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Original article

Polychromatic luminescence and improved antifungal performance of succinic acid in the lattice of L-Lysine monohydrochloride

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ABSTRACT

The incorporation of succinic acid (SA) in the lattice of L-Lysine monohydrochloride (LM) has opened the new avenue in the field of production and application of scintillator materials such as LED and antifungal drug. Crystalline trait and monoclinic structure were scanned by XRD. The existence of carbonyl, carboxylate and protonated amine group were confirmed through FTIR and UV spectra predicted the transmittance of SA: LM crystal. Polychromatic luminescence behaviour had achieved through the incorporation of SA instead of blue luminescence, which is a new result. Also SA: LM exhibited good response towards pathogenic fungi which causes numerous types of infections and diseases in both humans and animals. The high inhibitory zone at 16 mm was formed by the grown SA: LM crystal against the life threatening fungi like *Candida albicans*. Also fungal inhibition against *candida parapsilosis* and *Aspergillus flavus*, respectively, were tuned by the inclusion of succinic acid.

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1. Introduction

L-lysine is one of the acentric crystal because the basic chain is made with optically active carbon atom. Also the specular character of this L-Lysine is due to its phonon subsystem with hydrogen bonds (Krishnakumar et al., 2010). Natural characteristic cationic lysine is the electro optic material likewise it has wide potential character like pharmacologic movement, nonlinear optical impact, strong electrostatic interaction and optical parametrical effect as well as it is an indispensable amino acid to the human body especially in the formation of collagen (Rubin et al., 1960; Ozga et al., 2008; Lasser et al., 1960; Dousa et al., 2011; Wang et al., 2018; Cao et al., 2016). Succinic acid is come under the category of metabolite and biologically dynamic carboxylic acids (Kondratenko et al., 2020) formed by microorganisms, animals and plants (Juliet and Subramanian, 2018). Complexes of succinic acid plays a vital role to deliver inhibitory action against microor-

ganism and utilized in pharmaceutical industry (Demir et al., 2010a, 2010b; Lin et al., 2008; Ahn et al., 2016). Furthermore, it can be utilized in the creation of infrared (IR) MALDI analytical methods (Krishnan et al., 2008).

Our environment consists of very diverse microorganisms that include all bacteria, virus and fungus so on. It can be found in rock surfaces, soil, inside rocks, toxic waste, buried mites under the earth and almost in every parts of the atmosphere. The property of toxin production and penetration causes various types of infections, diseases in both humans and animals. Among all microorganism, fungus and bacteria possess greatest threat to all lives because they could cause illness in them (Boehlke et al., 2020; Calzavara-Pinton et al., 2005). The synthesis of antifungal and antibacterial drugs is lower in contrast to the rate of spreading of disease by both fungus and bacteria. So with basic characterization here, concentration given to magnify the optical, luminescence, chemical and biological activities of the grown crystals.

2. Material and methods

2.1. Materials

Sigma Aldrich Chemicals delivered the analytical grade materials such as L-Lysine monohydrochloride (C₆H₁₅ClN₂O₂) and Succinic acid (C₄H₆O₄). Deionised water was used as solvent.



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2.2. Growth method of crystals

To grow the crystal under atmospheric condition, slow evaporation is the finest method. This method was used to grow SA doped LM single crystal in the molecular ratio 0.02: 0.98. Enumerate amount of L-Lysine monohydrochloride and succinic acid was used to prepare supersaturated solution. Filtered saturated solution was lidded and kept for slow evaporation. Colourless crystals were obtained nearly after 20 days. Fig. 1. shows the grown SA: LM crystal.

2.3. Characterization of crystals

The structure was found by ENRAF NONIUS CAD4 X-ray diffractometer and the powder XRD of the sample were recorded with the help of XPert Pro- PAnalytic powder diffractometer. Using Thermo Nicolet avatar 370 spectrometer, vibrational studies was carried out in the middle infrared region ($400\text{--}4000\text{ cm}^{-1}$). Optical property of SA: LM crystals were assessed in the UV–Visible region by means of Perkin Elmer (Lamda 35) spectrometer. Polychromatic light emission of sample was appraised by make use of Varian Cary Eclipse Photo Luminescence Spectrophotometer. Fungal activity test was undertaken by disk diffusion method.

