Application of NLO and Antibacterial Activity of Tricine Doped Potassium Metal Ion Crystal

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Research Article

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Abstract

We have successfully produced Tricine Potassium Nitrate (TPN) single crystal synthesis using the solution growth method in this study. The powder X-ray diffraction (PXRD) technique was used to identify the phases of TPN crystals. Fourier transform infrared (FT-IR) analysis was performed to examine the functional groups contained in the produced crystals. To measure optical transparency, a UV-VIS-NIR investigation was conducted between 200 and 800nm. TPN crystal's photoluminescence (PL) spectrum was recorded. Vickers' hardness tester was used to investigate the mechanical characteristics of the formed crystal. Thermal gravimetric/differential thermal analysis was used to investigate the thermal behaviors of the produced crystals. The surface morphology of the formed crystal was determined using a field emission scanning electron microscope. Wet etching experiments were used to investigate the TPN crystal's growth feature. The shock damage threshold technique was used to determine the shock strength at which the crystal poses a risk. The Kurtz-Perry technique was used to investigate the effectiveness of the developed crystals' second harmonic generation (SHG). The antibacterial activity of TPN grown crystal against various standard bacterial strains.

1. Introduction

Over the last few years, research on elevated nonlinear optical (NLO) crystals has taken center stage. Due to their Photonic [1] Optoelectronic[2], new technologies[3] in sectors such as telecommunications[4], signal processing[5], and optical interconnections[6], they are streaming in all dimensions with unprecedented progress. Later-generation NLO materials are required to support a highly sophisticated information society, where substantial improvements in signal processing speed [7], frequency bandwidth [8], power consumption [9], and device compactness [10] are crucial. The important non-ultra-fast response in NLO materials as a result of electrons, low refractive index, and distributed wavelength [11]. It has never been more important to investigate and create NLO material to build a future society. The creation of a new class of materials as a result of ongoing research into new and more efficient NLO materials [12]. Various materials are now employed for NLO applications, including organic [13], inorganic [14], semi-organic [15], and amino acid-based complexes [16]. These materials and their derivatives have a lot of nonlinearity, as well as a lot of charge transfer and polarizability [17].

The carbon atom in an amino acid-based complex crystal is chiral. NH proton acceptors, also known as zwitterions, and molecular design flexibility. These materials have received a lot of attention as potential candidates for optical applications [18]. These amino-acids-based crystals have a wide transparency range, mechanical strength, strong polarizability, chemical stability, and excellent harmonic generation (SHG) [19]. The advantages of both organic, inorganic, and semi-organic crystals are highly investigated due to their capacity to enhance NLO characteristics [20]. To enhance the qualities and properties of semi-organic crystals, researchers focus on finding families of semi-organic crystals that blend amino acids with inorganic or metal complexes. Antibacterial research has received considerable attention recently because of its potent microbe-killing properties [21]. A new class of antimicrobial and antibacterial drugs must be more effective or have better performances [22]. Good et al[21] subsequently prepared N-
(Tris(hydroxymethyl)methyl]glycine (HOCH$_2$CNHCH$_2$COOH (tricine) as a biological identified research buffer [22]. It is commonly utilized to interact with divalent alkaline-earth and transition metals as excellent buffers and complexation [23]. The use of tricine with various metal ions in chemical applications has been studied [24]. Tricine was chosen as a promising chelating agent because of its structural frame, which includes carboxylate oxygen, imido nitrogen, and alcoholic oxygen atoms[3].

