Superconducting State Parameters of Ternary Metallic Glasses

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The screening dependence investigations 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 $N_O V$ of some ternary metallic glasses viz. $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ have been reported for the first time using Ashcroft's empty core (EMC) model potential. Five local field correction functions proposed by Hartree (H), Taylor (T), Ichimaru-Utsumi (IU), Farid et al. (F) and Sarkar et al. (S) are used in the present investigation to study the screening influence on the aforesaid properties. It is observed that the electron-phonon coupling strength λ and the transition temperature T_C are quite sensitive to the selection of the local field correction functions, whereas the Coulomb pseudopotential μ^*, isotope effect exponent α and effective interaction strength $N_O V$ show weak dependences on the local field correction functions. The T_C obtained from H-local field correction function are found an excellent agreement with available experimental data. Also, the present results are found in qualitative agreement with other such earlier reported data, which confirms the superconducting phase in the ternary metallic glasses.

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

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I. Introduction

During last several years, the superconductivity remains a dynamic area of research in condensed matter physics with continual discoveries of novel materials and with an increasing demand for novel devices for sophisticated technological applications. A large number of metals and amorphous alloys are superconductors, with critical temperature T_C ranging from 1-18K. Even some heavily doped semiconductors have also been found to be superconductors. Basically, all the metal superconductors are type-I superconductors at room temperature [1-11]. The pseudopotential theory has been used successfully in explaining the superconducting state parameters (SSP) for metallic complexes by many workers [1-11]. Many of them have used well known model pseudopotential in the calculation of the SSP for the metallic complexes. Recently, Vora et al. [3-11] have studied the SSP of some metals, In-based binary alloys, alkali-alkali binary alloys, Cu-Zr metallic glasses, 5d-transition metals binary alloys and large number of metallic glasses based on the various elements of the periodic table using single parametric model potential formalism. The study of the SSP of the ternary metallic glasses may be of great help in deciding their applications; 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 a ternary system 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 for 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 essential [3-11].

Therefore, in the present article, we have used well known McMillan's theory [13] of the superconductivity for predicting the SSP of some $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ ternary metallic glasses. We have used Ashcroft's empty core (EMC) model potential [14] for studying the electron-phonon coupling strength λ, Coulomb pseudopotential μ^*, transition temperature T_C, isotope effect exponent α and effective interaction strength $N_O V$ for the first time. To see the impact of various exchange and correlation functions on the aforesaid properties, we have employed here five different types of local field correction functions proposed by Hartree (H) [15], Taylor (T) [16], Ichimaru-Utsumi (IU) [17], Farid et al.

(F) [18] and Sarkar et al. (S) [19]. We have incorporated for the first time more advanced local field correction functions due to IU [17], F [18] and S [19] with EMC model potential in the present computation of the SSP for ternary metallic glasses.

II. Computational Methodology

In the present investigation for ternary metallic glasses, the electron-phonon coupling strength λ is computed using the relation [3-11]

$$\lambda = \frac{m_b \Omega_0}{4\pi^2 k_F M \langle \omega^2 \rangle} \int_0^{2k_F} q^3 \left| V(q) \right|^2 dq . \quad (1)$$

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 effective averaged square phonon frequency $\langle \omega^2 \rangle$ is calculated using the relation given by Butler [20], $\langle \omega^2 \rangle^{1/2} = 0.69\theta_D$, where θ_D is the Debye temperature of the ternary systems.

Using $X = q/2k_F$ and $\Omega_O = 3\pi^2 Z/(k_F)^3$, we get Eq. (1) in the following form,

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

where Z and $W(X)$ are the valence and the screened EMC pseudopotential [14] of the ternary metallic glasses, respectively.

