Superconducting properties of (NH$_3$)$_y$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ under pressure

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Abstract

We prepared two superconducting phases of (NH$_3$)$_y$Li$_x$FeSe$_{0.5}$Te$_{0.5}$, which show superconducting transition temperatures ($T_c$'s) as high as 20.2 and 29.5 K at ambient pressure, here called the ‘low-$T_c$ phase’ and ‘high-$T_c$ phase’. The temperature dependence of electrical resistance ($R$) was measured for the low-$T_c$ phase of (NH$_3$)$_y$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ over a pressure ($p$) range of 0–14 GPa, and for the high-$T_c$ phase of (NH$_3$)$_y$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ over 0–19 GPa, yielding double-dome superconducting $T_c$–$p$ phase diagrams, i.e. two superconducting phases (SC-I and SC-II) were found for both the low-$T_c$ and high-$T_c$ phases under pressure. For the low-$T_c$ phase, the maximum $T_c$ was 20.2 K at 0 GPa for SC-I, and 19.9 K at 8.98 GPa for SC-II. For the high-$T_c$ phase, the maximum $T_c$ was 33.0 K at 1.00 GPa for SC-I, and 24.0 K at 11.5–13.2 GPa for SC-II. These results imply that the maximum $T_c$ value of the high pressure phase (SC-II) does not exceed the maximum value of the SC-I, unlike what was shown in the $T_c$–$p$ phase diagrams of (NH$_3$)$_3$Li$_x$FeSe and (NH$_3$)$_3$Cs$_x$FeSe investigated previously. Nevertheless, the double-dome $T_c$–$p$ phase diagram was found in metal-doped FeSe$_{0.5}$Te$_{0.5}$, indicating that this feature is universal in metal-doped FeSe$_{1-z}$Te$_2$. Moreover, no structural phase transitions were observed for either the low-$T_c$ or high-$T_c$ phases of (NH$_3$)$_y$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ over the wide pressure range of 0–15.3 GPa, and the $T_c$–lattice constant ($c$) plots for both phases were recorded to determine the critical point separating SC-I and SC-II.

1. Introduction

Recently, the pressure dependence of superconductivity in metal-doped two-dimensional (2D) layered materials has attracted much attention [1–11] because of the expectation that a new superconducting pairing mechanism will be developed, as well as the emergence of new superconducting phases exhibiting higher superconducting transition temperatures ($T_c$’s) than those observed at ambient pressure. The pressure-driven high-$T_c$ phase has been extensively investigated in metal-doped FeSe [6–11]. The first discovery of a pressure-driven high-$T_c$ phase was reported for K$_{0.8}$Fe$_{1.78}$Se$_2$, K$_{0.8}$Fe$_{1.78}$Se$_2$ and Tl$_{0.6}$Rh$_{0.4}$Fe$_{1.67}$Se$_2$ crystals [6], and our group reported a very high value of $T_c$ (= 49 K) in (NH$_3$)$_3$Cs$_x$FeSe at 21 GPa [9], showing that the double-dome $T_c$–$p$ phase diagram consisted of two superconducting phases (SC-I and SC-II). As a matter of fact, such a double-dome $T_c$–$p$ phase diagram has also been reported for other materials such as Bi$_2$Sr$_2$CuO$_{6+\delta}$ [12] and FeS [13].

A double-dome superconducting $T_c$–$p$ plot was observed in (NH$_3$)$_3$Li$_x$FeSe, the $T_c$ of which reached 55 K at 11 GPa [10]. The Hall effect measurement under pressure indicated that a dramatic increase in electron density in the high-pressure phase (SC-II) had occurred, suggestive of a Lifshitz transition, in which the topology of the Fermi surface undergoes major changes.

Recently, we investigated the pressure dependence of $T_c$ in the high-$T_c$ and low-$T_c$ phases of (NH$_3$)$_y$Na$_x$FeSe [14], and prepared the $T_c$–lattice constant ($c$) phase diagram. The $T_c$ increased with an increase in $c$, and the
further increased separation of FeSe layers suppressed the value of $T_c$, as reported previously [14–18]. Moreover, a discontinuous change of $T_c$ at $c = 14$ Å was found in the $T_c$–$c$ phase diagram of metal-doped FeSe [14]. Thus, a single critical point separating the phases of SC-I and SC-II was unambiguously confirmed for (NH$_3$)$_3$M$_x$FeSe (M: alkali or alkali-earth metal atom). From this background, we worked to determine whether such a double-dome $T_c$–$p$ phase diagram is universally observed for (NH$_3$)$_3$M$_x$FeSe$_{0.5}$Te$_{0.5}$.

