Superconducting State Parameters of Binary Superconductors

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A well known pseudopotential is used to investigate the superconducting state parameters viz. electron-phonon coupling strength λ, Coulomb pseudopotential μ^*, transition temperature T_C, isotope effect exponent α and effective interaction strength N_0V for the Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors theoretically for the first time. We have incorporated here five different types of the local field correction functions to show the effect of exchange and correlation on the aforesaid properties. Very strong influence of the various exchange and correlation functions is concluded from the present study. The comparison with other such experimental values is encouraging, which confirms the applicability of the model potential in explaining the superconducting state parameters of binary mixture.

Keywords: Pseudopotential, Superconducting state Parameters, Local field correction function, Binary superconductors.

PACS numbers: 61.43.Dq; 71.15.Dx; 74.20. − z; 74.70.Ad

1. 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 1-18 K. Even some heavily doped semiconductors have also been found to be superconductors. The pseudopotential theory has been used successfully in explaining the superconducting state parameters (SSP) for metallic complexes by many workers [1-16]. Many of them have used well known model pseudopotential in the calculation of the SSP for the metallic complexes. Recently, we have [3-15] studied the SSP of some metallic superconductors using single parametric model potential formalism. The study of the SSP of the binary alloy based superconductors 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 binary superconductors involves the assumption of pseudoions with average properties, which are assumed to replace three types of ions in the binary 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 [3-15].

A well known empty core (EMC) model potential of Ashcroft [17] is applied here in the theoretical study of the SSP viz. electron-phonon coupling strength λ, Coulomb pseudopotential μ^*, transition temperature T_C, isotope effect exponent α and effective interaction strength N_0V of Ag_xZn_{1-x} and Ag_xAl_{1-x} binary

superconductors for the first time. To see the impact of various exchange and correlation functions on the aforesaid properties, we have used five different types of local field correction functions proposed by Hartree (H) [18], Taylor (T) [19], Ichimaru-Utsumi (IU) [20], Farid et al. (F) [21] and Sarkar et al. (S) [22]. We have incorporated for the first time the more advanced and newly developed local field correction functions i.e. IU, F and S in the investigation of the SSP of Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors. In the present computation, the use of pseudo-alloy-atom model (PAA) is proposed and found successful. It is well established that pseudo-alloy-atom (PAA) is more meaningful approach to explain such kind of interactions in binary systems [3-15]. To describe electron-ion interactions in the binary systems, the Ashcroft's empty core (EMC) single parametric local model potential [17] is employed in the present investigation. The form factor $W(q)$ of the EMC model potential in wave number space is (in au) [17]

$$W(q) = \frac{-8\pi Z}{\Omega_0 q^2 \varepsilon(q)} \cos(qr_C) \qquad (1)$$

where Z, $\Omega_0, \varepsilon(q)$ and r_c are the valence, atomic volume, Hartree dielectric function and parameter of the model potential of binary superconductors, respectively. The parameter of the model potential is determined using the first zero of the form factor [3-15].

2. METHOD OF COMPUTATION

In the present investigation for binary mixtures, the electron-phonon coupling strength λ is computed using the relation [3-16]

$$\lambda = \frac{m_b \Omega_0}{4\pi^2 k_F M \langle w^2 \rangle} \int_0^{2k_F} q^3 |W(q)|^2 \, dq \qquad (2)$$

Here m_b is the band mass, M the ionic mass, Ω_0 the atomic volume, k_F the Fermi wave vector and $W(q)$ the screened pseudopotential. The effective averaged

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square phonon frequency $\langle\omega^2\rangle$ is calculated using the relation given by Butler [23], $\langle\omega^2\rangle = 0.69\,\theta_D$, where θ_D is the Debye temperature of the binary superconductors.

Using $X = q\,/\,2k_F$ and $\Omega_0 = 3\pi^2 Z\,/\,(k_F)^3$, we get Eq. 2 in the following form,

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

where Z and $W(X)$ are the valence and the screened EMC pseudopotential [17] of the binary super-conductors, respectively.

The Coulomb pseudopotential μ^* is given by [3-16]

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

Where E_F is the Fermi energy and $\varepsilon(X)$ the modified Hartree dielectric function, which is written as [18]

$$\varepsilon(X) = 1+\big(\varepsilon_H(X) - 1\big)\big(1 - f(X)\big). \qquad (5)$$

Here $\varepsilon_H(X)$ is the static Hartree dielectric function and the expression of $\varepsilon_H(X)$ is given by [18],

$$\varepsilon_H(X) = 1+\frac{me^2}{2\pi k_F\hbar^2\eta^2}\left(\frac{1-\eta^2}{2\eta}\ln\left|\frac{1+\eta}{1-\eta}\right|+1\right);\eta=\frac{q}{2k_F} \quad (6)$$

While $f(X)$ is the local field correction function. In the present investigation, the local field correction functions due to H, T, IU, F and S are incorporated to see the impact of exchange and correlation effects. The details of all the local field corrections are below.