The well known screened Ashcroft's empty core (EMC) model potential [14] used in the present computations of the SSP of ternary metallic glasses is of the form,

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

here r_C is the parameter of the model potential of ternary metallic glasses. The Ashcroft's empty core (EMC) model potential is a simple one-parameter model potential [14], which has been successfully found for various metallic complexes [5-8]. When used with a suitable form of dielectric screening functions, this potential has also been found to yield good results in computing the SSP of metallic complexes [5-8]. Therefore, in the present work we use Ashcroft's empty core (EMC) model potential with more advanced Ichimaru-Utsumi (IU) [17], Farid et al. (F) [18] and Sarkar et al. (S) [19] local field correction functions for the first time. The model potential parameter r_C may be obtained by fitting either to some experimental data or to realistic form factors or other data relevant to the properties to be investigated. In the present work, r_C is fitted with experimental T_C of the ternary metallic glasses for most of the local field correction functions.

The Coulomb pseudopotential μ^* is given by [3-11]

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

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 [15]

$$\varepsilon(X) = 1 + (\varepsilon_H(X) - 1)(1 - f(X)) \quad (5)$$

$\varepsilon_H(X)$ is the static Hartree dielectric function [15] and $f(X)$ the local field correction function. In the present investigation, the local field correction functions due to H [15], T [16], IU [17], F [18] and S [19] are incorporated to see the impact of exchange and correlation effects.

The H-screening function [15] is purely static, and it does not include the exchange and correlation effects. The expression of it is,

$$f(X) = 0 . \quad (6)$$

Taylor (T) [16] has introduced an analytical expression for the local field correction function, which satisfies the compressibility sum rule exactly. This is the most commonly used local field correction function and covers the overall features of the various local field correction functions proposed before 1972. According to T [16],

$$f(X) = \frac{q^2}{4k_F^2}\left[1 + \frac{0.1534}{\pi k_F^2}\right] . \quad (7)$$

The IU-local field correction function [17] is a fitting formula for the dielectric screening function of the degenerate electron liquids at metallic and lower densities, which accurately reproduces the Monte-Carlo results as well as it also, satisfies the self consistency

condition in the compressibility sum rule and short range correlations. The fitting formula is

$$f(X) = A_{IU}Q^4 + B_{IU}Q^2 + C_{IU} + \left[A_{IU}Q^4 + \left(B_{IU} + \frac{8A_{IU}}{3}\right)Q^2 - C_{IU}\right]\left\{\frac{4-Q^2}{4Q}\ln\left|\frac{2+Q}{2-Q}\right|\right\} \cdot \quad (8)$$

On the basis of IU [17] local field correction function, Farid et al. (F) [18] have given a local field correction function of the form

$$f(X) = A_F Q^4 + B_F Q^2 + C_F + \left[A_F Q^4 + D_F Q^2 - C_F\right]\left\{\frac{4-Q^2}{4Q}\ln\left|\frac{2+Q}{2-Q}\right|\right\} \cdot \quad (9)$$

Based on Eqs. (8-9), Sarkar et al. (S) [19] have proposed a simple form of local field correction function, which is of the form

$$f(X) = A_S\left\{1 - \left(1 + B_S Q^4\right)\exp\left(-C_S Q^2\right)\right\}. \quad (10)$$

Where, $Q = 2X$.

The parameters A_{IU} , B_{IU} , C_{IU} , A_F , B_F , C_F , D_F , A_S , B_S and C_S are the atomic volume dependent parameters of IU, F and S-local field correction functions. The mathematical expressions of these parameters are narrated in the respective papers of the local field correction functions [17-19].

After evaluating λ and μ^*, the transition temperature T_C and isotope effect exponent α are investigated from the McMillan's formula [3-11]

$$T_C = \frac{\theta_D}{1.45}\exp\left[\frac{-1.04(1+\lambda)}{\lambda - \mu^*(1+0.62\lambda)}\right], \quad (12)$$

$$\alpha = \frac{1}{2}\left[1 - \left(\mu^* \ln\frac{\theta_D}{1.45T_C}\right)^2 \frac{1+0.62\lambda}{1.04(1+\lambda)}\right]. \quad (13)$$

The expression for the effective interaction strength $N_O V$ is studied using [3-11]

$$N_O V = \frac{\lambda - \mu^*}{1 + \frac{10}{11}\lambda}. \quad (14)$$

III. Results and discussion

The values of the input parameters for the some ternary metallic glasses viz. $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ under investigation are assembled in Table 1. The presently calculated results of the SSP are tabulated in Table 2 with the other such experimental findings [12].