In this study, the pressure dependence of $T_c$ in (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ was fully investigated over a wide pressure range of 0–19 GPa in order to clarify the presence of the pressure–driven high-$T_c$ phase, and to prepare the $T_c$–$c$ phase diagram of metal-doped FeSe$_{0.5}$Te$_{0.5}$. For this purpose, we measured the x-ray diffraction (XRD) of (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ at 0–15 GPa. One of the most significant points in this study was to find the critical point separating SC-I and SC-II phases in the $T_c$–$c$ phase diagram, in which a discontinuous change of $T_c$ should be observed against $c$. This study aimed at clarifying whether the single critical point found in (NH$_3$)$_3$M$_x$FeSe is also observed for (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$, which could lead to a universal or systematic understanding of superconductivity in metal-doped FeSe$_{1–x}$Te$_x$.

2. Experimental

Samples of (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ were prepared as previously described in [19, 20]. The XRD patterns of samples under pressure were measured at 297 K, using synchrotron radiation at BL12B2 of SPring-8; the wavelength $\lambda$ of the x-ray beam was 0.6838 Å. A clock-type diamond anvil cell (DAC) was used for the high-pressure XRD measurement, with the sample being set into the hole of a stainless steel (SUS) plate; the photo of the DAC is shown in figure S1(a) of the supplementary material, which is available online at stacks.iop.org/NJP/21/113010/mmedia. The culet size of diamond and hole size of SUS gasket were 180 $\mu$m and 450 $\mu$m, respectively. Daphne 7373 was employed as the pressure medium for the XRD measurement under high pressure. The pressure was monitored by ruby fluorescence. The superconductivity of the (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ samples was checked at 0 GPa using the DC magnetic susceptibility ($M$/$H$) as recorded by a SQUID magnetometer (Quantum Design MPMS2); $M$ and $H$ represent magnetization and applied magnetic field, respectively. Two phases of low-$T_c$ and high-$T_c$ were separately observed in (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ samples at ambient pressure, as described later.

The (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ samples (low-$T_c$ and high-$T_c$ phases) were loaded directly on a Kapton sheet/epoxy resin/rhenium in the box-type DAC in an Ar-filled glove box; six Cu electrodes were attached to the Kapton sheet, and this cell was used for the measurement of $R$. The culet size of diamond was 300 $\mu$m and the diameter of sample was 100 $\mu$m. The photo of the DAC is shown in figure S1(b) of supplementary material. The applied pressure was monitored by ruby fluorescence. The $R$ of the sample was measured in a standard four-terminal measurement mode using an Oxford superconducting magnet system; the temperature was regulated using an Oxford Instruments MercuryTiC. Electric current ($I$) was supplied by a Keithley 220 programmable current source, and the voltage ($V$) was measured by an Agilent 34420 digital nanovoltmeter.

3. Results and discussion

First, we checked the superconductivity of a pure FeSe$_{0.5}$Te$_{0.5}$ sample from the $M$/$H$–$T$ plot (figure 1(a)), which showed a $T_c$ value as high as 16.2 K, consistent with that of $\beta$-FeSe$_{0.5}$Te$_{0.5}$. This result suggested that the $\beta$-FeSe$_{0.5}$Te$_{0.5}$ sample had successfully been prepared. In addition, the energy dispersive x-ray spectroscopy data also indicated the stoichiometry of FeSe$_{0.51(2)}$Te$_{0.49(2)}$, for the prepared FeSe$_{0.5}$Te$_{0.5}$ sample. We used this sample in the preparation of the (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ that was used throughout this study.