The H-screening function [18] is purely static, and it does not include the exchange and correlation effects. The expression of it is,

$$f(X) = 0 \qquad (7)$$

Taylor (T) [19] 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 Taylor (T) [19],

$$f(X) = \frac{q^2}{4\,k_F^2}\left[1+\frac{0.1534}{\pi\,k_F^2}\right] \qquad (8)$$

The Ichimaru-Utsumi (IU)-local field correction function [20] 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

$$f(X) = A_{IU}Q^4 + B_{IU}Q^2 + C_{IU} +$$

$$+\left[A_{IU}Q^4 + \left(B_{IU}+\frac{8A_{IU}}{3}\right)Q^2 - C_{IU}\right]\left\{\frac{4-Q^2}{4Q}\ln\left|\frac{2+Q}{2-Q}\right|\right\} \quad (9)$$

On the basis of Ichimaru-Utsumi (IU) [20] local field correction function, Farid et al. (F) [21] have given a local field correction function of the form

$$f(X) = A_F Q^4 + B_F Q^2 + C_F +$$

$$+\left[A_F Q^4 + D_F Q^2 - C_F\right]\left\{\frac{4-Q^2}{4Q}\ln\left|\frac{2+Q}{2-Q}\right|\right\} \qquad (10)$$

Based on Eqs. (9-10), Sarkar et al. (S) [22] have proposed a simple form of local field correction function, which is of the form

$$f(X) = A_S\left\{1 - \left(1 + B_S Q^4\right)\exp\left(-C_S Q^2\right)\right\} \qquad (11)$$

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 [20-22].

After evaluating λ and μ^*, the transition temperature T_C and isotope effect exponent α are investigated from the McMillan's formula [3-16]

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

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

The expression for the effective interaction strength N_0V is studied using [3-16]

$$N_0V = \frac{\lambda - \mu^*}{1 + 10\lambda/11} \qquad (14)$$

3. RESULTS AND DISCUSSION

The input parameters and constants used in the present calculations are given in Table 1. To determine the input parameters and various constants for PAA model, the following definitions for binary super-conductors $A_X B_{1-X}$ are adopted [3-15],

$$Z = XZ_A + (1-X)Z_B \qquad (15)$$

$$M = XM_A + (1-X)M_B \qquad (16)$$

$$\Omega_0 = X\Omega_{0A} + (1-X)\Omega_{0B} \qquad (17)$$

$$\theta_D = X\theta_{DA} + (1-X)\theta_{DB} \qquad (18)$$

Where X is the concentration factor of the second metallic component.

Tables 2-3 and Fig. 1-10 show the presently calculated values of the SSP viz. electron-phonon coupling strength λ, Coulomb pseudopotential μ^*, transition temperature T_C, isotope effect exponent α and effective interaction strength N_0V at various

concentrations for binary superconductors with available experimental findings [24, 25].

Table 1 – Input parameters and other constants

Metals	Z	r_C (au)	Ω_0 (au)^3	k_F (au)	M (amu)	θ_D (K)
Ag	1	1.045	115.00	0.6362	107.87	225
Zn	2	1.135	102.00	0.8342	65.38	327
Al	3	1.114	111.30	0.9276	26.98	428

The calculated values of the electron-phonon coupling strength λ for Ag$_x$Zn$_{1-x}$ and Ag$_x$Al$_{1-x}$ binary superconductors, using five different types of the local field correction functions with EMC model potential, are shown in Tables 2-3 and Fig. 1-2 with the experimental data [24, 25]. 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 23.70 %-41.17 %, 23.79 %-41.32 %,

