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1 **Dynamic Shock Wave Induced Amorphous to Crystalline Switchable Phase Transition of**
2 **Lithium Sulfate**

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15 **Abstract**

16 In recent years, there have been significant efforts put forth by the materials science
17 researchers to search for new phase – change materials especially possessing the caliber of
18 influencing switchable phase changes i.e., from crystal – crystal and crystal – amorphous. Phase–
19 change materials of such kind have attracted a tremendous demand for the technologically
20 important applications such as current resistive memories and thermal energy storage. In the
21 present article, the switchable phase transitions of amorphous – glassy - crystalline – amorphous
22 occurring in the samples of lithium sulfate have been systematically experimented and
23 demonstrated at dynamic shock wave loaded conditions of various counts of shock pulses. The
24 shocked samples have been evaluated by the powder X-ray diffraction (PXRD), Ultraviolet
25 Visible spectroscopy (UV-Vis) and Raman spectroscopy. Shock wave induced orientational
26 order-disorder of the SO₄ tetrahedron and the positional disorders of the lithium atoms have led
27 to the observed switchable phase transitions with respect to the number of shock pulses.

28 **Keywords:** Li₂SO₄, shock waves, switchable phase transition, orientational order-disorder,
29 positional disorder

30 **Introduction**

31 Switchable crystallographic phase transitions always have the special position of creative
32 interest in solid state materials due to their controllable structural formation and functional
33 diversity as compared to the forward and backward irreversible solid state phase transitions. This
34 phenomenon can be applied in various applications as found in pressure transmitters, molecular
35 switches, resistive memories, etc. Moreover, studies on the reversible phase transition of crystals
36 would further push forward the current level of understanding of the molecules and their
37 structures with respect to temperature and pressure.¹⁻⁴ It is well known that pressure serves as a
38 thermodynamic variable which induces various solid state phase transition routes such as crystal-
39 crystal, crystal-amorphous and amorphous-crystal that are very much possible to be obtained in
40 the laboratory conditions.^{5,6} On the one hand, the majority of static high pressure experiments
41 that have been carried out on materials have the potential to authenticate the occurrence of
42 reversible crystallographic phase transition when pressure is released.⁷⁻¹⁰ In recent years, studies
43 on the impact of shock waves imposed on solids have gained remarkable attention attracting a lot
44 of materials scientists due to the variety of changes observed in properties of materials such as
45 phase transitions and deformations.¹¹⁻¹⁴ On the other hand, reversible crystallographic phase
46 transition occurring at dynamic shock wave loaded conditions is quite an unexpected behavior as
47 compared to the results of static high pressure compression experiments so that in-depth research
48 is further required in order to get a systematic understanding of the shock wave induced
49 reversible crystallographic phase transitions. Moreover, even though several thousands of shock
50 wave induced irreversible phase transitions have been observed and reported over the past 100
51 years of shock wave research in materials science¹¹⁻¹⁴, it could be noted that there are not many
52 reports available for the dynamic shock wave induced crystallographically reversible phase
53 transitions in solid state. Reversible magnetic phase transitions and crystallographic phase
54 transition behaviors at dynamic shock wave loaded conditions have been observed in a few
55 recent publications.

56 It has been demonstrated that cobalt oxide (Co₃O₄) nano- crystalline particles undergo
57 reversible magnetic phase transition from super-paramagnetic to paramagnetic nature¹⁵ and Zinc

58 ferrite (ZnFe_2O_4) nano-crystalline particles undergo paramagnetic to super-paramagnetic
59 behavior with respect to the number of shock pulses.¹⁶ Furthermore, potassium sulfate (K_2SO_4)
60 crystal exhibits the reversible crystallographic phase transition (from orthorhombic to hexagonal)
61 with respect to the number of shock pulses.¹⁷ On this note, lithium sulfate has been scrutinized
62 for the present investigation, considering the possible switching behavior between the
63 crystallographic phases by the impact of shock waves since both the crystals belong to the family
64 of divalent metal sulfate crystals (A_2BO_4). In general, sulfate materials are used as a classical
65 example of materials so as to be investigated for the phase transition behaviour subjecting to
66 experiments involving high-pressure and temperature.¹⁸⁻²⁰ Most of the sulfate materials obey the
67 first order phase transition caused by orientation order-disorder effect occurring at high-pressure
68 and high temperature regions.¹⁸⁻²⁰ Hence, the present investigation on shock wave induced phase
69 changes of Li_2SO_4 has a strong research objective in academic level as well as industrial point of
70 view. The title sample has five crystallographic structures such as α , β , γ , δ and ε wherein β -
71 Li_2SO_4 belongs to the room temperature phase which is phase transformed to α - Li_2SO_4 at 845 K
72 and it is used as a solid electrolyte because of its outstanding electrical conductivity i.e.
73 particularly α - Li_2SO_4 and the remaining phases are represented as high-pressure phases.²¹⁻²⁵ Even
74 though several publications are available for Li_2SO_4 crystal on phase transitions occurring at
75 high-pressure and high temperature conditions, to date, no one has reported the reversible
76 amorphous –glassy - crystalline – amorphous phase transitions of Li_2SO_4 sample.

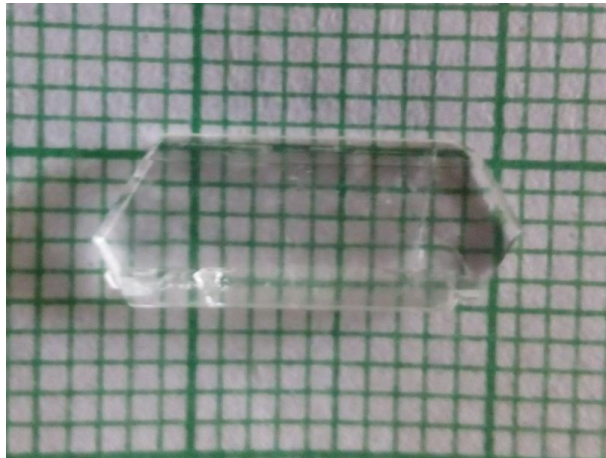
77 The present research article is aimed at demonstrating the reversible crystallographic
78 phase transition with respect to the number of shock pulses as it has been already witnessed for
79 potassium sulfate crystal.¹⁷ Since shock wave induced reversible phase transition is very fast and
80 cost effective, such kind of experiments may bring about a systematic methodology with which it
81 would be possible to induce the reversible phase transition in potential materials such that a lot of
82 insights could be derived. On those lines, many of the requirements which are based on phase –
83 change materials can be fulfilled for the scientific world as well as industrial applications.