Figures 1(b) and (c) show $M$/$H$–$T$ plots for the (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ samples (low-$T_c$ and high-$T_c$ phases), in zero-field cooling (ZFC) and field cooling (FC) modes; the nominal $x$ values were 0.5 for the low-$T_c$ phase and 1.0 for the high-$T_c$ phase. The samples’ photos are shown in the insets of figures 1(b) and (c). The color of both of the (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ samples is black, which is the same as the (NH$_3$)$_3$M$_x$FeSe and (NH$_3$)$_3$M$_x$FeSe$_{0.5}$Te$_{0.5}$ samples reported previously [19, 20]. As seen from figure 1(b), the $T_c$ value is determined from the crossing point of the $R$ drops due to the low-$T_c$ phase (major phase) and high-$T_c$ phase (minor phase) of (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$, because of a coexistence of two phases in this sample. Actually, a clear inflection point of $M$/$H$–$T$ plot (ZFC mode) ascribable to the $T_c$ value of low-$T_c$ phase is found because the fraction of low-$T_c$ phase is much higher than that of high-$T_c$ phase. The $T_c$ value for the low-$T_c$ phase was 20.2 K, as seen from figure 1(b). On the other hand, the $T_c$ value for the high-$T_c$ phase of (NH$_3$)$_3$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ was determined to be 29.5 K from the crossing point of the drop of $M$/$H$ and $M$/$H$–$T$ plot in the normal state at ZFC mode (figure 1(c)). This sample contains a high percentage of high-$T_c$ phase, in addition to a trace of pure FeSe$_{0.5}$Te$_{0.5}$. The shielding fractions determined at 5 K were 60% and 12%, respectively, for the low-$T_c$ and high-$T_c$ phases. Thus, a clear superconducting transition was observed for each phase.
Figures 2(a) and (b) show the temperature dependence of normalized $R/R(50\text{ K})-T$ plots for the low-$T_c$ and high-$T_c$ phases of (NH$_3$)$_y$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ under pressure. A clear change of $T_c$ with changing pressure is observed for both phases. The $R-T$ plot was not recorded at ambient pressure but only under pressure, because of the difficulty in the formation of Ohmic contact between electrodes and polycrystalline sample without any
glue at ambient pressure; the glue could not be used for high reactivity of this sample. The good electric contact
was obtained without glue under pressure by pressurizing the sample and electrodes.

As seen from figures 2(a) and (b), the superconducting area first shrinks with increasing pressure, then
extends with a further increase in pressure. Finally, the superconducting area decreases with an increase in
pressure; the extended $R$–$T$ plots at 8.98, 11.3 and 13.5 GPa for low-$T_c$ phase (figure 2(a)) are shown in figure S2
of the supplementary material to clarify the superconducting transition.

The above behavior is the same for both phases, but the turning points for the evolution of the
superconducting area are quite different, i.e. they were $\sim 2.11$ GPa for the low-$T_c$ phase and
$\sim 10.2$ GPa for the high-$T_c$ phase. Here, the low-pressure area in which $T_c$ further decreases with increasing pressure refers to
superconducting phase I (SC-I), and the high-pressure area in which $T_c$ first increases with increasing pressure and then decreases with a further increase in pressure refers to superconducting phase II (SC-II). In figures 2(a)
and (b), the area shown as green is SC-I, and SC-II is shown as red.

Moreover, typical $R/R(280 \text{ K})$–$T$ plots of the normal states for low-$T_c$ and high-$T_c$ phases at low pressures
(0.49–7.33 GPa and 1.00–5.89 GPa) are shown in figures 2(c) and (d). Above $T_c$, the $R/R(280 \text{ K})$ value for the low-$T_c$ phase at 0.49 GPa increases with increasing temperature up to $\sim 200 \text{ K}$, and it saturates above 200 K, while the $R/R(280 \text{ K})$ value for the high-$T_c$ phase at 1.00 GPa increases with increasing temperature up to $\sim 200 \text{ K}$, where it decreases slightly. Such a convex $R$–$T$ plot is often observed for metal-doped FeSe [4, 8].