3. Results

Crystalline quality of the grown samples are identified from the sharp narrow diffractions peaks obtained by powder XRD analysis (Fig. 2) and Phase analysis demonstrate that crystal SA: LM is monoclinic. The various vibrational analysis of the samples are obtained from Fig. 3 and the peculiar vibration of amino acid due to NH_3 stretching is obtained in the range 2924 , 1585 and 1506 cm^{-1} . The synthesized crystals exhibit good inhibitory action against the life threatening pathogens which are shown in Fig. 4. SA: LM crystal shows a notable action against *Candida* species such as *Candida albicans*, *Candida parapsilosis*, and *Aspergillus flavus* by forming 16 mm , 14 mm , and 16 mm diameter zone. The transmittance behaviour of SA doped LM crystal is depicted in Fig. 5. The SA doped LA crystal shows 67% percentage of transmittance. At 345 nm wavelength the sample is excited and the emission spectrum was recorded, it is given in Fig. 6. Also it revealed the various luminescence property at different wavelength.

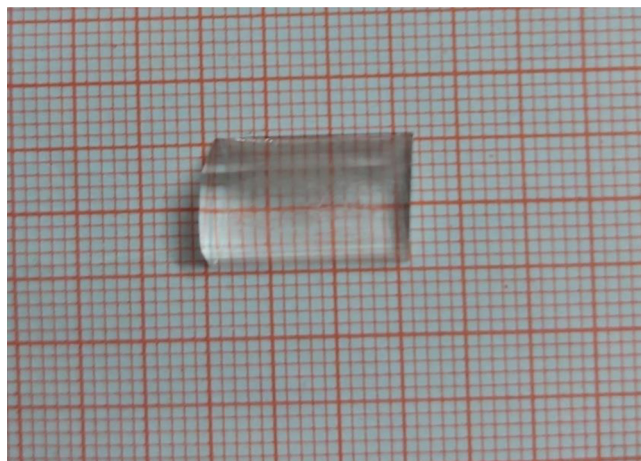


Fig. 1. Photograph of SA: LM crystal.

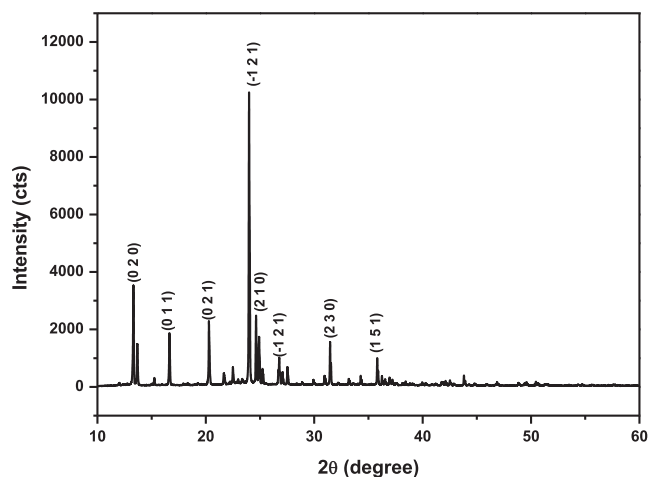


Fig. 2. Powder XRD pattern of SA: LM crystal.

4. Discussion

4.1. X-Ray diffraction analysis

The structure of L- Lysine monohydrochloride was not affected by the small amount of SA doping undoubtedly cleared from the phase analysis which does not shows any secondary phases. Phase analysis demonstrate that crystal SA: LM is monoclinic with unit cell dimensions $a = 5.88\text{ \AA}$, $b = 13.32\text{ \AA}$, $c = 7.49\text{ \AA}$, $\alpha = \gamma = 90^\circ$, $\beta = 97.79^\circ$ and $V = 581.271\text{ \AA}^3$ (Ramesh Babu et al., 2006). This is in agreement with the SP_2 space group. The successful incorporation of SA ion in LM is recognised from the shrinkage in the lattice parameter, subtle shift in intensity of peaks and diffraction angle.