84

85

86 **Experimental methodology**

87 In this study, Lithium sulfate (Li_2SO_4) samples were obtained by employing the
88 conventional slow evaporation method. Commercially available Li_2SO_4 (98.5%) was bought
89 from Sigma Aldrich and was used without further purification for the growth process. The
90 saturated solution of Li_2SO_4 was prepared by dissolving it in double distilled water. The solution
91 was stirred continuously for 5 hours with the help of a magnetic stirrer in order to completely
92 dissolve Li_2SO_4 which was filtered into a beaker. The solution was kept undisturbed for the
93 crystallization. After 34 days, an optically transparent specimen with the dimension of $14 \times 6 \times 1$
94 mm^3 was obtained as shown in Fig.1.



95

96

Fig.1 As grown Li_2SO_4 specimen by the slow evaporation method

97

98 In total, four identical samples (1mm thickness) have been cut and polished maintaining a
99 high quality. Before beginning the shock wave loading experiment, it has been confirmed that all
100 the four samples belong to the amorphous state. Among the four samples, one sample has been
101 kept as the control while the other three samples have been utilized for the respective 1st, 2nd, and
102 3rd shocked conditions which means that for the first sample, one shock pulse has been applied
103 while for the second sample, two shock pulses have been applied and for the 3rd sample, three
104 shock pulses have been exposed. In the present investigation, a shock wave of Mach number 2.2
105 is utilized that has the transient pressure of 2.0 MPa and temperature 864 K. The shock waves
106 have been generated by an in-house tabletop pressure driven shock tube (Reddy tube). The
shock tube has three sections such as driver, driven and diaphragm sections which are made of

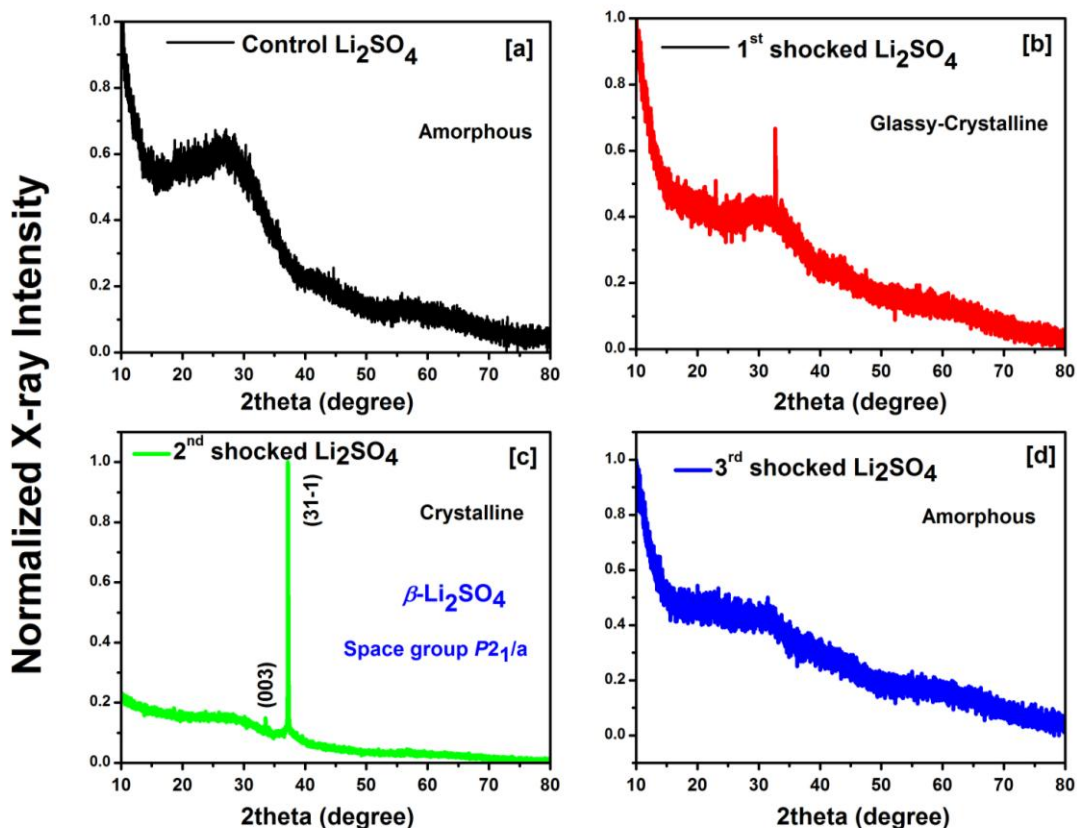
107 seamless steel. The driver and driven sections consist of long tubes of 48 cm and 180 cm,
108 respectively and both have 1.5 cm of inner diameter with the wall thickness of 3mm and the
109 atmospheric air is used as the input source for the required shock wave generation. The working
110 methodology of the shock tube and the loading process have been detailed in our previous
111 publications.^{14,15}

112 The shock wave loaded samples have been further investigated using a powder
113 XRD (Rigaku - SmartLab X-Ray Diffractometer, Japan in which Cu K α has been used as the X-
114 ray source, $\lambda=1.5407$ Å) and UV-Vis spectroscopy (with a varian Cary 5E UV – Visible
115 spectrometer between 200 and 800 nm). Raman spectrometry (LabRAM HR Evolution, France)
116 has been employed to understand the phase details of the test materials over the wavenumber
117 region of 100^{-1} to 1300 cm^{-1} with the laser source of wavelength 532 nm.