Table 2 – Superconducting state parameters of the Ag-Zn binary superconductors

Alloys	SSP	Present results					Expt. [24]
		H	**T**	**IU**	**F**	**S**	
Ag$_{0.13}$Zn$_{0.87}$	λ	0.3018	0.4081	0.4252	0.4260	0.3733	0.292
	μ^*	0.1379	0.1503	0.1520	0.1523	0.1455	–
	T_C (K)	0.0120	0.2764	0.3747	0.3772	0.1383	0.10
	α	− 0.3008	0.0709	0.1017	0.1011	0.0065	–
	N_0V	0.1286	0.1881	0.1970	0.1973	0.1701	–
Ag$_{0.14}$Zn$_{0.86}$	λ	0.2995	0.4054	0.4224	0.4232	0.3707	0.290
	μ^*	0.1380	0.1504	0.1522	0.1524	0.1456	–
	T_C (K)	0.0103	0.2571	0.3511	0.3534	0.1270	0.09
	α	− 0.3259	0.0610	0.0930	0.0923	− 0.0057	–
	N_0V	0.1269	0.1863	0.1953	0.1955	0.1684	–
Ag$_{0.15}$Zn$_{0.85}$	λ	0.2978	0.4035	0.4206	0.4214	0.3689	0.289
	μ^*	0.1381	0.1506	0.1523	0.1526	0.1457	–
	T_C (K)	0.0092	0.2439	0.3355	0.3375	0.1192	0.09
	α	− 0.3458	0.0536	0.0867	0.0860	− 0.0149	–
	N_0V	0.1257	0.1850	0.1941	0.1944	0.1672	–
Ag$_{0.155}$Zn$_{0.845}$	λ	0.2972	0.4029	0.4201	0.4209	0.3684	0.289
	μ^*	0.1381	0.1506	0.1523	0.1526	0.1458	–
	T_C (K)	0.0088	0.2396	0.3306	0.3324	0.1166	0.09
	α	− 0.3535	0.0510	0.0847	0.0839	− 0.0182	–
	N_0V	0.1252	0.1846	0.1938	0.1940	0.1668	–
Ag$_{0.16}$Zn$_{0.84}$	λ	0.2961	0.4016	0.4188	0.4195	0.3671	0.289
	μ^*	0.1382	0.1507	0.1524	0.1527	0.1458	–
	T_C (K)	0.0082	0.2313	0.3203	0.3221	0.1119	0.09
	α	− 0.3664	0.0460	0.0804	0.0795	− 0.0243	–
	N_0V	0.1244	0.1838	0.1929	0.1932	0.1659	–
Ag$_{0.175}$Zn$_{0.825}$	λ	0.2940	0.3993	0.4167	0.4174	0.3650	0.295
	μ^*	0.1383	0.1509	0.1526	0.1529	0.1460	–
	T_C (K)	0.0071	0.2162	0.3025	0.3040	0.1030	0.11
	α	− 0.3944	0.0363	0.0723	0.0714	− 0.0368	–
	N_0V	0.1228	0.1823	0.1915	0.1918	0.1644	–
Ag$_{0.185}$Zn$_{0.815}$	λ	0.2919	0.3968	0.4142	0.4149	0.3626	0.298
	μ^*	0.1384	0.1510	0.1527	0.1530	0.1461	–
	T_C (K)	0.0061	0.2015	0.2841	0.2854	0.0947	0.12
	α	− 0.4217	0.0261	0.0635	0.0625	− 0.0495	–
	N_0V	0.1213	0.1807	0.1900	0.1902	0.1628	–
Ag$_{0.20}$Zn$_{0.80}$	λ	0.2899	0.3948	0.4124	0.4131	0.3607	0.303
	μ^*	0.1386	0.1512	0.1529	0.1532	0.1463	–
	T_C (K)	0.0052	0.1890	0.2693	0.2704	0.0874	0.14
	α	− 0.4503	0.0167	0.0558	0.0547	− 0.0618	–
	N_0V	0.1198	0.1793	0.1887	0.1889	0.1614	–
Ag$_{0.25}$Zn$_{0.75}$	λ	0.2825	0.3869	0.4048	0.4054	0.3529	0.312
	μ^*	0.1391	0.1518	0.1536	0.1539	0.1469	–
	T_C (K)	0.0028	0.1460	0.2159	0.2165	0.0633	0.18
	α	− 0.5694	− 0.0226	0.0232	0.0219	− 0.1130	–
	N_0V	0.1141	0.1739	0.1836	0.1838	0.1559	–
Ag$_{0.305}$Zn$_{0.695}$	λ	0.2756	0.3800	0.3984	0.3990	0.3458	0.316
	μ^*	0.1397	0.1526	0.1544	0.1547	0.1477	–
	T_C (K)	0.0015	0.1134	0.1748	0.1752	0.0456	0.19
	α	− 0.7061	− 0.0630	− 0.0096	− 0.0111	− 0.1682	–
	N_0V	0.1087	0.1690	0.1792	0.1793	0.1508	–

