14	–
	T_C (K)	2·6805	2·6734	2·68
	α	0·3080	0·341	–
	N_OV	0·2753	0·275	–
$(Ni_{33}Zr_{67})_{0·95}Cu_{0.05}$	λ	0·5596	0·543	–
	μ^*	0·1524	0·141	–
	T_C (K)	2·4326	2·4411	2·43
	α	0·2977	0·332	–
	NOV	0·2699	0·270	–
$(Ni_{33}Zr_{67})_{0·90}Cu_{0.10}$	λ	0·5430	0·526	–
	μ^*	0·1529	0·141	–
	T_C (K)	2·0707	2·0787	2·07
	α	0·2812	0·317	–
	N_OV	0·2612	0·261	–
$(Ni_{33}Zr_{67})_{0.85}Cu_{0.15}$	λ	0·5339	0·517	–
	μ^*	0·1536	0·142	–
	T_C (K)	1·8701	1·8759	1·87
	α	0·2694	0·307	–
	N_OV	0·2561	0·255	–

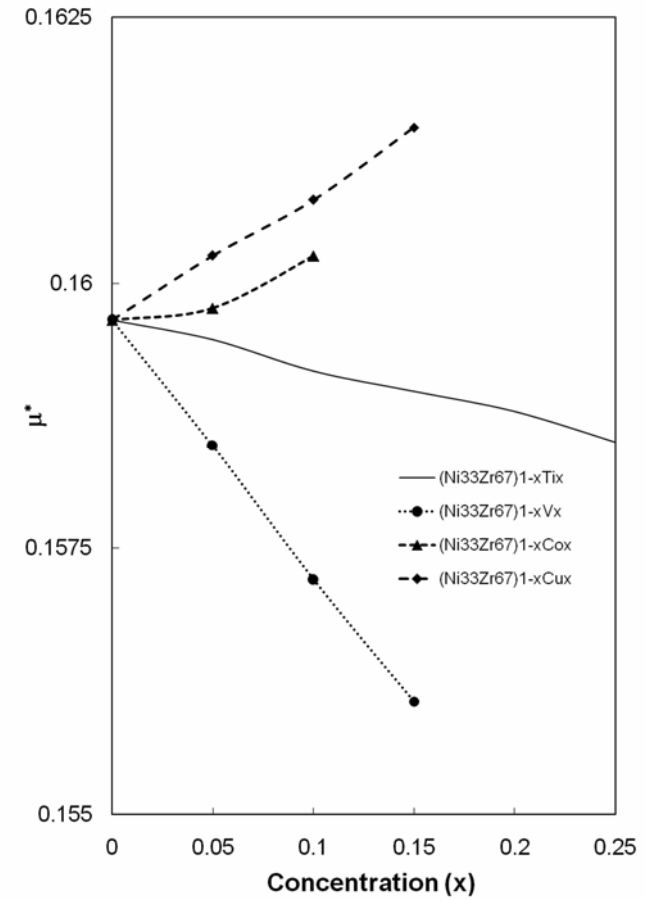

Figure 2. Coulomb pseudopotential (μ^*) of ternary metallic glasses.

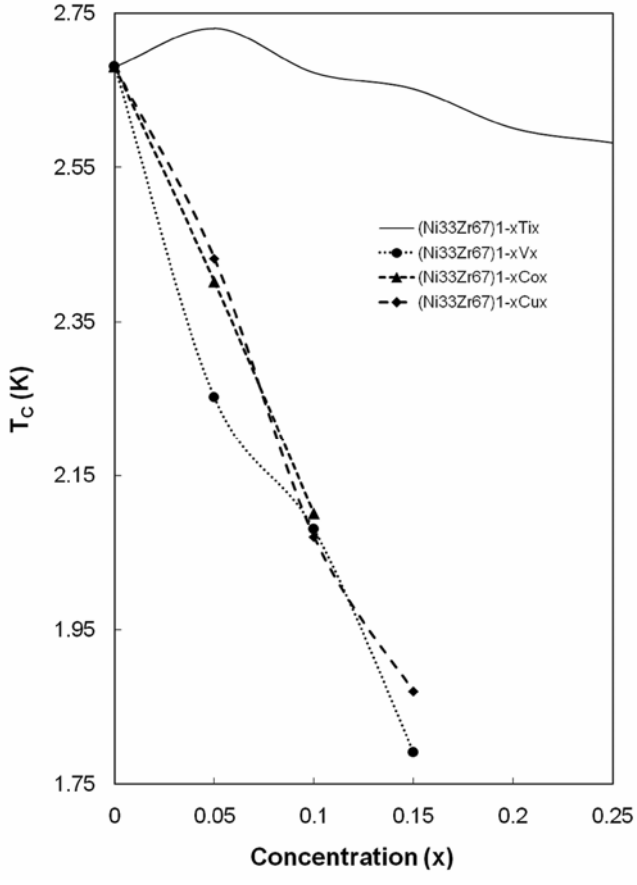

Figure 3. Transition temperature (T_C) of ternary metallic glasses.

other such theoretical (Sharma *et al* 2005) and experimental (Yamada *et al* 1988) findings. The graphical representations of the superconducting properties state parameters (SSP) are also plotted in figures 1–5, where these parameters are plotted against the concentration, x, of the third element (M) for the four different series of ternary metallic glasses.