118 **Results and Discussion**

119 **Structural properties of Li₂SO₄ samples**

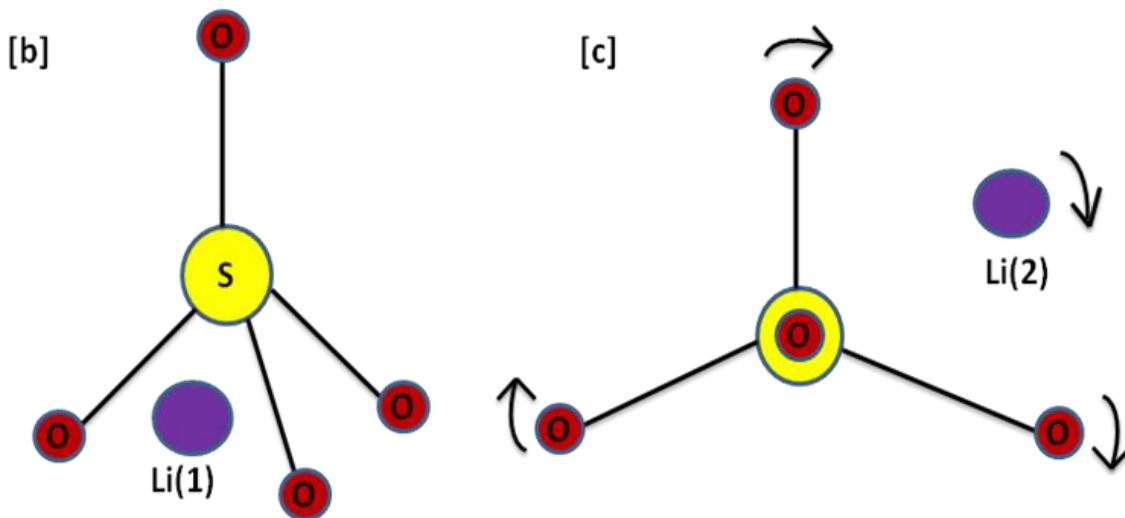
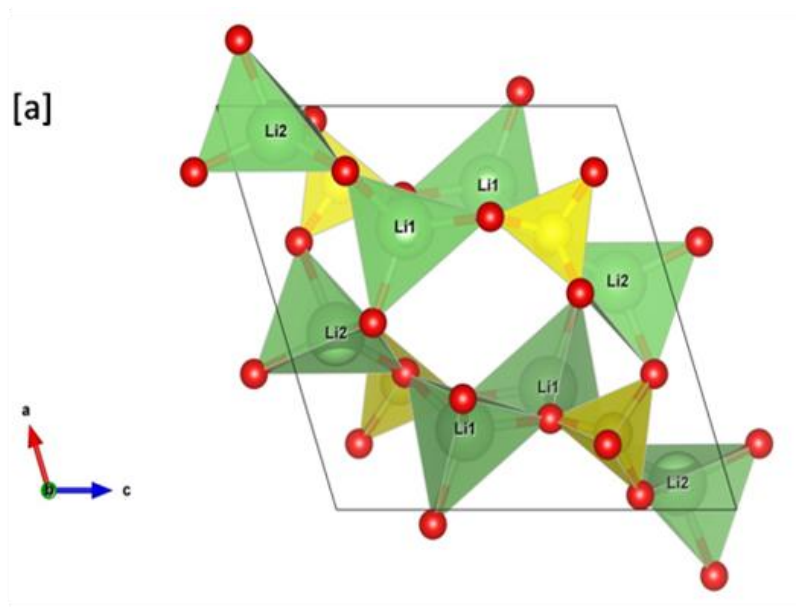
120 The diffraction patterns of the control and the shock exposed Li₂SO₄ samples are
121 presented in Fig.2 (a-d). The control sample looks well-shaped and transparent; however, the X-
122 ray diffraction study reveals that the sample is in amorphous nature (Fig.2a). In general,
123 particularly for Li₂SO₄, it is a critical task for the crystal growers to grow a good quality single
124 crystal with the monoclinic phase due to the discontinuous changes occurring for Li atoms in the
125 tetrahedral site which may induce a large number of improper locations for Li atoms in the
126 crystal lattice.²⁴⁻²⁸



127

128 Fig.2 Powder XRD profiles of the control and shocked Li_2SO_4 (a) the control, (b) 1st shocked
 129 (c) 2nd shocked (c) 3rd shocked samples

130 Moreover, the test sample has two lithium atoms such as Li (1) and Li (2) bonded with
 131 oxygen atoms. Among these two atoms, Li (1) atom is static while Li (2) is mobile and SO_4
 132 tetrahedral is coordinated with Li atoms. Due to its mobile nature, Li (2) and SO_4 orientation may
 133 generate positional disorder along with orientational disorder and the corresponding schematic
 134 diagram is presented in Fig.3. As per the crystallographic structures of the test sample, Li^+ ions
 135 have three different lattice sites such as $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$ and $\frac{3}{4}$, $\frac{3}{4}$, $\frac{3}{4}$. Among the listed lattice
 136 sites, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$ provides too small space whereas $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$ and $\frac{3}{4}$, $\frac{3}{4}$, $\frac{3}{4}$ provide too large
 137 space.^{26,27} However, Li^+ (1) ions are occupied in the tetrahedral site quiet easily compared to Li^+
 138 (2) site due to the different lattice site sizes. On the other hand, the test sample has two lithium
 139 atoms in the structure which are non-equivalent to the symmetric operation. Moreover, among
 140 the two lithium atoms, one (Li-1) is static and the second (Li-2) is mobile.^{27,28}



141

142

Fig.3 (a) Crystal packing of β - Li_2SO_4 (b) $\text{Li}(1)$ - SO_4 (c) $\text{Li}(2)$ - SO_4