Namely, the $R/R(280 \text{ K})$–$T$ plots show metallic-like behavior with weak carrier localization. The $R/R(280 \text{ K})$–$T$ plot for the low-$T_c$ phase suggests insulating behavior at 2.11–7.33 GPa, while that for the high-$T_c$ phase exhibits clearer metallic behavior at 3.09–5.89 GPa. The former pressure range in the low-$T_c$ phase corresponds to SC-II, and the latter pressure range in the high-$T_c$ phase corresponds to SC-I. The results indicate that SC-I and SC-II are metal-like and insulator-like, respectively.

Figures 3(a) and (b) show $T_c$–$p$ phase diagrams of the low-$T_c$ and high-$T_c$ phases of $(\text{NH}_3)_y\text{Li}_x\text{FeSe}_{0.5}\text{Te}_{0.5}$ that were prepared based on the temperature dependence of $R$ shown in figure 2. The SC-I and SC-II are clearly obtained in both phases, i.e. two superconducting phases (SC-I and SC-II) are found for both the low-$T_c$ and
high-\( T_c \) phases of (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\) under pressure. In the low-\( T_c \) phase, the maximum \( T_c \) in SC-I was 20.2 K at 0 GPa, and that for SC-II was 19.9 K at 8.98 GPa. In the high-\( T_c \) phase, the maximum \( T_c \) value for SC-I was 33.0 K at 1.00 GPa, and that for SC-II was 24.0 K at 11.5−13.2 GPa. The results imply that the maximum \( T_c \) value in the high pressure phase (SC-II) cannot exceed the maximum value in SC-I, in contrast with the \( T_c - p \) phase diagrams of (NH\(_3\))\(_3\)Li\(_x\)FeSe \([10]\) and (NH\(_3\))\(_3\)Cs\(_x\)FeSe \([9]\). Nevertheless, a double-dome \( T_c - p \) phase diagram was clearly obtained for (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\), indicating that this is characteristic behavior of \( T_c \) with varying pressure in (NH\(_3\))\(_3\)M\(_x\)FeSe\(_{1-y}\)Te\(_y\)\( (z = 0 \) and \( z = 0) \).

Furthermore, it should be noted that the \( T_c - p \) phase diagram was reported for Rb\(_{0.8}\)Fe\(_{2-x}\)Se\(_2\)\( _{3-x}\)Te\(_x\)\( (z' = 0.19 \) and 0.28) by Gu \textit{et al} \([8]\), indicating that the maximum \( T_c \) values of SC-I and SC-II decrease with an increase in \( z' \) (i.e. the amount of Te); the sample was prepared by the annealing method, and NH\(_3\) was not included (i.e. \( y = 0)\). The maximum \( T_c \) of SC-II was lower than that of SC-I for Rb\(_{0.8}\)Fe\(_{2-x}\)Se\(_2\)\( _{3-x}\)Te\(_x\)\( (z' = 0.28)\), consistent with the results for the low-\( T_c \) and high-\( T_c \) phases of (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\). Thus, a double-dome \( T_c - p \) phase diagram (SC-I and SC-II) similar to those of Rb\(_{0.8}\)Fe\(_{2-x}\)Se\(_2\)\( _{3-x}\)Te\(_x\)\( (z' = 0.28)\) were generally found for (NH\(_3\))\(_3\)M\(_x\)FeSe\(_{1-y}\)Te\(_y\)\( (y = 0 \) or \( y = 0, x = 0, \) and \( z = 0 \) or \( z = 0)\), i.e. the double-dome \( T_c - p \) phase diagram is a universal feature for metal-doped FeSe\(_{1-y}\)Te\(_y\).