There has also been the suggestion of stable complexation of Th$^{4+}$, Ce$^{3+}$, La$^{3+}$, and Uo$^{2+}$ (El-Roudy et al 1997). Due to their structural flexibility, tricine as a chelating agent in Cu(II) can connect with metal ions to construct unidentate, bidentate, and tridentate structures (Ramos et al 2001). Several authors performed complexometric investigations of tricine with various metal ions [25–29]. Because of their metal cation complexation, Lanthanum (III), Cerium (III), and Thorium (IV) dioxouranyl (IV) complexes with Tricine produce complexes. Potassium Nitrate is an alkali metal nitrate ionic salt containing the potassium ion K$^+$ and the nitrate ions NO$_3^-$ . KNO$_3$ is a primary ingredient in a variety of energetic material compositions [30–33]. K$^+$ doped with L$^-$serine [34] Potassium Nitrate with Bismuth [35] Potassium nitrate with glycine [36] These crystals have a wide range of applications in the field of optoelectronics. In recent years, a lot of effort has gone into establishing speedy sensitive and environmentally friendly materials synthesis for organic-based metals ions, and these yield materials are the promise for the next technical breakthrough in materials engineering[37]. Slow evaporation solution growth has been the preferred paradigm for growing defect-free crystals over the past decade due to its simple design and cost-effectiveness. This research uses the most reactive potassium metal ion as a dopant in Tricine over a long period. This work is carried out greatest reactive Potassium metal ion as a dopant in the Tricine via sluggish evaporation technique.

2. Experimental

2.1. Crystal Growth

In a clean beaker, dissolve tricine and potassium nitrate in 100 mL distilled water. At room temperature, the solution is periodically stirred with a magnetic stirrer. In the prepared saturated KNO$_3$ solution, tricine was added in a 1:1 ratio and agitated continuously for 4 hours at room temperature. This solution was filtered and wrapped with Whatman paper with perforations to the atmosphere to enable the solvent to evaporate slowly.

3. Structural Studies

3.1. Powder-X-Ray Diffraction:

Powder X-ray diffraction evaluation was made using a Smart Lab X-ray Diffractometer (Rigaku Corporation, Japan) with a Step Size of 0.01 and an angle range of 2-1080 at room temperature with CuK radiation ($\lambda=0.15418$nm) and power requirements of 100-240V,15A. For this examination, samples of well fine powder with 1g in the sample specimen and the core attributes are required.
Figure 2 depicts a powder X-ray diffraction examination of powdered TPN generated Crystals with an X-ray diffraction pattern. This TPN powder pattern has a Monoclinic and Orthorhombic structure, as shown in Figure 2, with * denoting Tricine peaks and hkl values implying Potassium Nitrate peaks. The positions of the obtained peaks are very similar to the data in [JCPDS card no 19-1820], [JCPDS card No. 05-0377] with Tricine. The role of potassium nitrate as a dopant in the lattice of formed crystals has also been established. A powder X-ray diffraction investigation reveals that the generated TPN crystal is highly crystalline.

3.2. Fourier transforms infra-red analysis:

The vibrations of various functional groups present in both samples are quantified in this investigation. Acquiring a functional confirmation study. Potassium bromide (KBr) based pellets were determined by adding a pressure of 10 kg/cm² for around 30 seconds on crystalline powders. For solid samples, the standard KBr procedure was utilized, with 1mg sample per 300mg KBr. The FTIR spectrum is recorded using a Perkin Elmer FTIR 1760x spectrophotometer with a wavelength range of 400 cm⁻¹ to 4000 cm⁻¹. This device had a spectral resolution of 4cm⁻¹. % Transmittance Vs Wavelength of these FTIR spectrum samples observed at ambient temperature.

Figure 3 depicts The N-H Asymmetric stretch that induces the vibration peak at 3497cm⁻¹. The significant C-H stretch corresponds to the peaks detected at 3000cm⁻¹. The 1607cm⁻¹ peak indicates a moderately strong C=C stretch. Due to NO₃ stretching, a strong peak was found at 1378cm⁻¹ (ref). Strong C-O stretch is indicated by a peak stretch of 1070 cm⁻¹. Wide (CH₂)n bend and strong C-H bend stretching can be seen at 716cm⁻¹, 822cm⁻¹. The presence of functional groups is consistent with the presence of Tricine and Potassium Nitrate in this TPN-developed Crystal are shown in Table 1.