The calculated values of the electron-phonon coupling strength λ for ternary metallic glasses, using five different types of the local field correction functions with EMC model potential, are shown in Table 2 with the experimental data [12]. It is noticed from the present study that, the percentile influence of the various local field correction functions with respect to the static H-screening function on the electron-phonon coupling strength λ is 18.45%-35.65%, 14.62%-36.92%, 14.25%-38.71%, 14.35%-38.54%, 16.24%-39.77%, 15.71%-39.40%, 16.82%-37.99%, 16.71%-37.99%, 16.71%-38.06%, 16.45%-38.06%, 16.45%-37.85%, 16.29%-37.93% and 16.07%-37.83% for $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ ternary metallic glasses, respectively. Also, the H-screening yields lowest values of λ, whereas the values obtained from the F-function are the highest. It is also observed from the Table 2 that, λ goes increasing for $(Mo_{0.6}Ru_{0.4})_{1-x}B_x$ and $(Mo_{0.6}Ru_{0.4})_{1-x}Si_x$ ternary metallic glasses as the concentration 'x' of the third metallic elements decreases. The increase in λ with concentration 'x' of the third metallic elements shows a gradual transition from weak coupling behaviour to intermediate coupling behaviour of electrons and phonons, which may be attributed to an increase of the hybridization of sp-d electrons of the third metallic elements with increasing concentration (x). This may also be attributed to the increase role of ionic vibrations in the third metallic elements-rich region.

The computed values of the Coulomb pseudopotential μ^*, which accounts for the Coulomb interaction between the conduction electrons, obtained from the various forms of the local field correction functions are tabulated in Table 2. It is observed from the Table 2 that for all the ternary metallic glasses, the μ^* lies between 0.11 and 0.14, which is in accordance with Mcmillan [13], who suggested $\mu^* \approx 0.13$ for transition metals. The weak screening influence shows on the computed values of the μ^*. The percentile influence of the various local field correction functions with respect to the static H- screening function on μ^* for the ternary metallic glasses is observed in the range of 4.16%-8.58%, 3.01%-7.69%, 3.01%-7.10%, 2.98%-

7.71%, 2.98%-7.72%, 3.37%-7.96%, 3.23%-7.85%, 3.78%-8.83%, 3.71%-8.77%, 3.65%-8.74%, 3.58%-8.68%, 3.59%-8.71% and 3.60%-8.71% for $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ ternary metallic glasses, respectively. Again the H-screening function yields lowest values of the μ^*, while the values obtained from the F-function are the highest.

Table 2 contains calculated values of the transition temperature T_C for ternary metallic glasses computed from the various forms of the local field correction functions along with the experimental findings [12]. From the Table 2 it can be noted that, the static H-screening function yields lowest T_C whereas the F-function yields highest values of T_C. The present results obtained from the H-local field correction functions are found in good agreement with available experimental data [12]. The theoretical data of T_C for most of the ternary metallic glasses is not available in the literature. It is also observed that the static H-screening function yields lowest T_C whereas the F-function yields highest values of T_C. The calculated results of the transition temperature T_C for $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ ternary metallic glasses deviate in the range of 51.75%-539.56%, 0.07%-114.83%, 0.02%-100.44%, 0.03%-103.25%, 0.05%-103.04%, 0.07%-120.30%, 0.0%-87.80%, 0.13%-215.45%, 0.11%-202.01%, 0.06%-187.20%, 0.10%-171.44%, 0.17%-165.86% and 0.04%-158.0% from the experimental findings, respectively.