The pressure-dependent XRD patterns of (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\), which contain both phases (low-\( T_c \) and high-\( T_c \) phases), are shown in figure 4(a). The XRD patterns can be well fitted by the Le Bail method using three phases (low-\( T_c \) and high-\( T_c \) phases in (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\), and pure \( \beta\)-FeSe\(_{0.5}\)Te\(_{0.5}\), as seen from the XRD pattern at 1.13 GPa (figure 4(b)). The space group for low-\( T_c \) and high-\( T_c \) phases in (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\) was I4/mmm (No. 139, body-centered tetragonal lattice), and that of pure \( \beta\)-FeSe\(_{0.5}\)Te\(_{0.5}\) was P4/mmm (No. 129, tetragonal lattice). The lattice constants, \( a \) and \( c \), determined by Le Bail fitting for the XRD pattern at 1.13 GPa are listed in table 1, together with the pattern \( R \) factor (\( R_p \)) and weighted pattern \( R \) factor (\( wR_p \)) showing the quality of fit between experimental and calculated XRD patterns. All XRD patterns were thoroughly analyzed by Le Bail fitting considering the above three phases. The \( R_p \) value was below 1.57% and the \( wR_p \) was below 1.01% in the Le Bail fittings for the XRD patterns at 1.13−15.3 GPa, indicating a good fit. Moreover, the indices for pressure-dependent XRD peaks due to the high-\( T_c \) and low-\( T_c \) phases, as well as pure FeSe\(_{0.5}\)Te\(_{0.5}\) are shown in figure S3 of supplementary material. All peaks remained in a whole pressure range, and no new peaks appeared. These results indicate no structural phase transitions in a whole pressure range.

As seen from table 1, the \( c \) value \( (= 13.139(3) \) Å) of low-\( T_c \) phase in (NH\(_3\))\(_3\)Li\(_x\)FeSe\(_{0.5}\)Te\(_{0.5}\) is much smaller than that, 18.28(2) Å, of high-\( T_c \) phase, indicating that crystal structure is different between two phases, i.e. probably on-center structure that Li atom is located at \((0,0,0)\) for low-\( T_c \) phase, while off-center structure that N atom of NH\(_3\) is located at \((0,0,0)\) for high-\( T_c \) phase, in the same manner as (NH\(_3\))\(_3\)Cs\(_x\)FeSe \([21]\).

The values of \( c \) versus pressure for low-\( T_c \) and high-\( T_c \) phases are shown in figure 4(c), exhibiting the smooth shrinkage of \( c \) values, i.e. only peak positions shifted against pressure. This also implies no structural phase transitions for either phase at 0−15 GPa, i.e. the emergence of SC-II does not accompany any structural phase transitions. This result is the same as that reported previously for (NH\(_3\))\(_3\)Cs\(_x\)FeSe \([9]\) and (NH\(_3\))\(_3\)Li\(_x\)FeSe \([10]\). Thus, the emergence of SC-II is probably due to a change in the electronic state such as enhancement of the density of states (DOS). In the case of (NH\(_3\))\(_3\)Li\(_x\)FeSe, the pressure-dependent Hall effect measurement clearly showed the enhancement of electron density in SC-II \([10]\), and a Lifshitz transition was suggested as the cause of the Fermi surface topology change. This is the most promising scenario for the origin of double-dome \( T_c - p \)
phase diagram. Actually, such a pressure-driven electronic transition is proposed for Bi$_2$Sr$_2$CuO$_{6+δ}$ [12], as well as (NH$_3$)$_2$Li$_2$FeSe [10].

The $T_c$–c plots for low-$T_c$ and high-$T_c$ phases are shown in figures 5(a) and (b). The double-dome $T_c$–c plot for the low-$T_c$ phase is depicted at 12.5–13.5 Å, while that for the high-$T_c$ phase covers 16.5–19.0 Å; the SC-I and SC-II phases are separated at $\sim$13 Å for the low-$T_c$ phase and at 16.8 Å for the high-$T_c$ phase, implying the presence of two critical points for (NH$_3$)$_2$Li$_2$FeSe$_{0.5}$Te$_{0.5}$. Namely, the single critical point found for (NH$_3$)$_2$M$_x$FeSe $(\sim$14 Å) has not been obtained for (NH$_3$)$_2$Li$_2$FeSe$_{0.5}$Te$_{0.5}$. Thus, the $T_c$–c phase diagrams of low-$T_c$ and high-$T_c$ phases must be independently treated.