Table 1 Wavenumber assignments of TPN grown Crystal

| Frequency in Wave number (cm⁻¹) | Assignments of Functional Groups              |
|--------------------------------|-----------------------------------------------|
| 716.58                         | Wide (CH₂)n bend                               |
| 822.03                         | Strong C-H bend                                |
| 1070.27                        | Medium- strong C-O stretch                     |
| 1378.11                        | Strong N-O Asymmetric stretch                  |
| 1607.06                        | Medium- strong C=C stretch                     |
| 3000.83                        | Strong C-H stretch                             |
| 3497.67                        | Wide- medium N-H Asymmetric stretch            |

4. Optical Studies
4.1. UV-Vis Spectroscopy:

UV-Vis spectroscopy (Shimadzu UV1800), a 160 digital double-beam recording spectrometer, and 1cm Quartz cells would be used to record the optical transmittance and absorbance spectra of two powdered materials. The measuring properties wavelength range (200 – 1100) nm insteps of 1nm The chosen slit width was 2nm. The perceived values of absorbance were recorded and stored in the memory of a computer and plotted.

Figure 4 (a) illustrates To determine whether the generated single crystals are suitable for optical applications. A UV-Vis spectrometer was used to record the optical transmission spectrum of the synthesized TPN crystal in the wavelength range 200 to 800nm. Figures 4 (a) and (b) show the recorded spectrum and band gap. The lower cutoff wavelength is around 302 nm, with a 4.631eV bandgap. The crystal's transmittance in the visible area is found to be 99 %. The generated crystal's quality makes it acceptable for NLO applications.

4.2. PhotoLuminescence:

By shifting the excitation wavelength and vice versa, the PL spectra of the powder sample were obtained at room temperature. The emission spectra were captured at a wavelength of 297 to 550nm, with a data interval of 1.0nm and a scan speed of 600nm/min. The PL spectrum was recorded using a SHIMADZU "RF-6000 Series" PL spectrometer with a bandwidth of 5.0nm for excitation and emission. A 2,000-hour-long-life Xe lamp should be used to scan wavelengths up to 900nm with a resolution of 0.5nm. Fluorescence is the spontaneous emission of light radiation that proceeds when a system transitions from its lowest vibration energy level of the primary excited single state to its ground state.

Figure 5 shows the spectrum emitted by the radioactive recombination of a photo-generated minority carrier is used to quantify the bandgap energy in photoluminescence (PL) techniques. A significant amount of contaminants, on the other hand, causes a high free carrier density in the bands. As a result, a unique carrier interaction alters the line form and spectral energy of the PL spectrum dramatically. Figure 5 in the range of 200-800 nm, the emission spectra of a grown single crystal of TPN were observed. For the exciting wavelength 300nm, emission peaks may be seen at 320nm to 580nm.

4.3. Non-Linear Optical Study:

At the Indian Institute of Science in Bangalore, the NLO property of crystal was measured using the Kurtz and Perry second harmonic generation (SHG) technique. The developed crystal TPN was powdered to uniform particle size, and a comparison was established with a known SHG material, potassium dihydrogen orthophosphate (KDP), which is also crushed and sieved to a uniform particle size range. The powdered samples were placed in sealed microcapillary tubes with a standard bore diameter of around 1.5 mm. As a light source, a high-intensity Nd:YAG laser was used. A power meter measures the incident beam's power. An oscilloscope (TDS 3052 B 500 MHz, Phosphor digital oscilloscope) connected to a
photomultiplier tube (PMT – Hamamatsu – model R 2059) is also required. The user can collect SHG data using the PMT and oscilloscope setup and compare the results towards the reference materials.

The transmitted fundamental wave was sent through a monochromator (Czerny Turner monochromator) that separated 532 nm (second harmonic signal) from green light, which was detected by a photomultiplier tube and shown on a storage oscilloscope. The second harmonic generation properties of a powdered sample of the synthesized crystal were investigated using the Kurtz-Perry technique. The powdered sample of the generated crystal was exposed to a highly intense Q-Switched Nd:YAG laser(=1064nm) beam with an energy of 1.2mJ. The emission of green radiation (532nm) from the sample demonstrated the crystal’s frequency conversion capabilities.