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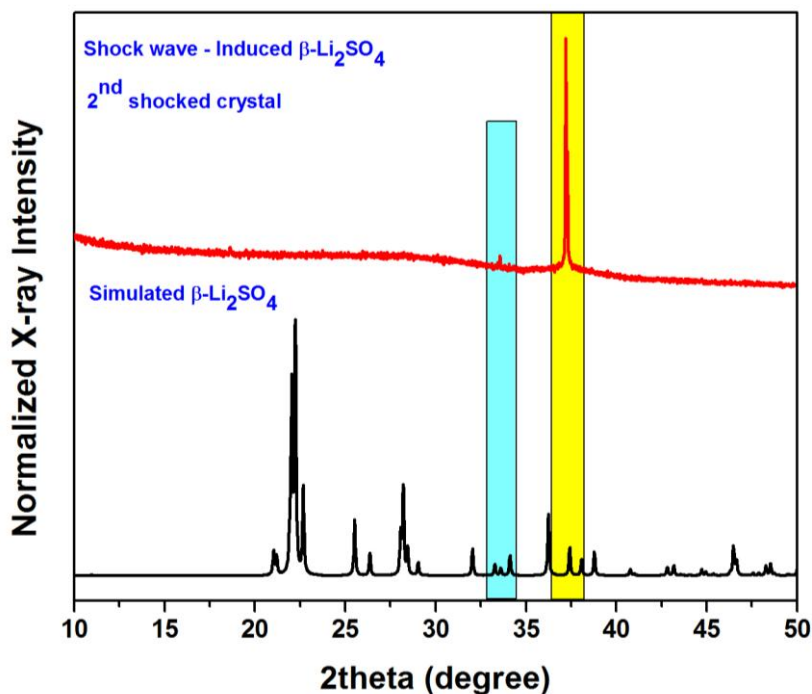
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Due to the mobile nature of $\text{Li}(2)$ atom, the interaction between the $\text{Li}(2)$ and oxygen atom is significantly reduced so that the lattice disorder enhances. Hence, it leads to the amorphization during the crystal growth.^{25, 26} At the first shocked condition, the corresponding XRD profile (Fig. 2b) shows a low intensity peak at 32.5° which does not match with either α or β or else with any other high-pressure phases so that it is considered as a glassy material.²⁹ Moreover, such kind of a crystal with this phase may be called as plastic crystal. The XRD profile of the test sample obtained upon the exposure of 2nd shock wave is presented in Fig. 2c.

150 Tiny and intense crystalline peaks are observed at 33.4° and 37.2°. The observed crystalline peak
151 positions match well with the simulated peak position of β -Li₂SO₄ as shown in Fig.4.



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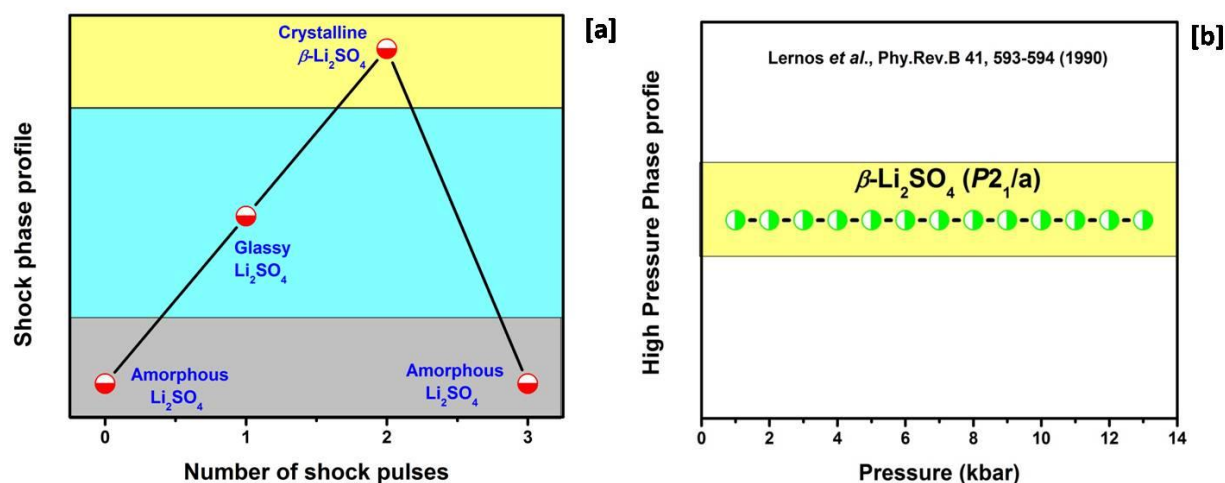
153 Fig.4 Powder-XRD patterns of simulated and shock induced β -Li₂SO₄

154 The applied 2nd shock wave has induced a phase transition from amorphous to crystalline
155 for the test sample via glassy phase at 1st shocked condition. From the literature, it is noted that
156 β to α - Li₂SO₄ phase transition is due to the enhancement of the orientational disorder of SO₄
157 tetrahedron.²¹⁻²⁶ On the other hand, the results of several high-pressure and high temperature
158 experiments have revealed that SO₄ tetrahedron plays a major role in the phase transitions of
159 crystalline to amorphous and vice versa.³⁰ In the case of the cationic LiO₄, the tetrahedra has 14
160 times higher compressibility than that of the anionic SO₄ tetrahedra.^{18,21} At shocked conditions,
161 deformation of the LiO₄ tetrahedra might have taken place, whereas the SO₄ groups are expected
162 to undergo tilting which plays a key role in the order-disorder process.^{18,21} At shocked
163 conditions, the tilting angle of the SO₄ tetrahedron changes with respect to the number of shock
164 waves such that the Li⁺ ions' atomic sites, especially Li(2) is changed due to the existence of
165 positional disorder caused by the impact of shock waves. As per the reported phase transition