It is seen from the present data of the superconducting properties of ternary metallic glasses that, addition of V, Co and Cu as third element (M) to a binary amorphous alloy '$Ni_{33}Zr_{67}$' decreases the parameters λ, α and N_OV whereas the Coulomb pseudopotential (μ^*) increases for Ti, Co and Cu-based superconductors, while those for V-based superconductors, the Coulomb pseudopotential (μ^*) decreases with concentration (z) of third element (M), showing that the presence of third element (M) causes the suppression of the superconductivity, in particular ternary glasses. Decrease in λ, α and N_OV suggests weak coupling in these superconductors, the coupling being weakest for Co. This is in conformity with the fact that $(Ni_{33}Zr_{67})_{1-x}Co_x$ ternary metallic glasses do not remain superconducting for higher values of the concentration x of the third element (M). This may be due to change in influential electron band structure from 4d to 3d as suggested by Varma and Dynes (1976). It is observed from the table 2 that for $(Ni_{33}Zr_{67})_{1-x}M_x$. ($M$ = Ti, V, Co, Cu) ternary metallic glasses, μ^* lies between 0·14 and 0·16, which is in accordance with McMillan (1968), who suggested $\mu^* \approx 0{\cdot}13$ for transition metals.

It is also observed that the transition temperature T_C decreases as V, Co or Cu is added to binary amorphous alloy '$Ni_{33}Zr_{67}$'. Both specific heat measurements and band structure calculation (Mizutani *et al* 1987, 1989; Yamada *et al* 1988; Zehringer *et al* 1988) reveal the decrease in density of states at E_F with the addition of the third element (M). Since T_C is related to the modifications of density of states (DOS) at E_F, $N(E_F)$, decrease in T_C can be related to the modifications of DOS at the Fermi level, $N(E_F)$ (Sharma *et al* 2005). The difference is noticed when Ti is added to the binary amorphous alloy '$Ni_{33}Zr_{67}$' (figure 3). In this case, T_C rises initially and then decreases with the concentration, x, of the third

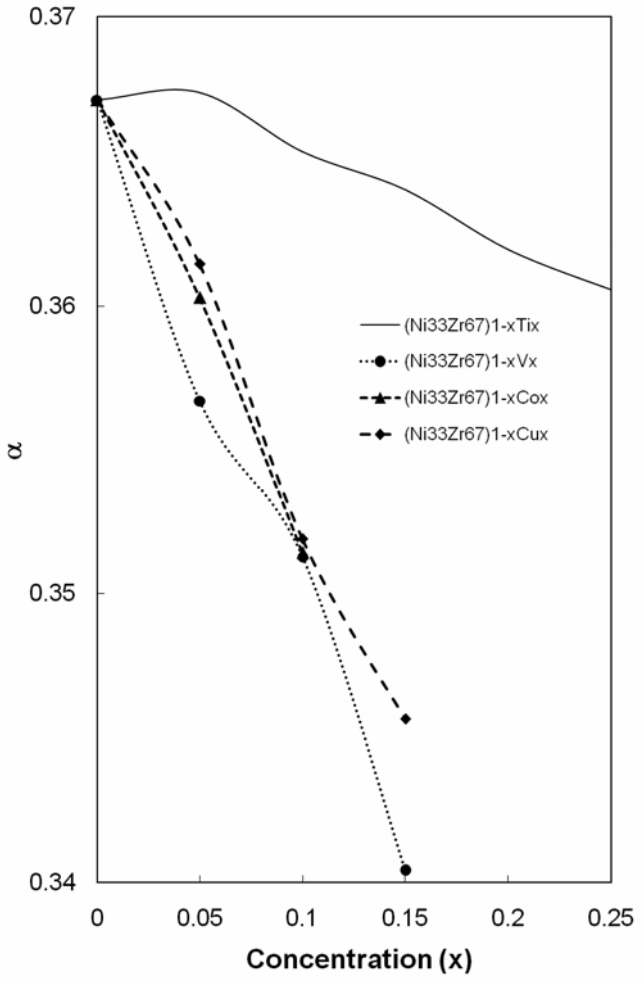

Figure 4. Isotope effect exponent (α) of ternary metallic glasses.