4.2. Vibrational analysis

The C—C—N symmetric stretching obtained at the wave number 862 cm^{-1} (Robert et al., 2010). The absorption peak at 3171 cm^{-1} is assigned to N-H bond stretching (Petrosyan and Ghazaryan, 2009). According to Kalaiselvi et al the COO^- asymmetric stretching and NH_3 rocking were observed in the region 1619 and 1182 cm^{-1} (Kalaiselvi et al., 2007). In SA: LM also same vibration obtained at 1619 and 1182 cm^{-1} . C—N vibration imputed in the wave numbers 1348 and 1320 cm^{-1} (Ozga et al., 2008) and C—C stretching is noticed in the wave number 997 cm^{-1} . 3422 cm^{-1} is assigned to stretching vibration of water molecule. Krishnakumar et al reported that at $3450\text{--}3250\text{ cm}^{-1}$ stretching vibration of H_2O molecule take place. C—O stretching vibration is noticed at 1216 cm^{-1} (Krishnakumar et al., 2010). These wave numbers slightly shifted from the reference values which is due to the addition of SA.

4.3. Fungal activity

The *Candida* species are unicellular fungi which is present in humans at gastrointestinal, mucosal surfaces of the oral cavity, skin, vagina and urogenital tracts (Tsai et al., 2013). But on the other hand it is also a threat to human health by causing oropharyngeal candidiasis (OPC) and vulvovaginal candidiasis (VVC) (Coleman et al., 1993; Vargas and Joly, 2002; Sanchez et al., 1993; Hosseini et al., 2020). Furthermore VVC is a major threat for women infected with HIV. In United States by substantiation, the candida infection is the fourth most nosocomial infection and ranked second in death due to that infection (Pfalter et al., 1998; David Trofa et al., 2008). Aspergillosis is an infection brought about

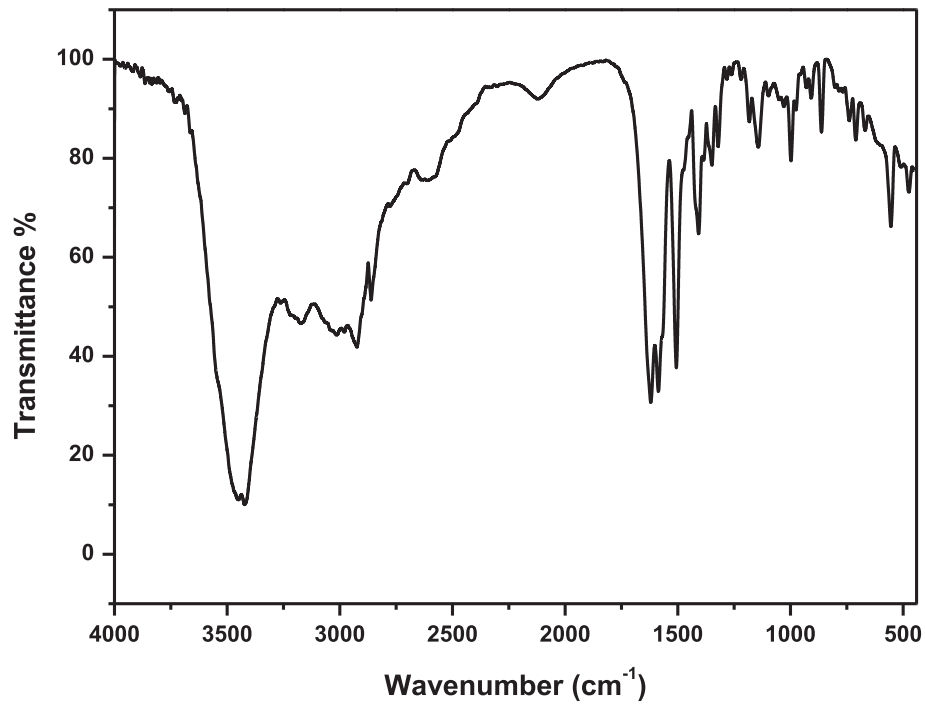


Fig. 3. Vibrational spectra of SA: LM crystal.