166 studies, it could be suggested that during the shock wave loaded condition, orientational order of
167 the SO_4 tetrahedron with static and mobile lithium atoms might have appeared during the second
168 shock wave loaded condition.^{25, 31,32} The bond angles between lithium and oxygen atoms of O-
169 Li(1)-O is $106.5\text{-}115.2^\circ$ and O-Li(2)-O is $88.6\text{-}124.5^\circ$. Due to the presence of wider angle, Li(2)
170 has undergone maximum deformation level. Moreover, the bond energies of Li-O and S-O are
171 $333.5 (\pm 8.4)$ and 110 kJmol^{-1} , respectively which makes the SO_4 tetrahedra less stable compared
172 to the LiO_4 tetrahedron. In addition to that, the applied shock waves may supply the sufficient
173 latent heat to crystallize the glassy phase of Li_2SO_4 which can be called as shock wave induced
174 dynamic re-crystallization.¹⁷ As seen in Fig.4, β - phase of the test sample's standard powder
175 XRD pattern has several diffraction peaks appearing between 20 and 50 degree. But, the
176 observed shocked crystal's XRD profile shows the strong diffraction peak (31-1) and a tiny
177 diffraction peak (300) which confirms that the phase transition has occurred at the 2nd shocked
178 condition.

179 Furthermore, the 3rd shock wave loading process has been enabled for the test sample in
180 such a way that XRD measurement could make a clear phase diagram of Li_2SO_4 specimen with
181 respect to the number of shock pulse. It has been strongly expected that the XRD pattern would
182 provide the high-pressure phase of the test sample ($\alpha\text{-Li}_2\text{SO}_4$) as exhibited by potassium
183 sulfate.¹⁷ On the other hand, it has been a surprise to observe the amorphous nature of Li_2SO_4
184 specimen at the 3rd shock wave loaded condition as reflected by the disappearance of diffraction
185 peaks in the XRD pattern. The corresponding XRD profile is presented in Fig.2d. In this context,
186 the orientational – disorder of the SO_4 tetrahedron plays a significant part to initiate and enable
187 the crystalline - amorphous phase transition. Since the SO_4 tetrahedron is absolutely free for the
188 rotation, it could enforce the orientational – disorder behavior at shock wave loaded conditions.¹⁷
189 At the 3rd shock wave loaded condition, the thermodynamic barrier of the system and the critical
190 phase transition region could have experienced break-down because of the higher transient
191 pressure and temperature so that the test sample might have undergone the process of complete
192 atomic disorder. The lattice symmetry of Li_2SO_4 is completely broken at the 3rd shock wave
193 paving the way for the crystalline – amorphous phase transition. On the other hand, Li(2) sites
194 might have experienced the positional disorder occurring at this stage that could have stimulated
195 the shock wave induced amorphization of Li_2SO_4 . It is worthwhile to note that the control and

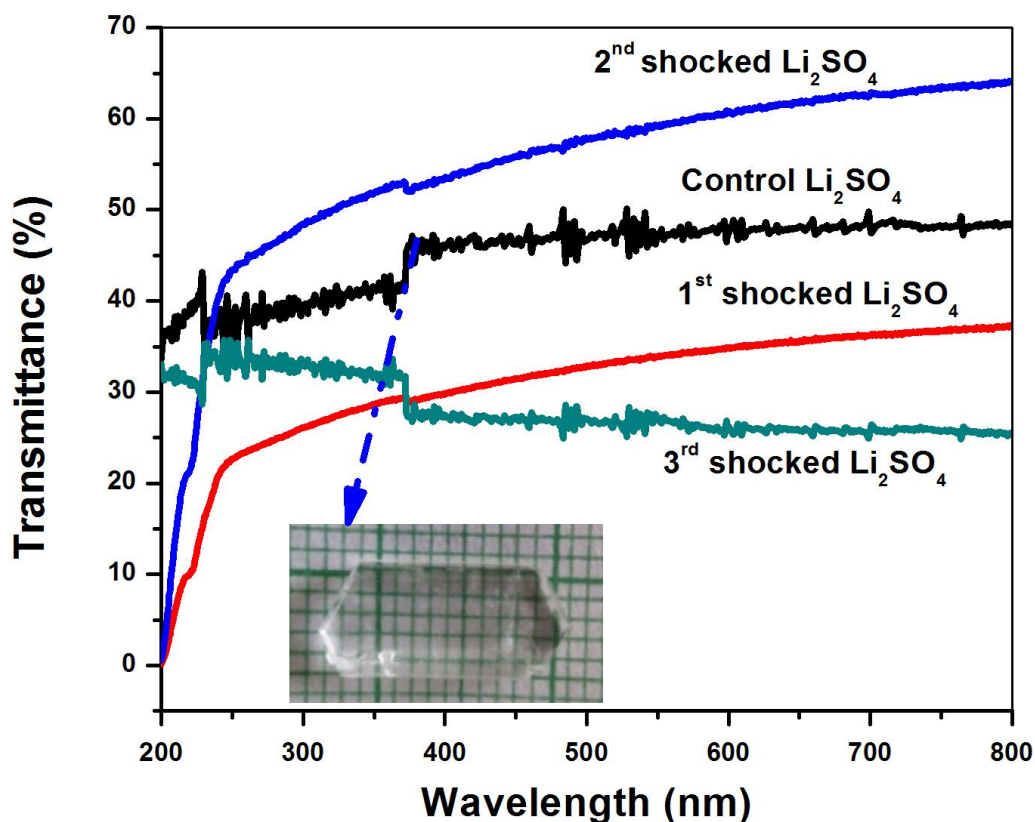
196 the 3rd shocked test samples have the amorphous nature which confirms that the test sample has
 197 undergone the reversible amorphization phase transition via glassy phase and crystalline phase
 198 by the influence of the shock waves. The shocked phase-profile of the test sample with respect to
 199 the number of shocks is presented in Fig.5a and the static pressure compression phase profile of
 200 the material is displayed in Fig.5b [20].