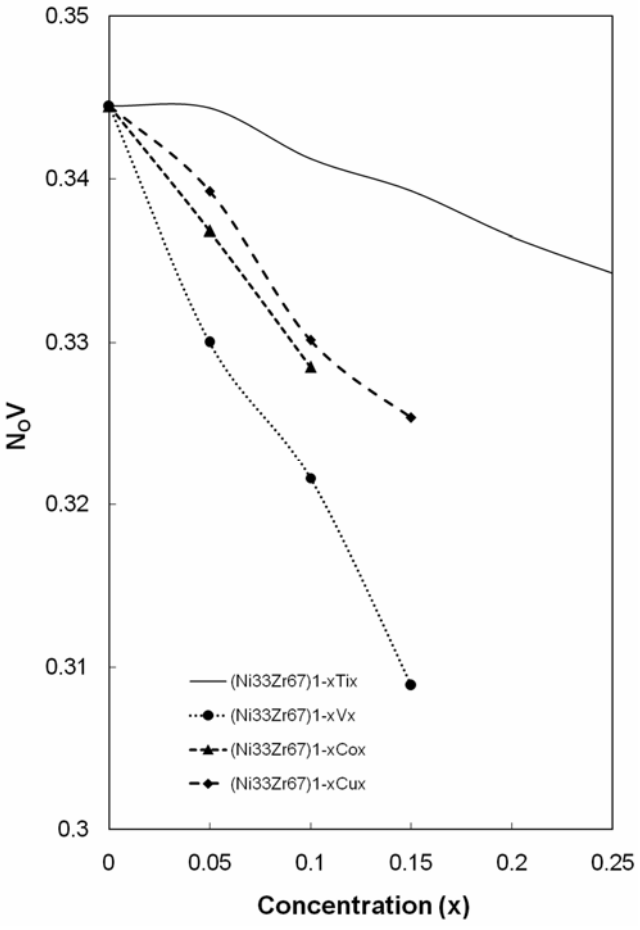

Figure 5. Effective interaction strength (N_OV) of ternary metallic glasses.

element (M), showing a peak at about $x = 0{\cdot}05$. This indicates that on addition of Ti, 3d states grow near E_F and hence contribute substantially to the Fermi level, $N(E_F)$, favouring superconducting behaviour in this case (Sharma *et al* 2005).

It is also observed that superconductivity persists only for small values of x (i.e. $x \leq 0{\cdot}25$), which is because the third element (M) considered here are all 3d-transition metals that have smaller band width and stronger localized character than Zr, and thus they cause narrowing of bands in ternary system (Sharma *et al* 2005). These narrow bands have magnetic instabilities which prevent superconductivity as suggested by Allen and Cohen (1969). The present results for the transition temperature T_C show an excellent agreement with the experimental (Yamada *et al* 1988) and theoretical (Sharma *et al* 2005) findings. Variation of the transition temperature T_C with the concentration x of the third element (M) can be expressed by following quadratic formulae:

$$T_C(K) = -2{\cdot}214x^2 + 0{\cdot}033x + 2{\cdot}698[(Ni_{33}Zr_{67})_{1-x}Ti_x], \quad (15)$$

$$T_C(K) = 14x^2 - 7{\cdot}78x + 2{\cdot}661[(Ni_{33}Zr_{67})_{1-x}V_x], \quad (16)$$

$$T_C(K) = -4{\cdot}765x^2 - 5{\cdot}324x + 2{\cdot}680[(Ni_{33}Zr_{67})_{1-x}Co_x], \quad (17)$$

$$T_C(K) = 5x^2 - 6{\cdot}33x + 2{\cdot}693[(Ni_{33}Zr_{67})_{1-x}Cu_x]. \quad (18)$$

These quadratic formulae of T_C obtained in the present study closely resembles the quadratic T_C equations suggested by Sharma *et al* (2005) on the basis of experimental data for the ternary systems:

$$T_C(K) = -3{\cdot}1393x^2 + 0{\cdot}3014x + 2{\cdot}6961[(Ni_{33}Zr_{67})_{1-x}Ti_x], \quad (19)$$

$$T_C(K) = -25{\cdot}6700x^2 - 9{\cdot}7907x + 2{\cdot}6740[(Ni_{33}Zr_{67})_{1-x}V_x], \quad (20)$$

$$T_C(K) = -9{\cdot}1800x^2 - 4{\cdot}713x + 2{\cdot}6734[(Ni_{33}Zr_{67})_{1-x}Co_x], \quad (21)$$

$$T_C(K) = 1{\cdot}7190x^2 - 5{\cdot}7677x + 2{\cdot}6830[(Ni_{33}Zr_{67})_{1-x}Cu_x]. \quad (22)$$

These equations may be employed for predicting T_C values of other amorphous superconductors in these systems. The wide extrapolations predicts T_C for the hypothetical case of 'amorphous pure $Ni_{33}Zr_{67}$' alloy. From the overall comparisons of the presently computed results with those of Sharma *et al* (2005), it is noted that, the present results are found to be in good agreement with other experimental data (Yamada *et al* 1988). Therefore, the results obtained from Sarkar *et al* (1998) with EMC model potential (Ashcroft 1966) is produced consistent results of the superconductivity of ternary metallic glasses.