Table: 2 SHG efficiency of TPN grown Crystal

| Crystal | SHG Efficiency |
|---------|----------------|
| KDP     | 80mV           |
| I/P Energy | 1.2mJ/Pulse |
| Tricine | 16mV           |
| TPN     | 32mV           |

The appropriate second harmonic generation efficiency of a developed crystal is known to demonstrate a high degree of polarizability due to a highly delocalized electron system interacting with an electron releasing and an electron-accepting group. The SHG effectiveness of pure and TPN crystals is shown in Table 2. The SHG of doped crystals differs from that of pure Tricine.

5. Mechanical Studies

5.1. Hardness Measurements:

The Vicker tester has been used to determine the microhardness of TPN crystals. Using a diamond pyramid indenter connected to an incident ray research microscope, static indentation test loads were applied to the formed crystal. Using the Shimadzu HMV-2T, microhardness research was conducted on the smooth and flat surface of a crystal with a dimension of 0.5nxm0.6nxm0.5mm for several loads ranging from 25, 50, and 100 g at a constant time of indentation (10 s). Vickers microhardness tester with right-hand diamond pyramidal with a square base and 136° angle between opposite faces. The Vickers pyramid has a square base, and the depth of indentation is 1/7th of the indentation diagonal. The ratio of the longitudinal and transverse diagonals will be 7:1. Normally, the full load is applied for 10 to 15 seconds. A microscope will be used to measure the two diagonals of the indentation left in the material’s surface after the load has been removed, and the average will be calculated. The area of the indentation’s sloping surface was calculated. The Vickers hardness is computed by adding the kg load by the square mm area of the indentation and the indenter attached to an optical microscope. An average of at least three impressions was recorded for each load a dwell time of 10s. The calibrated microscope attached to
the system has determined the diagonal length (d) of the indentation mark after unloading. X,Y axes of stroke with resolution 0.001mm. This device is an automatic reading function with a digital image measuring range 80 X 100 µm (V x H) automated focused time 3s.

In the manufacturing of devices, the mechanical strength of the materials is crucial. Vicker’s hardness test was used to determine microhardness at room temperature. For applied loads ranging from 25 to 100 grams, hardness measurements were taken. \( Hv = 1.8344P/d^2 \) is the Vickers hardness number (H). P is the applied load, and d is the indentation impression's diagonal length. Figure 6 depicts the fluctuation of Hv as a function of the applied load p. The hardness number of developed crystals grows with the applied load, as seen in the graph and Hardness Parameters of TPN grown Crystal are shown in Table 3.

Table: 3 Hardness Parameter of TPN grown Crystal

| Hardness Value (Hv)(Kg/mm²) | Yield Strength (σy)(Kg/mm²) | Elastic Stiffness, \( C_{11} \times 10^{14} \)(Pa) | Fracture toughness, \( K_c(\mu m^{-1})^{3/2} \) | Brittness, \( B_i(\mu m)^{1/2} \) |
|----------------------------|-----------------------------|-----------------------------------------------|---------------------------------------------|----------------------------------|
| 63.74805859                | 21.24935286                 | 1438.193049                                  | 0.031418122                                 | 2029.02194                      |

The yield power (σy) using this relation (38)

\[ \sigma_y = \frac{Hv}{3} \]

Elastic stiffness constant (\( C_{11} \)) for grown TPN crystal have been assessed by Wooster’s empirical formula (39)

The formula \( K_c = P/\beta \cdot C^{3/2} \) is used to calculate fracture toughness (Kc) and brittleness index (Bi). The geometrical constant is equal to 7 Vickers diamond indenter \( Bi = Hv/Kc \), where P is the applied load, l is the crack length, and is the geometrical constant. The plot yield strength is shown in Figure 7 as a straight line graph. The yield strength refers to the stress at which a material begins to deform in the context of our inquiry, i.e., the plot of applied load and yield strength. The yield strength is lowest for low loads, demonstrating the crystal's elastic nature, and subsequently increases as the load increases.