201
 202 Fig.5 (a) Schematic shocked phase-profile of the control and shocked Li_2SO_4 samples (b)
 203 Static pressure compression phase profile of $\beta\text{-Li}_2\text{SO}_4$ [20]

204 UV-Visible spectroscopic studies

205 For optically transparent materials, UV – Vis spectroscopic analysis is one of the prime
 206 studies to understand the electronic structure and optical properties. In Fig 6, the observed optical
 207 transmittance spectra of the control and the shocked test samples are reported. The absence of
 208 characteristic absorption peak in Fig. 6 for the control sample is one of the evidences of its
 209 amorphous nature.^{33,34} At the 1st shocked condition, the test sample shows the absorption band
 210 edge at 243 nm and it exhibits 37% optical transmittance at 800 nm. At shocked condition, the
 211 appearance of absorption band edge for the 1st shocked sample is due to the phase transition from
 212 amorphous – glassy phase.



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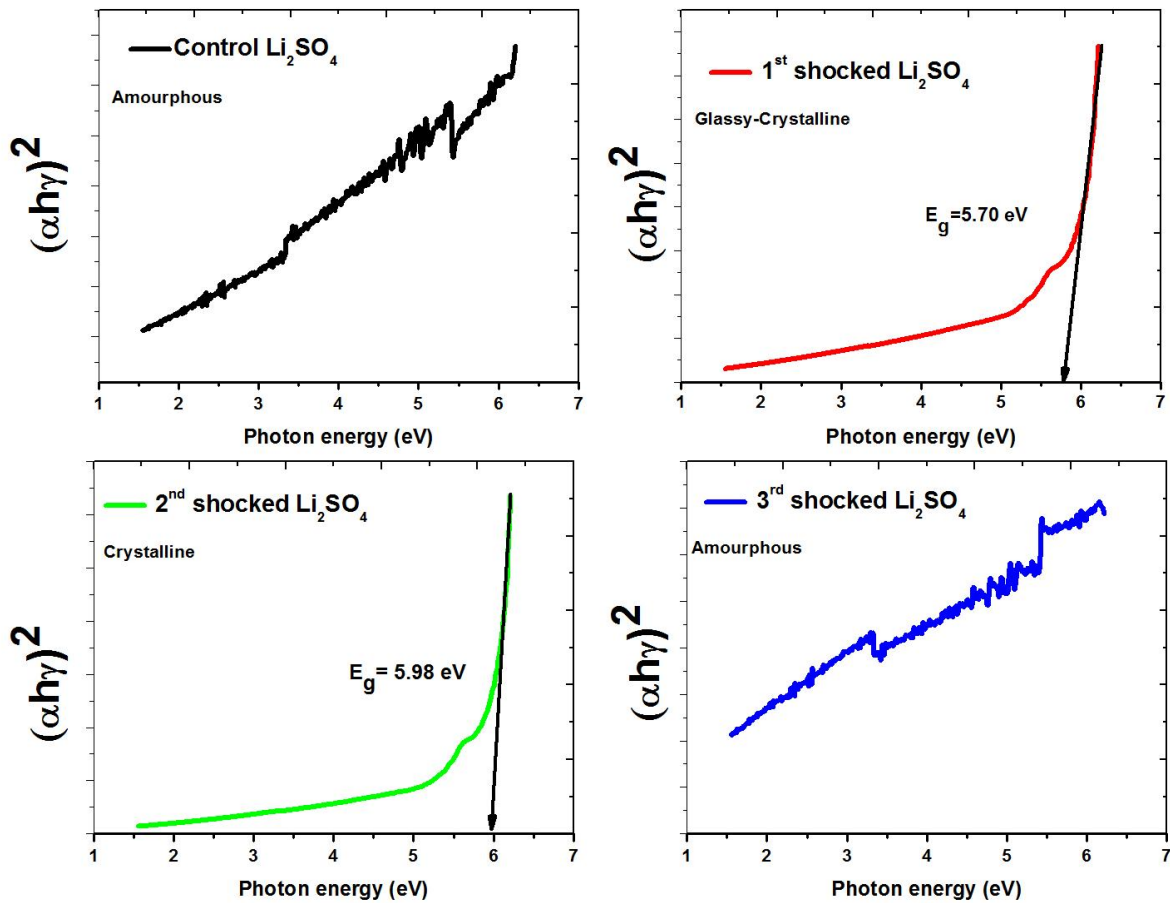
214 Fig.6 Optical transmittance spectra of the control and shock exposed Li_2SO_4

215 At the second shocked condition, the test sample's absorption band edge of the test
 216 sample has got shifted towards the lower wavelength and the optical transmittance has
 217 significantly increased from 37 % to 64 % at 800 nm. These two factors give rise to the
 218 considerable authentication for the phase transition occurring due to the shock wave induced
 219 orientational disorder-order process which might have led to the changes in optical transmittance
 220 for the test sample. It has been observed similar changes in the α -phase of potassium sulfate
 221 crystal which undergoes red shift resulting to lower optical transmittance than that of β -phase at
 222 shock wave loaded condition.¹⁷ Making a comparison, it can be represented that the glassy phase
 223 has a partial disorder phase as against the β -phase of Li_2SO_4 . Hence, it has lower optical
 224 transmittance than that of β -phase of Li_2SO_4 . Furthermore, after the 3rd shock, the crystal
 225 showcases the optical transmittance spectrum similar to the control sample with slight changes in

226 terms of optical transmittance percentage and shape of the pattern. Hence, it confirms
227 categorically that the test sample has undergone the amorphous nature because of the
228 disappearance of orientational order of β -phase of Li_2SO_4 by the impulsion of shock waves. It
229 could be noted that the results of structural and optical transmittance are found to be well
230 matched with respect to the number of shock pulse which clearly indicates the reproducibility of
231 the unprecedented results at shocked conditions.