Table 3 – Superconducting state parameters of the Ag-Al binary superconductors

Alloys	SSP	Present results					Expt. [25]
		H	T	IU	F	S	
$Ag_{0.76}Al_{0.24}$	λ	0.2666	0.3850	0.4079	0.4091	0.3433	0.285
	μ^*	0.1433	0.1572	0.1591	0.1594	0.1521	–
	T_C (K)	0.0003	0.0973	0.1684	0.1714	0.0287	0.05
	α	− 1.0876	− 0.1089	− 0.0341	− 0.0334	− 0.2760	–
	N_0V	0.0992	0.1687	0.1815	0.1820	0.1458	–
$Ag_{0.73}Al_{0.27}$	λ	0.2735	0.3920	0.4147	0.4158	0.3507	0.301
	μ^*	0.1427	0.1565	0.1584	0.1587	0.1514	–
	T_C (K)	0.0008	0.1265	0.2099	0.2128	0.0417	0.10
	α	− 0.8884	− .0647	0.0012	0.0013	− 0.2072	–
	N_0V	0.1047	0.1736	0.1862	0.1866	0.1512	–
$Ag_{0.70}Al_{0.30}$	λ	0.2806	0.3992	0.4217	0.4227	0.3583	0.305
	μ^*	0.1422	0.1558	0.1576	0.1579	0.1507	–
	T_C (K)	0.0016	0.1624	0.2592	0.2620	0.0591	0.12
	α	− 0.7225	− 0.0245	0.0335	0.0332	− 0.1464	–
	N_0V	0.1103	0.1786	0.1909	0.1913	0.1566	–
$Ag_{0.69}Al_{0.31}$	λ	0.2835	0.4024	0.4249	0.4259	0.3615	0.305
	μ^*	0.1420	0.1555	0.1574	0.1577	0.1505	–
	T_C (K)	0.0021	0.1795	0.2825	0.2853	0.0676	0.12
	α	− 0.6652	− 0.0090	0.0462	0.0458	− 0.1241	–
	N_0V	0.1125	0.1808	0.1930	0.1934	0.1588	–
$Ag_{0.68}Al_{0.32}$	λ	0.2856	0.4045	0.4270	0.4279	0.3638	0.305
	μ^*	0.1418	0.1553	0.1572	0.1575	0.1503	–
	T_C (K)	0.0026	0.1924	0.2995	0.3022	0.0744	0.12
	α	− 0.6232	0.0017	0.0548	0.0543	− 0.1081	–
	N_0V	0.1142	0.1822	0.1944	0.1947	0.1605	–
$Ag_{0.67}Al_{0.33}$	λ	0.2879	0.4067	0.4291	0.4300	0.3661	0.306
	μ^*	0.1417	0.1551	0.1569	0.1573	0.1500	–
	T_C (K)	0.0031	0.2064	0.3179	0.3205	0.0820	0.13
	α	− 0.5824	0.0124	0.0634	0.0628	-0.0923	–
	N_0V	0.1159	0.1837	0.1958	0.1961	0.1621	–
$Ag_{0.63}Al_{0.37}$	λ	0.2980	0.4173	0.4393	0.4402	0.3770	0.295
	μ^*	0.1410	0.1542	0.1561	0.1564	0.1492	–
	T_C (K)	0.0069	0.2800	0.4127	0.4149	0.1234	0.11
	α	− 0.4272	0.0567	0.0997	0.0990	− 0.0289	–
	N_0V	0.1235	0.1907	0.2024	0.2027	0.1696	–
$Ag_{0.60}Al_{0.40}$	λ	0.3063	0.4263	0.4481	0.4489	0.3860	0.292
	μ^*	0.1405	0.1536	0.1555	0.1558	0.1487	–
	T_C (K)	0.0121	0.3532	0.5045	0.5065	0.1668	0.09
	α	− 0.3254	0.0887	0.1263	0.1254	0.0152	–
	N_0V	0.1297	0.1965	0.2079	0.2082	0.1757	–

23.89 %-41.50 %, 23.95 %-41.61 %, 23.99 %-41.69 %, 24.15 %-42.00 %, 24.24 %-42.16 %, 24.41 %-42.48 %, 24.91 %-43.52 %, 25.49 %-44.79 %, 28.79 %-53.47 %, 28.23 %-52.03 %, 27.69 %-50.66 %, 27.52 %-50.25 %, 27.35 %-49.81 %, 27.17 %-49.36 %, 26.51 %-47.71 % and 26.03 %-46.55 % for $Ag_{0.13}Zn_{0.87}$, $Ag_{0.14}Zn_{0.86}$, $Ag_{0.15}Zn_{0.85}$, $Ag_{0.155}Zn_{0.845}$, $Ag_{0.16}Zn_{0.84}$, $Ag_{0.175}Zn_{0.825}$, $Ag_{0.185}Zn_{0.815}$, $Ag_{0.20}Zn_{0.80}$, $Ag_{0.25}Zn_{0.75}$, $Ag_{0.305}Zn_{0.695}$, $Ag_{0.76}Al_{0.24}$, $Ag_{0.73}Al_{0.27}$, $Ag_{0.70}Al_{0.30}$, $Ag_{0.69}Al_{0.31}$, $Ag_{0.68}Al_{0.32}$, $Ag_{0.67}Al_{0.33}$, $Ag_{0.63}Al_{0.37}$ and $Ag_{0.60}Al_{0.40}$ binary superconductors, 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 Tables 2-3 that, λ goes on decreasing from the values of $0.2756 \rightarrow 0.4260$ as the concentration 'x' of 'Ag' is increased from $0.13 \rightarrow 0.305$, while for concentration 'x' of 'Al' increases, λ goes on increasing from $0.2666 \rightarrow 0.4489$. The increase or decrease in λ with concentration 'x' of 'Zn' and 'Al'