The yield strength increases as well, indicating the material’s plastic character. Figure 8 shows a plot of \( \log p vs \log d \) for the developed crystal, with the slope indicating the work hardening index n, indicating that the grown crystal obeys the reverse indentation size effect. Hard materials have a range of \( n<1.6 \), while soft materials have a range of \( n>1.6 \), according to Onitsch (40). As a result of the slope value of 0.18, it is determined that the produced crystal is a hard substance.

6. Thermal Studies
6.1. Thermal Property Analysis:

The TG/DTA was used to determine the thermal behavior. The EXSTAR TG/DTA6300 device was used to record the TG/DTA for TPB. This is a high-resolution balancing mechanism. This was tested at temperatures ranging from ambient temperature to 1500 degrees Celsius. Automatic Cooling unit: Force Air Cooling; cooling rate less than 15 minutes from 1000 to 50°C at atmosphere 10-2 Torr gas. The sample of weight 8.805mg was heated in an environment of nitrogen at a heating rate of 10 °C/min at room temperature to 700 °C using an alumina crucible 7.5l sealed. Noise's thermal gravimetric weight is 0.1g, and its sensitivity is 0.2g.

When a sample is heated, cooled, or maintained isothermally at a constant temperature, DSC analysis quantifies the heat flow created in it. Differential scanning calorimeters can measure a variety of properties and processes, including melting points, crystallization behavior, and chemical reactions. Powder dry samples were introduced into a differential scanning calorimeter (DSC) for thermal analysis using a Mettler-Toledo DSC 822E/400. They were placed in standard aluminium pans with a 40-liter lid and subjected to the following thermal cycle in nitrogen: kept at 250°C for five minutes, heating from 250 to 390°C at 20°C/min, and holding at 390°C for five minutes. The samples were taken 6.576 mg and six consecutive cycles were run on each sample without opening the DSC furnace to ensure noble mixing of the sample and reproducibility of the results. The DSC thermograms were analyzed.

The TG/DTA curve for the grown TPN crystal is shown in Figure 9. The TG diagram demonstrates that the material is stable up to 421°C Celsius. The moisture and melting point of the organic (Tricine) substance account for the two abrupt endothermic and exothermic peaks at 186°C and 171°C, respectively. The presence of inorganic salt is indicated by endothermic peaks at 335°C and 379°C. (KNO3). This implies that this TPN crystal was generated via the combination of KNO3 and Tricine.

The conversion temperature of KNO3 is indicated by the first and second endothermic peaks at 131°C and 176°C with less thermogram in Figure 10, while the melting point of KNO3 is indicated by the third endothermic peak at 379°C. These findings are consistent with TG/TDA analysis.

7. Magnetic Studies

The vibrating sample magnetometer (VSM) module of the physical property measuring system (PPMS-9T) is used to measure magnetism (Quantum Design, USA). The chamber's compatible and adaptable sample mounts have a 2.6cm diameter to accommodate a variety of sample probes. It works with samples weighing less than 1 gram. In the magnetic field of 0.05 T, the temperature dependency of magnetization is found for both ZFC and FC cases. The specimen was cooled from 300 K to 5 K in the absence of a magnetic field before being heated from 5 to 300 K (zero field cooled (ZFC)) in a 0.05 T applied field. The data was then taken with decreasing temperature, i.e., field-cooled Cooling (FC), and the temperature was decreased up to 5 K, with the magnetization direction of each particle fixed in the
magnetic field direction. Automated temperature-controlled and field-controlled systems of PPMS run an extremely powerful workstation for the study of magnetic materials.

At ambient temperature, the magnetic characteristics of the formed crystal were investigated using a vibrating sample magnetometer (VSM). The hysteresis loop of magnetization of the material against the applied magnetic field is shown in Figure 11. It displays the material's ferromagnetic characteristics as well as its responsiveness to an externally applied field. Because of partially full shells or unpaired electrons, ferromagnetism only arises in materials containing atoms or ions with a permanent magnetic moment. The ferromagnetic characteristics of materials were determined using the hysteresis loop of a crystalline sample weighing 56.000x10^{-3}g and a field of 20000G. Magnetization saturation and retentivity have values of 67.666x10^{-6} emu and 2.9462x10^{-6} emu, respectively. The fields required to reduce the magnetization to zero after saturation are known as coercivity, and their value is -102.40G. Hard ferromagnetic materials have a high coercivity, while soft ferromagnetic materials have low coercivity. The soft ferromagnetic material has a low microcrystalline anisotropy and fewer flaws like crystal gain. These findings indicate that the formed crystal is a soft ferromagnetic material that could be suitable for use as a recording medium.