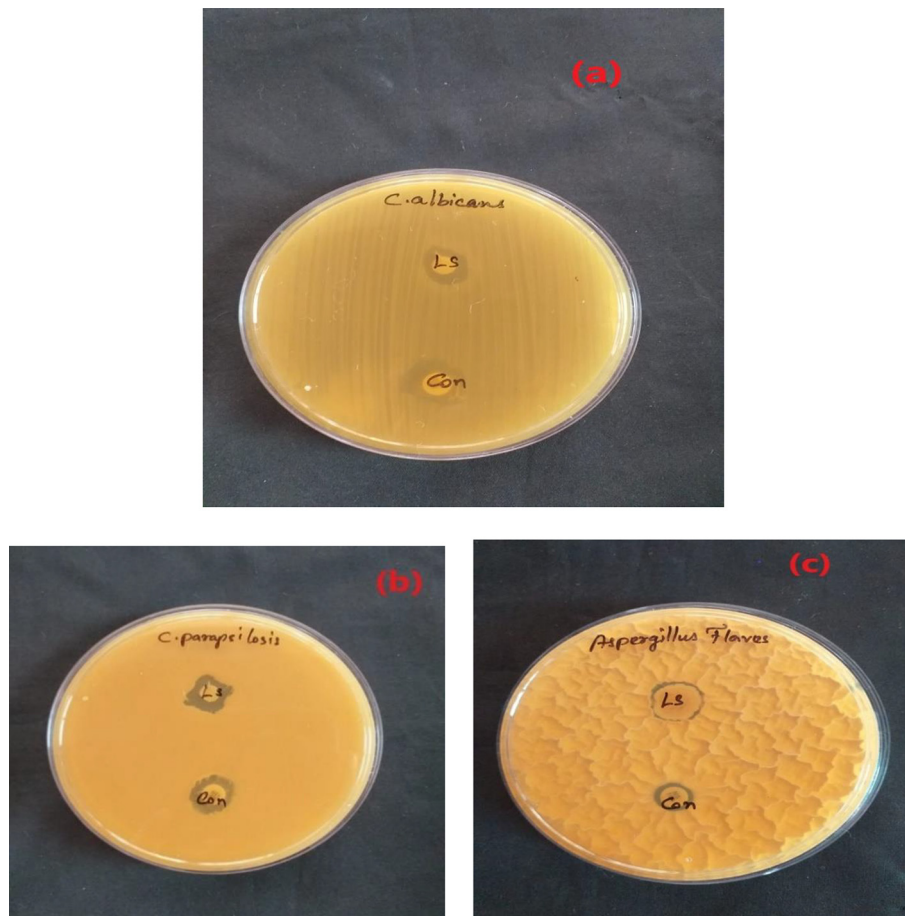


Fig. 4. Zone of inhibition of SA: LM against (a) *candida parapsilosis* (b) *Candida albicans* and (c) *Aspergillus flaves*.

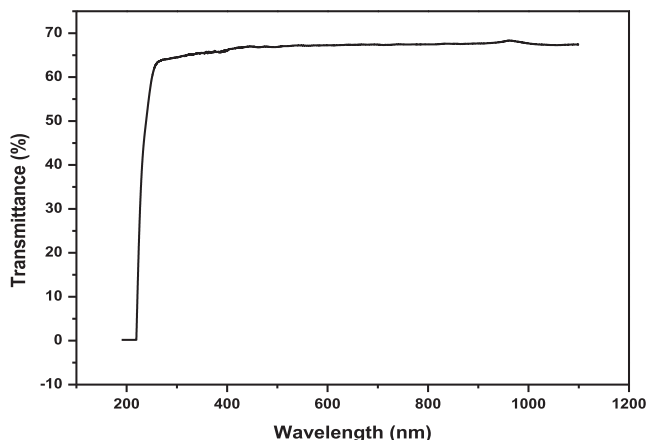


Fig. 5. Transmittance spectra of SA: LM crystal.

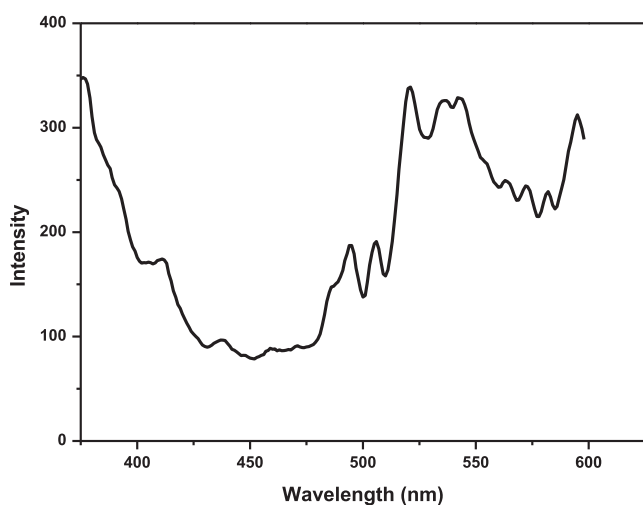


Fig. 6. Photoluminescence spectrum of SA: LM crystal.