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 'Zn' and 'Al' with increasing or decreasing concentration (x). This may also be attributed to the increase role of ionic vibrations in the 'Zn' or 'Al' metals-rich region. The present results are found in qualitative agreement with the available experimental data [24, 25]. The calculated results of the electron-phonon coupling strength λ for $Ag_{0.13}Zn_{0.87}$, $Ag_{0.14}Zn_{0.86}$, $Ag_{0.15}Zn_{0.85}$, $Ag_{0.155}Zn_{0.845}$, $Ag_{0.16}Zn_{0.84}$, $Ag_{0.175}Zn_{0.825}$, $Ag_{0.185}Zn_{0.815}$, $Ag_{0.20}Zn_{0.80}$, $Ag_{0.25}Zn_{0.75}$, $Ag_{0.305}Zn_{0.695}$, $Ag_{0.76}Al_{0.24}$, $Ag_{0.73}Al_{0.27}$, $Ag_{0.70}Al_{0.30}$, $Ag_{0.69}Al_{0.31}$, $Ag_{0.68}Al_{0.32}$, $Ag_{0.67}Al_{0.33}$, $Ag_{0.63}Al_{0.37}$ and $Ag_{0.60}Al_{0.40}$ deviate in the range of 3.35 %-45.90 %, 3.26 %-45.94 %, 3.04 %-45.80 %, 2.83 %-45.62 %, 2.46 %-45.17 %, 0.35 %-41.50 %, 2.06 %-39.24 %, 4.32 %-36.32 %, 9.46 %-29.94 %, 12.79 %-26.27 %, 6.47 %-43.55 %, 9.14 %-

38.14 %, 8.01 %-38.60 %, 7.06 %-39.65 %, 6.34 %-40.30 %, 5.92 %-40.52 %, 1.02 %-49.21 % and 4.53 %-53.73 % binary superconductors from the available experimental findings [24, 25], respectively. The presently computed results of the λ from H-screenings are found in qualitative agreement with the available experimental data [24, 25].
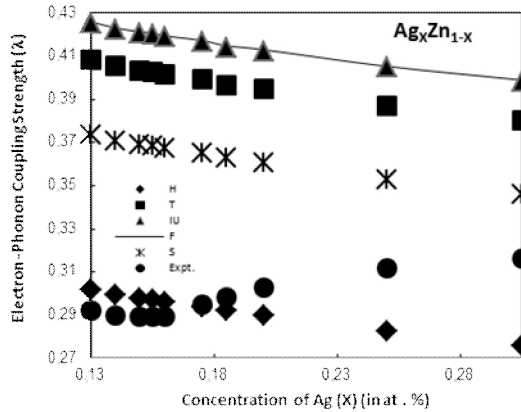

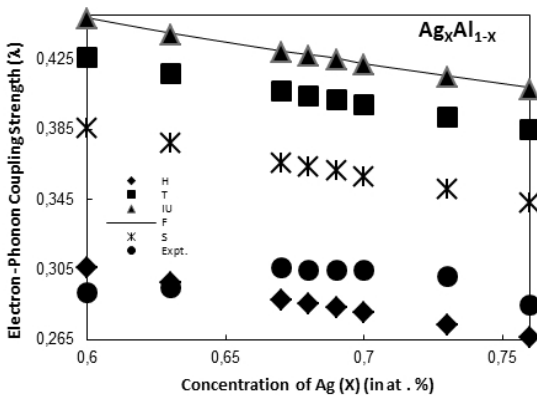**Fig. 1** – Variation of electron-phonon coupling strength (λ) with Ag-concentration (at %) for Ag_xZn_{1-x} glassy alloys

Fig. 2 – Variation of electron-phonon coupling strength (λ) with Ag-concentration (at %) for Ag_xAl_{1-x} glassy alloys