Figure 5(c) shows the $T_c$–c plot for (NH$_3$)$_2$M$_x$FeSe$_{0.5}$Te$_{0.5}$ that includes (NH$_3$)$_2$M$_x$FeSe$_{0.5}$Te$_{0.5}$(Na and Ca) [17, 20] and (EDA)M$_x$FeSe$_{0.5}$Te$_{0.5}$(EDA: ethylene diamine) [18] at 0 GPa. The plot clearly shows the presence of completely separated $T_c$–c plots. Specifically, the $T_c$–c plot above 16.5 Å prepared from the high-$T_c$ phase of (NH$_3$)$_2$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ and another metal-doped FeSe$_{0.5}$Te$_{0.5}$ [17, 18, 20] is similar to that of metal-doped FeSe [14], i.e. the sudden variation of the $T_c$–c plot at a c of 16.8 Å, and the suppression of $T_c$ by the further elongation of c above 18.2 Å are found. Moreover, the $T_c$–c plot for the low-$T_c$ phase of (NH$_3$)$_2$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ shows the sudden variation at $c = 13$ Å. Thus, a single critical point separating the SC-I and SC-II phases was not confirmed for (NH$_3$)$_2$M$_x$FeSe$_{0.5}$Te$_{0.5}$, unlike the $T_c$–c plot in metal-doped FeSe [14]. Actually, the c range of 13.5–16.5 Å is an undecided area, in that the correlation of $T_c$ and c is still unclear. Therefore, the behavior of $T_c$

![Figure 4](image-url)  

**Figure 4.** (a) Pressure-dependent XRD patterns of (NH$_3$)$_2$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ sample at 1.13–15.3 GPa. (b) Experimental XRD pattern (black cross) of (NH$_3$)$_2$Li$_x$FeSe$_{0.5}$Te$_{0.5}$ sample at 1.13 GPa, together with the calculated pattern (red solid line) by Le Bail fitting. The red, blue and black ticks refer to positions of low-$T_c$, high-$T_c$ and pure $\beta$-FeSe$_{0.5}$Te$_{0.5}$, respectively. The blue solid line corresponds to the difference between the experimental XRD pattern and the calculated one. (c) $c$–p plots for low-$T_c$ and high-$T_c$ phases of (NH$_3$)$_2$Li$_x$FeSe$_{0.5}$Te$_{0.5}$. The fittings are shown by dashed lines.

| No. | Phase          | Space group | $\alpha$ (Å) | $c$ (Å) | $V$(Å$^3$) |
|-----|----------------|-------------|-------------|--------|------------|
| I   | high-$T_c$      | I4/mmm      | 3.718(2)    | 18.28(2)| 252.8(2)   |
| II  | low-$T_c$       | I4/mmm      | 3.936(2)    | 13.139(3) | 203.61(3) |
| III | $\beta$-FeSe$_{0.5}$Te$_{0.5}$ | P4/nmm      | 3.821(4)    | 5.3530(5) | 78.169(8) |
against \(c\) at 13.5–16.5 Å must be pursued in \((\text{NH}_3)_y \text{M}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\), which may lead to the hidden relationship between \(T_c\) and \(c\) (or the plain spacing of \(\text{FeSe}_{0.5} \text{Te}_{0.5}\)).

4. Conclusion and outlook

Throughout this study, the presence of a pressure-driven superconducting phase (SC-II) was unambiguously confirmed for both the low-\(T_c\) and high-\(T_c\) phases in \((\text{NH}_3)_y \text{Li}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\). Specifically, the double-dome \(T_c–p\) phase diagrams were confirmed for both phases. The maximum \(T_c\) in SC-II did not exceed the highest \(T_c\) value recorded in SC-I in both phases, which is different from the behavior of \(T_c\) in \((\text{NH}_3)_y \text{Na}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\) [10, 11]. The pressure-dependent XRD patterns showed no sign of structural phase transitions under pressure for either phase, and the \(T_c–c\) plots recorded for \((\text{NH}_3)_y \text{M}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\) provided two completely separated double-dome phase diagrams. Thus, a single critical point was not found for \((\text{NH}_3)_y \text{M}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\), but we could look systematically at the \(T_c–c\) plot for \((\text{NH}_3)_y \text{M}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\) to clarify an important point which must be further pursued, i.e. investigating the behavior of \(T_c\) against \(c\) in the \(c\) range of 13.5–16.5 Å would be the most significant future task because it is very interesting and fascinating to elucidate how the low-\(T_c\) and high-\(T_c\) phases are connected, i.e. to pursue the hidden critical point in \((\text{NH}_3)_y \text{M}_x \text{FeSe}_{0.5} \text{Te}_{0.5}\).

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