It is also noted from the Table 2, the transition temperature T_C increases for $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$ and $(Mo_{0.6}Ru_{0.4})_{1-x}Si_x$ ternary systems as the concentration 'x' of the third metallic elements decreases. While the transition temperature T_C computed from H-local field correction function for $Ti_{50}Be_{34}Zr_{10}$ ternary glass is found in qualitative agreement with the experimental data [12].

The presently computed values of the T_C are found in the range, which is suitable for further exploring the applications of the ternary metallic glasses for usage like lossless transmission line for cryogenic applications. While alloying elements show good elasticity and could be drawn in the form of wires as such they have good chances of being used as superconducting transmission lines at low temperature of the order of 7K.

The values of the isotope effect exponent α for ternary metallic glasses are tabulated in Table 2. The computed values of the α show a weak dependence on the dielectric screening, its value is being lowest for the H- screening function and highest for the F-function. Since the experimental value of α has not been reported in the literature so far, the present data of α may be used for the study of ionic vibrations in the superconductivity of alloying substances. Since H-local field correction function yields the best results for λ and T_C, it may be observed that α values obtained from this screening provide the best account for the role of the ionic vibrations in superconducting behaviour of this system.

The values of the effective interaction strength N_OV are listed in Table 2 for different local field correction functions. It is observed that the magnitude of N_OV shows that the ternary metallic glasses under investigation lie in the range of weak coupling superconductors. The values of the N_OV also show a feeble dependence on dielectric screening, its value being lowest for the H-screening function and highest for the F-screening function. The variation of present values of the N_OV show that, the ternary metallic glasses under consideration fall in the range of weak coupling superconductors.

The effect of local field correction functions plays an important role in the computation of λ and μ^*, which makes drastic variation on T_C, α and N_OV. The local field correction functions due to IU, F and S are able to generate consistent results regarding the SSP of $Ti_{50}Be_{34}Zr_{10}$, $(Mo_{0.6}Ru_{0.4})_{78}B_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}B_{20}$, $(Mo_{0.4}Ru_{0.6})_{80}P_{20}$, $(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$, $(Mo_{0.6}Ru_{0.4})_{84}B_{16}$, $(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$, $(Mo_{0.6}Ru_{0.4})_{86}B_{14}$, $(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$, $(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$, $(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$, $(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$ and $(Mo_{0.6}Ru_{0.4})_{80}P_{20}$ternary metallic glasses as those obtained from more commonly employed H and T functions. Thus, the use of these more promising local field correction functions is established successfully. The computed results of α and N_OV are not showing any abnormal values for the ternary metallic glasses.

IV. Conclusions

Lastly we concluded that, the H-local field corrections when used with EMC model potential provide the best explanation for superconductivity in the ternary systems. The values of the electron-phonon coupling strength λ and the transition temperature T_C show an appreciable dependence on the local field correction function, whereas for the Coulomb pseudopotential μ^*, isotope effect exponent α and effective interaction strength N_OV a weak

dependence is observed. The magnitude of the λ, α and $N_O V$ values shows that, the ternary metallic glasses are weak to intermediate superconductors. In the absence of theoretical or experimental data for α and $N_O V$, the presently computed values of these parameters may be considered to form reliable data for these ternary systems, as they lie within the theoretical limits of the Eliashberg-McMillan formulation. The comparisons of presently computed results of the SSP of the ternary metallic glasses with available experimental findings are highly encouraging, which confirms the applicability of the EMC model potential and different forms of the local field correction functions. Such study on SSP of other multi component metallic alloys is in progress.

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Table 1. Input parameters and other constants.