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 shown in Tables 2-3 and Fig. 3-4. It is observed from that for Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors, the μ^* lies between 0.13 and 0.16, which is in accordance with McMillan [16], who suggested $\mu^* \approx 0.13$ for simple and non-simple 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 binary super-conductors is observed in the range of 5.51 %-10.48 %, 5.52 %-10.49 %, 5.53 %-10.51 %, 5.54 %-10.54 %, 5.54 %-10.52 %, 5.56 %-10.55 %, 5.57 %-10.56 %, 5.59 %-10.58 %, 5.66 %-10.66 %, 5.73 %-10.75 %, 6.13 %-11.28 %, 6.06 %-11.19 %, 5.99 %-11.10 %, 5.97 %-11.07 %, 5.95 %-11.04 %, 5.92 %-11.01 %, 5.84 %-10.91 % and 5.78 %-10.83 % for $Ag_{0.13}Zn_{0.87}$, $Ag_{0.14}Zn_{0.86}$, $Ag_{0.15}Zn_{0.85}$, $Ag_{0.155}Zn_{0.845}$, $Ag_{0.16}Zn_{0.84}$, $Ag_{0.175}Zn_{0.825}$, $Ag_{0.185}Zn_{0.815}$, $Ag_{0.20}Zn_{0.80}$, $Ag_{0.25}Zn_{0.75}$,

$Ag_{0.305}Zn_{0.695}$, $Ag_{0.76}Al_{0.24}$, $Ag_{0.73}Al_{0.27}$, $Ag_{0.70}Al_{0.30}$, $Ag_{0.69}Al_{0.31}$, $Ag_{0.68}Al_{0.32}$, $Ag_{0.67}Al_{0.33}$, $Ag_{0.63}Al_{0.37}$ and $Ag_{0.60}Al_{0.40}$ binary superconductors, respectively. Again the H-screening function yields lowest values of the μ^*, while the values obtained from the F-function are the highest. The theoretical or experimental data of the μ^* is not available for the further comparisons.
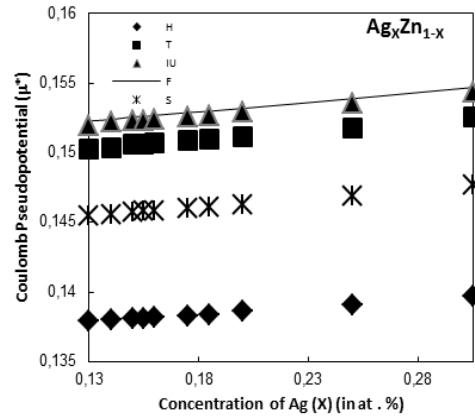

Fig. 3 – Variation of Coulomb pseudopotential (μ^*) with Ag-concentration (at %) for Ag_xZn_{1-x} glassy alloys
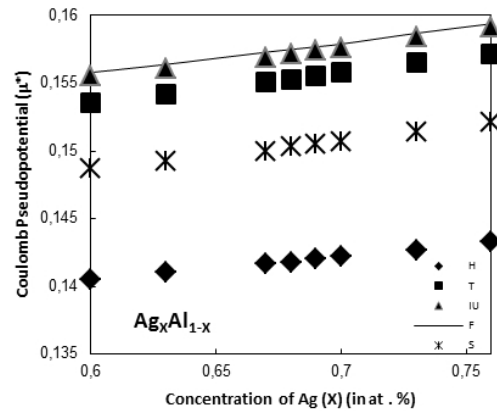

Fig. 4 – Variation of Coulomb pseudopotential (μ^*) with Ag-concentration (at %) for Ag_xAl_{1-x} glassy alloys

Tables 2-3 and Fig. 5-6 contains calculated values of the transition temperature T_C for Ag_xZn_{1-x} and Ag_x-Al_{1-x} binary superconductors computed from the various forms of the local field correction functions along with the experimental findings [24, 25]. From the Tables 2-3 and Fig. 5-6 it can be noted that, the static H-screening function yields lowest T_C whereas the F-function yields highest values of the T_C. The present results obtained from the H-local field correction functions are found in good agreement with available experimental data [24, 25]. The calculated results of the transition temperature T_C for binary superconductors viz. $Ag_{0.13}Zn_{0.87}$, $Ag_{0.14}Zn_{0.86}$, $Ag_{0.15}Zn_{0.85}$, $Ag_{0.155}Zn_{0.845}$, $Ag_{0.16}Zn_{0.84}$, $Ag_{0.175}Zn_{0.825}$, $Ag_{0.185}Zn_{0.815}$, $Ag_{0.20}Zn_{0.80}$, $Ag_{0.25}Zn_{0.75}$, $Ag_{0.305}Zn_{0.695}$, $Ag_{0.76}Al_{0.24}$, $Ag_{0.73}Al_{0.27}$, $Ag_{0.70}Al_{0.30}$, $Ag_{0.69}Al_{0.31}$, $Ag_{0.68}Al_{0.32}$, $Ag_{0.67}Al_{0.33}$, $Ag_{0.63}Al_{0.37}$ and $Ag_{0.60}Al_{0.40}$ deviate in the range of 38.30 %-277.18 %, 41.09 %-292.66 %, 32.49 %-274.95 %, 29.61 %-269.37 %, 24.29 %-257.90 %, 6.36 %-176.32 %, 21.12 %-137.87 %, 37.55 %-96.27 %, 18.92 %-98.43 %, 7.77 %-99.22 %, 42.67 %-242.83 %, 26.48 %-112.82 %, 35.31 %-118.33 %,