232 In Fig. 7, the optical band gap energies of the control and shock exposed samples are
233 presented as calculated by classical Tauc plot.³⁵ As it is known from the XRD and optical
234 transmittance measurements, the control Li_2SO_4 has the amorphous nature so that it is not
235 possible to calculate the band gap energy for the control sample. Moreover, the values of
236 absorption coefficient are not satisfied for Tauc plot so that it is not possible to find the band gap
237 energy. Hence, it is confirmed that the control sample has high electrical resistant behavior.
238 Moreover, the absence of lithium ions (Li_2) in the tetrahedral position is the major reason behind
239 the high electrical resistance. The initial phase of the amorphous nature is represented as the
240 RESET phase since it has a very high resistivity.

241 At the 1st and 2nd shocked conditions, the direct band gap energies are observed to be 5.70
242 and 5.98 eV, respectively. From the obtained values, it is clear that the crystalline samples have
243 higher values of band gap energy than that of the glassy phase. Hence, the crystalline sample has
244 lower electrical conductivity than the glassy phase. So far, numerous researchers have reported
245 the electrical conductivity of the test sample based on their phases and found that α - Li_2SO_4 has
246 higher electrical conductivity than that of the β - Li_2SO_4 due to the rotor type phase based on the
247 peddle wheel and percolation mechanism.^{27,28,36,37} From the available literature reports, there
248 could be two prominent reasons behind the changes in electrical conductivity observed for the
249 order and the disordered phases. Firstly, β - Li_2SO_4 is the ordered phase such that the rotational
250 freedom of the SO_4 tetrahedron is quite lower than that of the disordered phase. Hence, the
251 mobility of the lithium ions is low so that it has low electrical conductivity. Secondly in the case
252 of β - Li_2SO_4 phase, interaction of the lithium and oxygen atoms is quite low because of the higher
253 bond length. Hence, the crystalline phase has lower electrical conductivity than that of the glassy
254 phase.



255

256

Fig.7 Band-gap energy of the control and shocked Li_2SO_4

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The crystalline phase can be represented as the SET phase due to the conduction behavior. At the 3rd shock, the disappearance of the crystalline phase and the appearance of the amorphous nature occur and as per Tauc plot, it exhibits the similar results when compared to the control test sample. Hence, again it comes to the RESET phase. Such kind of SET and RESET reversible phase changing materials are highly used in sensors.^{38,39}

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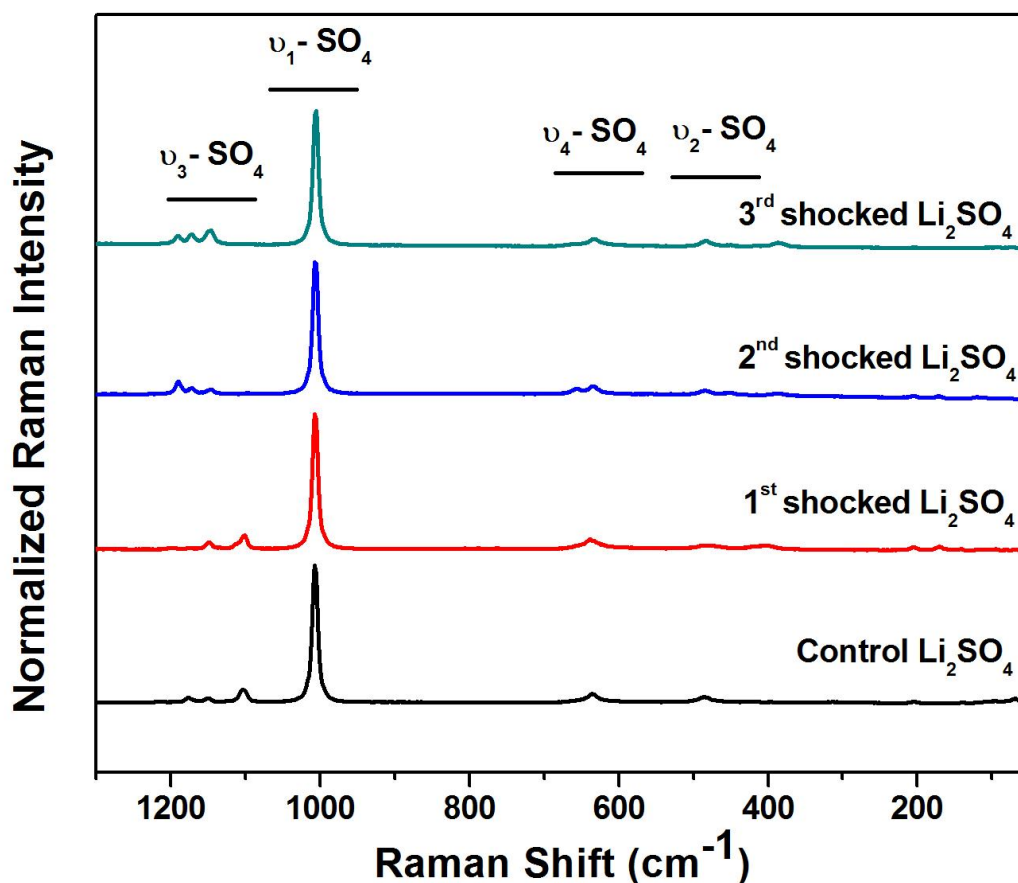
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266 **Raman Spectral Analysis**

267 As seen in Fig.8, the normal Raman bands of Li_2SO_4 are observed at 484, 634, 1007 and
268 1103 cm^{-1} in the control sample for the respective ν_2 , ν_4 , ν_1 and ν_3 SO_4 vibration bands. As per
269 the previous reports of $\beta\text{-Li}_2\text{SO}_4$,⁴⁰⁻⁴³ the SO_4 of ν_2 , and ν_4 double degenerate Raman bands and
270 one lithium Raman lattice mode should have evolved at 385 or 362 cm^{-1} .^{40,41}