by sort of fungi in particular *Aspergillus flavus* ordinarily trouble the respiratory framework (Smith and Denning, 2010; Ramirez-Camejo et al., 2012). Due to these infections on humans by fungi the curiosity to find antifungal drug is aroused. 16 mm extent of inhibitory zone was formed in opposition to *Candida albicans* by SA: LM which is more than that of antifungal activity of Nystatin. This Nystatin is used to patients who is affected by fungal infection (Ma et al., 2007; Monteiro et al., 2013; Zahabi et al., 2020). Moreover SA: LM material exhibit inhibitory action against *Candida parapsilosis* and *Aspergillus flavus* by forming 14 mm and 16 mm diameter zone, respectively, compared to *Candida albicans* in the diameter 9 mm reported by other authors (Kalaiselvi et al., 2018). Nano silver (Tantyan and Taufikurohmah, 2020) also showed less inhibitory zone than SA: LM crystal. These resisting activity of the sample against fungi leads to the development of effective anti-fungal drugs for wide range of applications.

4.4. Optical analysis

Depending on defects, orientation, optically active functional groups the range of transmittance varied (Anis et al., 2019; Senthil Pandian et al., 2011). The SA doped LM crystal shows about 67 percentage of transmittance and it is less than pure LM which shows 70 percentage transmittance (Aneeba et al., 2020). Because the concentration of doping reduced the transmittance of the crys-

tal due to the creation of extra defects (Zhou et al., 2019). This defects opened the way to SA: LM crystal towards polychromatic luminescence.

optical material:

L-lysine hydrochloride dihydrate

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5. Anti-microbial activities

5.1. Photoluminescence study

The typical approach for characterizing defects and other imperfection present in the sample is studied by using Photoluminescence Spectroscopic (PL) technique. It enables to examine the electronic transition and optically active intrinsic defect densities occurs due to absorption of light (Alexandar et al., 2017; Rajesh et al., 2017; Shejwal et al., 2016). The sample LM has a sturdy luminescence behaviour, which itself has its potential to act as a scintillator substance (Chen et al., 2016; Rani et al., 2013). The PL of SA: LM yields information about multiple energy levels existing between VB and CB which is accountable for radioactive recombination. The high intense PL emission of SA: LM is at 535 and 544 nm which are accountable for the powerful green luminescence. The first two peaks shows indigo and blue emission in the relative wavelength 459 and 494 nm and the rest shows yellow and orange emission at 572, 582 and 595 nm. The blue emission is due to the presence of NH_2 and Cl ions present in the sample. Chen et al depicted the luminescence behaviour of lysine, which is in the wavelength range 490 nm corresponding to blue emission (Chen et al., 2016). Notwithstanding in addition to above emission, SA: LM emitted the following colours like violet, indigo, yellow, orange owing to the inclusion of succinic acid. Because many of the literature showed the effect of SA in the luminescence property (Zhang et al., 2008; Wang et al., 2009; Cui et al., 2005; Demir et al., 2010ab). The enhancement of polychromatic emission of lysine is due to the doping of succinic acid.

6. Conclusion

The antifungal and high photo luminescence crystal SA: LM was synthesised and its crystalline properties were examined by XRD, FTIR, UV and photoluminescence spectroscopy. The monoclinic structure and functional groups are identified from XRD and FTIR. The formation of defects in grown crystal were identified from the transmittance graph. The intense responsive action against these pathogens proved that the succinic acid doped L-Lysine monohydrochloride could act as a potential antifungal drug in the field of medicine. The UV visible spectrum reveals that the crystals transmittance percentage was reduced by the defects present in them. The Photoluminescence characterisation shows the reinforced emission of violet, indigo, blue, green, yellow and orange colours due to polychromatic luminescence. These leading properties in SA: LM crystal opens the way in the field of antifungal drugs and also an effective supernumerary in the fabrication of scintillator materials.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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