43.71 %-137.76 %, 37.97 %-151.85 %, 36.89 %-146.51 %, 12.16 %-277.21 % and 85.32 %-462.80 % binary superconductors from the experimental findings [24, 25], respectively.
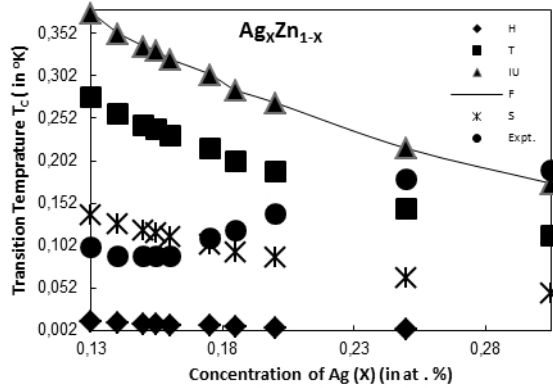

Fig. 5 – Variation of transition temperature (T_C) with Ag-concentration (at %) for Ag_xZn_{1-x} glassy alloys
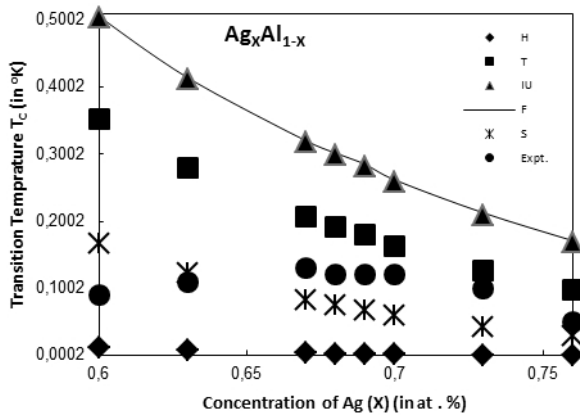

Fig. 6 – Variation of transition temperature (T_C) with Ag-concentration (at %) for Ag_xAl_{1-x} glassy alloys

The values of the isotope effect exponent α for binary superconductors are narrated in Tables 2-3 and Fig. 7-8. 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 negative value of the α is observed for most of the binary superconductors, which indicates that the electron-phonon coupling in these metallic complexes do not fully explain all the features regarding their superconducting behaviour. The theoretical or experimental data of the α is not available for the further comparisons.

The values of the effective interaction strength N_0V are shown in Tables 2-3 and Fig. 9-10 for different local field correction functions. It is observed that the
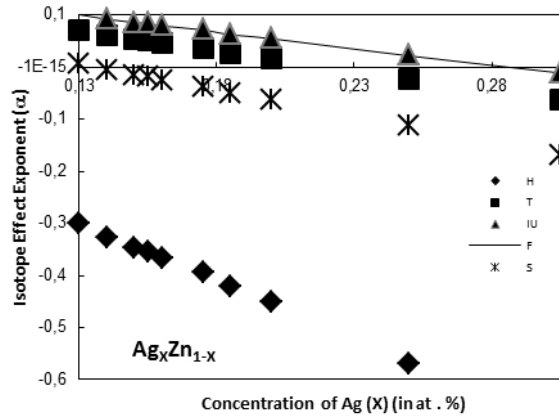

Fig. 7 – Variation of isotope effect exponent (α) with Ag-concentration (at %) for Ag_xZn_{1-x} glassy alloys
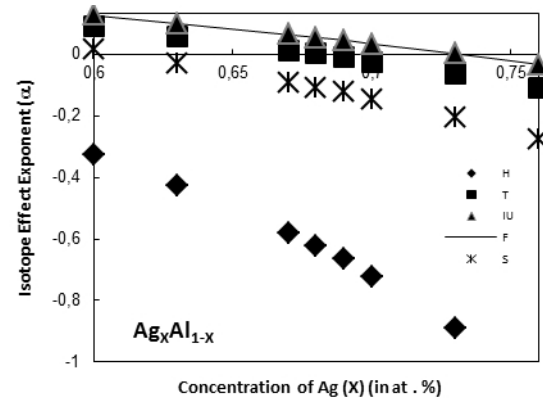