Ternary Metallic Glasses	Z	r_C (au)	Ω_O (au)^3	M (amu)	θ_D (K)	$\left\langle \omega^2 \right\rangle^2$ (au)^2 x 10^{-6}
$Ti_{50}Be_{34}Zr_{10}$	2.70	1.0871	96.42	36.68	190.00	0.69415
$(Mo_{0.6}Ru_{0.4})_{78}B_{22}$	4.72	0.5894	88.65	78.84	280.00	1.50751
$(Mo_{0.6}Ru_{0.4})_{80}B_{20}$	4.76	0.5843	89.66	80.59	277.00	1.47538
$(Mo_{0.4}Ru_{0.6})_{80}P_{20}$	4.84	0.5908	107.10	85.46	267.00	1.37078
$(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$	4.84	0.6692	110.13	77.05	554.70	5.91644
$(Mo_{0.6}Ru_{0.4})_{84}B_{16}$	4.85	0.5205	91.68	84.08	301.00	1.74212
$(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$	4.86	0.6616	109.44	78.45	552.12	5.86153
$(Mo_{0.6}Ru_{0.4})_{86}B_{14}$	4.89	0.5314	92.69	85.82	295.00	1.67335
$(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$	4.91	0.6544	108.06	81.25	546.96	5.75248
$(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$	4.94	0.6444	107.37	82.64	544.38	5.69834
$(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$	4.96	0.6407	106.68	84.04	541.80	5.64445
$(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$	4.98	0.6353	105.99	85.44	539.22	5.59083
$(Mo_{0.6}Ru_{0.4})_{80}P_{20}$	5.16	0.5746	109.26	84.62	265.00	1.35032

Table 2. Superconducting state parameters ternary metallic glasses.

Ternary Metallic Glasses	SSP	Present results					Expt. [12]
		H	T	IU	F	S	
$Ti_{50}Be_{34}Zr_{10}$	λ	0.4039	0.5296	0.5444	0.5479	0.4784	0.4
	μ^*	0.1201	0.1290	0.1302	0.1304	0.1251	–
	T_C (K)	0.4158	1.5446	1.7104	1.7524	1.0119	0.274
	α	0.2957	0.3629	0.3671	0.3682	0.3438	–
	N_OV	0.2076	0.2704	0.2770	0.2786	0.2462	–
$(Mo_{0.6}Ru_{0.4})_{78}B_{22}$	λ	0.6321	0.8295	0.8623	0.8655	0.7245	–
	μ^*	0.1131	0.1206	0.1216	0.1218	0.1165	–
	T_C (K)	5.4038	10.1946	10.9880	11.0608	7.6583	5.40, 5.42
	α	0.4329	0.4499	0.4519	0.4520	0.4429	–
	N_OV	0.3296	0.4041	0.4152	0.4162	0.3666	–
$(Mo_{0.6}Ru_{0.4})_{80}B_{20}$	λ	0.6475	0.8507	0.8844	0.8879	0.7422	–
	μ^*	0.1130	0.1205	0.1215	0.1217	0.1164	–
	T_C (K)	5.7510	10.6463	11.4495	11.5255	8.0532	5.75
	α	0.4359	0.4520	0.4538	0.4539	0.4453	–
	N_OV	0.3364	0.4118	0.4229	0.4240	0.3737	–
$(Mo_{0.6}Ru_{0.4})_{84}B_{16}$	λ	0.6554	0.8690	0.9044	0.9091	0.7488	–
	μ^*	0.1142	0.1218	0.1228	0.1230	0.1176	–
	T_C (K)	6.4006	11.9833	12.8916	13.0077	8.8574	6.40
	α	0.4356	0.4522	0.4541	0.4543	0.4446	–
	N_OV	0.3392	0.4174	0.4289	0.4304	0.3756	–
$(Mo_{0.6}Ru_{0.4})_{86}B_{14}$	λ	0.6542	0.8665	0.9017	0.9063	0.7481	–
	μ^*	0.1140	0.1216	0.1226	0.1228	0.1174	–
	T_C (K)	6.2534	11.6941	12.5811	12.6900	8.6755	6.25
	α	0.4357	0.4522	0.4541	0.4543	0.4448	–
	N_OV	0.3388	0.4167	0.4282	0.4296	0.3754	–
$(Mo_{0.4}Ru_{0.6})_{80}P_{20}$	λ	0.6183	0.8252	0.8603	0.8642	0.7187	0.65
	μ^*	0.1156	0.1235	0.1246	0.1248	0.1195	–