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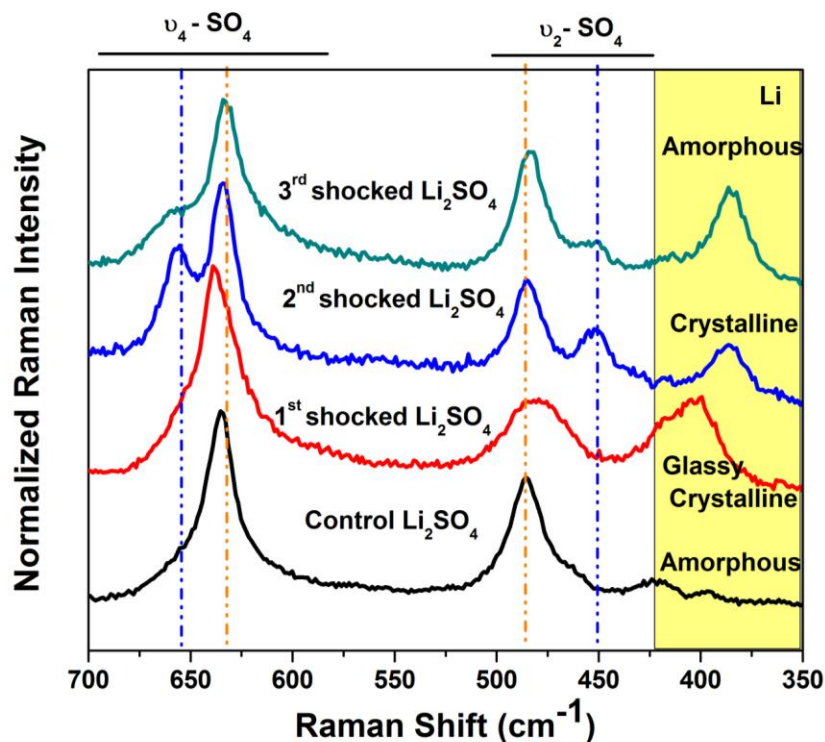


272

273 Fig.8 Raman spectra of the control and shocked Li_2SO_4

274 But, such kinds of characteristics Raman bands of $\beta\text{-Li}_2\text{SO}_4$ are completely not visible. It
275 may be due to the formation of positional disorder of lithium atoms and rotational disorder of
276 SO_4 tetrahedral. Hence, due to such kind of defects and disorders, the control sample might have
277 the amorphous nature which is very well corroborated with the results of XRD and UV-Visible

278 studies. At shocked conditions, the normal SO_4 Raman bands are not significantly altered. But,
 279 in the case of characteristic Raman band positions, considerable changes have been observed.
 280 The Raman band of ν_3 region has also undergone significant changes whereas the Raman bands
 281 of ν_2 , and ν_4 are highly coupled with lithium atoms. Hence, it is worthwhile to investigate more
 282 on these two Raman bands so that, for better visibility of such changes, the zoomed-in versions
 283 of the prominent region of Raman bands (ν_2 , and ν_4) of the control and shocked samples are
 284 provided in Fig.9.



285
 286 Fig.9 Zoomed-in versions of Raman spectra of the control and shocked Li_2SO_4 ($350\text{-}700\text{ cm}^{-1}$)
 287 As seen in Fig.9, at the 1st shocked condition, the normal ν_4 and ν_2 bands are reproduced
 288 with a very little Raman shift whereas a new Raman band appears at 399 cm^{-1} . As per the
 289 previous reports, this particular Raman band belongs to lattice mode of lithium ion for the
 290 ambient crystalline phase which indicates the reduction of net degree of positional disorder of
 291 lithium atoms reflecting the formation of the glass-crystalline nature of Li_2SO_4 . Moreover, the
 292 presence of single band at ν_4 and ν_2 regions support that the sample is not still crystalline.^{40,41}

293 Surprisingly, at the 2nd shocked condition, the singlet SO₄ Raman bands of ν_4 and ν_2 are
294 completely converted as doublet. Furthermore, the lithium Raman band is shifted from 399 to
295 385 cm⁻¹ and this position is found to be well matched with Bg polarization of lattice lithium
296 mode.^{40, 41} The Raman spectrum of the 2nd shocked condition well corroborate with β -Li₂SO₄
297 which demonstrates the crystalline nature of the test sample because of the rapid reduction of
298 positional disorder and rotational disorder of SO₄. In addition to that, at the 3rd shocked
299 condition, the lithium Raman band position is not altered. But the doublet Raman bands at ν_4 and
300 ν_2 regions become singlet that indicates the enhancement of rotational disorder of the SO₄
301 tetrahedral which leads to the amorphous nature of the test sample. Note that, in the case of
302 dynamic shocked conditions and high-pressure compression conditions, SO₄ anionic units are
303 found to have undergone significant rotational order-disorder effects and such results have been
304 well documented.^{44 - 47}

305 **Conclusion**

306 The switchable phase transformation of Li₂SO₄ samples from amorphous-glassy-
307 crystalline-amorphous phase under the influence of dynamic shock wave is reported for the first
308 time. The observed switchable nature is due to the orientational order-disorder processes
309 occurring in Li₂SO₄ specimen. Under the influence of shock wave, the position of the mobile Li
310 atom changes which is reflected in the post-shock measurements such as XRD, UV-Visible and
311 Raman spectral studies. The interesting switchable phase transition behavior of Li₂SO₄ has been
312 authentically demonstrated by crystallographic, optical and vibrational spectroscopic techniques.
313 Among the listed shock wave induced phases of the test sample, glassy phase has higher
314 electrical conductivity because of the presence of higher mobility of lithium ions based on peddle
315 –wheel mechanism. It is firmly believed that the present approach could be the starting point
316 which may trigger the pathway to find many more materials of possible reversibility occurring at
317 shocked conditions i.e., from amorphous to crystalline nature and vice versa. From the observed
318 results, it is very realistic that Li₂SO₄ sample has the suitability for the applications of phase –
319 change memory, sensors, molecular switches, pressure transmitters and thermal energy storage
320 devices. The investigations on the electrical conductivity and magnetic properties of the control
321 and shocked Li₂SO₄ samples are under progress.

322 **Compliance with ethical standards**

323 None

324 **Conflict of interest**

325 The authors declare that they have no conflict of interest.

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