Sharma *et al* (2005) have fitted the parameter of the model potential r_C with the RPA form of screening with available experimental data of T_C (Yamada *et al* 1988) and this screening function has not included exchange and correlation effects, while in the present case we have fitted the parameter of the model potential r_C with the modified Hartree screening (Harrison 1999) with most recent Sarkar *et al* (1998) local field correction functions with available experimental data of T_C (Yamada *et al* 1988). Therefore, in the present case we have incorporated screening effects on the aforesaid properties. This is very essential for drawing concrete remarks. The present results confirm the applicability of the EMC model potential and Sarkar *et al* (1998) local field correction function.

According to Matthias' rules (Matthias 1957, 1973), the ternary metallic glasses having $Z > 2$ do exhibit superconducting nature. Hence, $(Ni_{33}Zr_{67})_{1-x}M_x$ (M = Ti, V, Co, Cu) ternary metallic glasses exhibit superconducting nature in the present case. When we

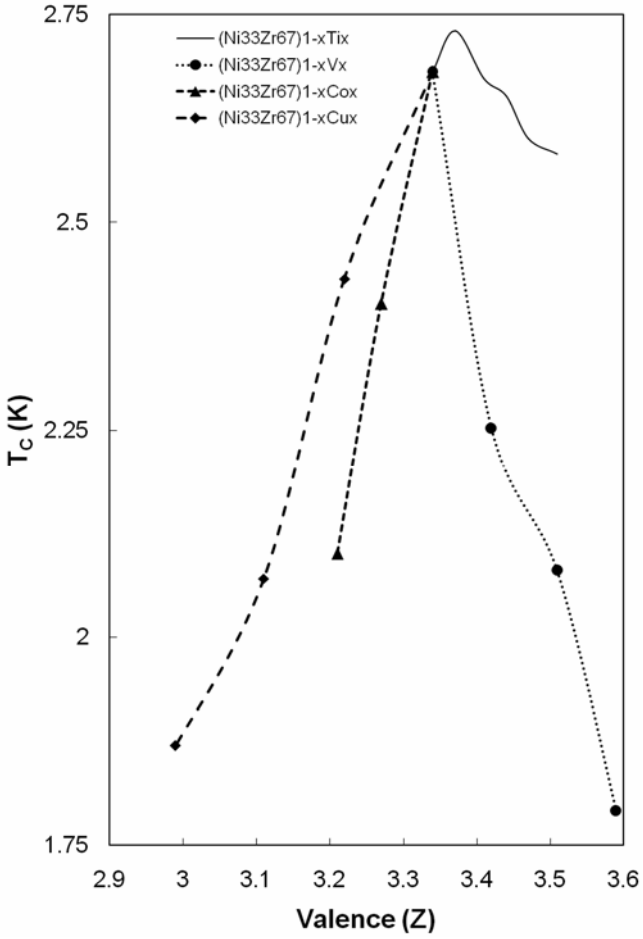

Figure 6. Variation of transition temperature (T_C) with valance (Z) of ternary metallic glasses.

go from $Z = 3{\cdot}21$ to $Z = 3{\cdot}34$, the electron–phonon coupling strength λ changes with lattice spacing '*a*'. Similar trends are also observed in the values of T_C for all ternary metallic glasses. Hence, a strong dependency of the superconducting state parameters (SSP) of the ternary metallic glasses on the valence Z is found. This is also seen in figure 6.

4. Conclusion

We conclude that T_C, α and $N_O V$ decrease as V, Co and Cu are added as third element (M) to binary amorphous superconductor ($Ni_{33}Zr_{67}$), but when Ti is added, T_C increases initially and then decreases and a peak is observed at about $x = 0{\cdot}5$. A good agreement between the presently computed results of T_C values and respective theoretical and experimental values proves the validity of this approach to ternary metallic glasses. Quadratic T_C equations may be successfully used for predicting T_C values of these systems. The present results confirm the applicability of the EMC model potential and Sarkar *et al* (1998) local field correction function. Such study on superconducting state parameters (SSP) of other multicomponent metallic glasses is in progress.

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