	T_C (K)	4.6833	9.4181	10.2240	10.3100	6.9723	4.68
	α	0.4260	0.4463	0.4486	0.4488	0.4381	–
	$N_O V$	0.3218	0.4009	0.4128	0.4141	0.3624	–
$(Mo_{0.6}Ru_{0.4})_{80}P_{20}$	λ	0.7226	0.9622	1.0026	1.0073	0.8361	0.65, 0.71
	μ^*	0.1147	0.1224	0.1235	0.1237	0.1184	–
	T_C (K)	7.3102	12.7635	13.6323	13.7281	9.9639	6.0, 7.31
	α	0.4450	0.4585	0.4600	0.4601	0.4528	–
	$N_O V$	0.3669	0.4479	0.4599	0.4613	0.4078	–
$(Mo_{0.6}Ru_{0.4})_{70}Si_{30}$	λ	0.4893	0.6465	0.6731	0.6752	0.5716	–
	μ^*	0.1269	0.1366	0.1379	0.1381	0.1317	–
	T_C (K)	3.2042	8.8915	10.0186	10.0944	5.9950	3.20
	α	0.3450	0.3920	0.3973	0.3974	0.3760	–
	$N_O V$	0.2508	0.3212	0.3321	0.3328	0.2895	–
$(Mo_{0.6}Ru_{0.4})_{72}Si_{28}$	λ	0.5008	0.6620	0.6892	0.6914	0.5845	–
	μ^*	0.1266	0.1362	0.1375	0.1377	0.1313	–
	T_C (K)	3.6039	9.6184	10.7901	10.8723	6.5512	3.60
	α	0.3539	0.3976	0.4025	0.4026	0.3824	–
	$N_O V$	0.2572	0.3282	0.3392	0.3400	0.2959	–
$(Mo_{0.6}Ru_{0.4})_{76}Si_{24}$	λ	0.5131	0.6773	0.7050	0.7073	0.5975	–
	μ^*	0.1259	0.1354	0.1367	0.1369	0.1305	–
	T_C (K)	4.0523	10.3443	11.5459	11.6318	7.1304	4.05
	α	0.3635	0.4035	0.4080	0.4081	0.3894	–
	$N_O V$	0.2640	0.3354	0.3463	0.3472	0.3026	–
$(Mo_{0.6}Ru_{0.4})_{78}Si_{22}$	λ	0.5315	0.7019	0.7306	0.7331	0.6181	–
	μ^*	0.1256	0.1350	0.1362	0.1365	0.1301	–
	T_C (K)	4.7547	11.5329	12.7978	12.8935	8.0647	4.75
	α	0.3744	0.4104	0.4145	0.4146	0.3974	–
	$N_O V$	0.2737	0.3461	0.3572	0.3580	0.3125	–
$(Mo_{0.6}Ru_{0.4})_{80}Si_{20}$	λ	0.5379	0.7101	0.7390	0.7416	0.6250	–
	μ^*	0.1252	0.1346	0.1359	0.1361	0.1297	–
	T_C (K)	5.0087	11.9174	13.1954	13.2931	8.3770	5.0
	α	0.3784	0.4129	0.4168	0.4169	0.4003	–
	$N_O V$	0.2772	0.3497	0.3608	0.3617	0.3158	–
$(Mo_{0.6}Ru_{0.4})_{82}Si_{18}$	λ	0.5477	0.7229	0.7523	0.7549	0.6357	–
	μ^*	0.1249	0.1342	0.1355	0.1357	0.1294	–
	T_C (K)	5.4019	12.5274	13.8300	13.9319	8.8687	5.40
	α	0.3837	0.4163	0.4200	0.4201	0.4043	–
	$N_O V$	0.2823	0.3552	0.3663	0.3672	0.3209	–