Fig. 8 – Variation of isotope effect exponent (α) with Ag-concentration (at %) for Ag_xAl_{1-x} glassy alloys
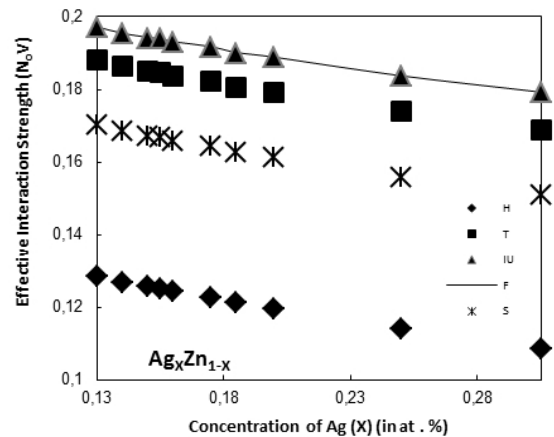

Fig. 9 – Variation of effective interaction strength (N_0V) with Ag-concentration (at %) for Ag_xZn_{1-x} glassy alloys

The values of the effective interaction strength N_0V are shown in Tables 2-3 and Fig. 9-10 for different local field correction functions. It is observed that the magnitude of N_0V shows that the Ag_xZn_{1-x} and Ag_x-Al_{1-x} binary superconductors under investigation lie in the range of weak coupling superconductors. The values of the N_0V 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 theoretical or experimental data of the N_0V is not available for the further comparisons.
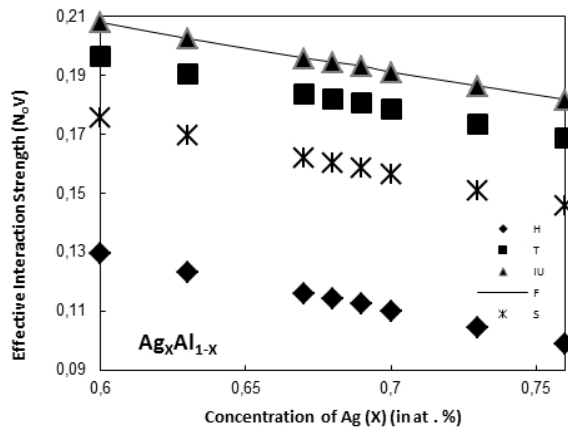
Fig. 10 – Variation of effective interaction strength (N_0V) with Ag-concentration (at %) for Ag_xAl_{1-x} glassy alloys

From the study of the Tables 2-3 and Fig. 1-10, one can see that among the five screening functions the screening function due to H (only static–without exchange and correlation) gives the minimum value of the SSP while the screening function due to F gives the maximum value. The present findings due to T, IU and S-local field correction functions are lying between these two screening functions. The local field correction functions due to IU, F and S are able to generate consistent results regarding the SSP of binary superconductors as those obtained for more commonly employed H and T functions. 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_0V. Thus, the use of these more promising local field correction functions is established successfully. The computed results of α and N_0V are not showing any abnormal values for Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors.

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_0V a weak dependence is observed. The magnitude of the λ, α and N_0V values shows that

Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors are weak to intermediate superconductors. In the absence of experimental data for α and N_0V, the presently computed values of these parameters may be considered to form reliable data for Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors, as they lie within the theoretical limits of the Eliashberg-McMillan formulation [16].

According to Matthias rules [26] the metallic glasses having $Z < 2$ do not exhibit superconducting nature. Hence, Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors are non-superconductors, but they exhibit superconducting nature in the present case. When we go from $Z = 1.480$ to $Z = 1.800$, the electron-phonon coupling strength λ changes with lattice spacing "a". Similar trends are also observed in the values of T_C for most of the Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors. Hence, a strong dependency of the SSP of the Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors on the valence Z is found.

Lastly, we would like to emphasize the importance of involving a precise form for the pseudopotential. It must be confessed that although the effect of pseudopotential in strong coupling superconductor is large, yet it plays a decisive role in weak coupling superconductors i.e. those substances which are at the boundary dividing the superconducting and nonsuperconducting region. In other words, a small variation in the value of electron-ion interaction may lead to an abrupt change in the superconducting properties of the material under consideration. In this connection we may realize the importance of an accurate form for the pseudopotential.

4. CONCLUSIONS

The comparison of presently computed results with available experimental findings is highly encouraging in the case of binary superconductors, which confirms the applicability of the model potential. The theoretically observed values of SSP are not available for most of the Ag_xZn_{1-x} and Ag_xAl_{1-x} binary superconductors therefore it is difficult to draw any special remarks. However, the comparison with other such theoretical data supports the present computations of the SSP. Such study on SSP of other binary and multi component alloys as well as metallic glasses is in progress.

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