8. Surface Analysis Studies

8.1. FE-SEM:

This field effect “gun” microscope (FE-SEM) operates at 0.5-30KV (SIGMA HV – Carl ZEISS with BRUKER QUANTAX 200 – Z10 EDX Detector). The field emission scanning electron microscope is a type of electron microscope that uses a raster scan pattern to photograph the sample surface by scanning it with a high-energy electron beam. To maintain the integrity of the samples measurements were taken at low voltage (between 0.5 and 2kv) without the standard deposits of carbon at the surface of the sample. Energy Dispersive X-ray (EDX) experiments were also performed. Characteristic x-ray intensity is measured relative to the lateral position on the sample. About 1 μm lateral resolution is possible. To perform Ca^{2+} cartography the FE-SEM operates at 15kv.

Figure 12 (a,b) The FE-SEM is one of the instruments for determining the roughness, fractal dimension, and fracture of a material's surface. The surface morphology of a well-grown TPN single crystal was investigated using FESEM. Figure 12(a) demonstrates that the crystal is produced via layer deposition and that the surface has some minor roughness due to the growing environment. Figure 12(b) shows the EDAX spectrum of a TPN crystal, which confirms the presence of consistent components in the crystal.

9. Etching Studies

To explore the distribution of surface flaws, etching investigations and as-formed crystals of TPN crystals were carried out. The samples were polished, then etched at room temperature with deionized water as an etchant for varied etching durations (10s, 20s, 30s), before being soaked with filter paper and viewed
under an optical microscope in reflection mode. The etch patterns seen on the surface of the TPN Crystal are depicted in Figures 13 (a,b,c). Etching is a popular and low-cost method for revealing dislocations and lattice in homogeneities in produced crystals. For various etching times, the figures depict the usual etch patterns seen on TPN crystal. When the water was used to etch the crystal, it is possible to identify the triangle type form that etches pits with the same shape. The pattern remains the same when the etching time is increased, but the size of the etch pits is found to increase.

10. Shock Wave Damage Analysis

Shock waves are formed by abrupt (within microseconds) releases of energy in the form of pressure and temperature, such as an explosion or volcanic eruption (Jagadeesh 2008). Controlled shockwaves with specific energy can be generated in the laboratory by shock tubes and used for constructive purposes. These controlled shockwaves with instantaneous increases in pressure and temperature have potential applications in engineering, manufacturing, medical, agricultural, biological, and scientific fields. Furthermore, they are employed for preservative injection into wood salts, oil extraction, needleless drug delivery, metal production, bio load reduction in natural products, and the insertion of DNA into a bacterium cell without destroying it (Jagadeesh, Takayama, 2002). In this experiment, a shock wave created by a hand-driven shock tube built in-house was directed onto a well-polished crystal surface that had been cleaned with solvent. The crystal was placed 1 cm from the open end of the driver part and then subjected to the test. To begin, apply a low-intensity shock pulse to a shock pulse with Match number 1. After that, the strength was increased up to Match number 5. An optical microscope was used to examine the crystal surface after each shock. We noticed that the shock pulse of Matches 1,1.2,1.3,1.7, and 2.0 remained unchanged. However, as the Match number increased to 2.3, the crystal's surface began to show damage, as shown in the photos in Figure 12. After that, a succession of shock pulses with the same Match number (2.3) were delivered, and the crystal surface was examined after each one. After each shock, optical microscope photographs of the crystal surface with Match number (2.3) and a magnification of 10 are shown in Figure 14. When shock is delivered to the surface, it is obvious. Pits of varying sizes and shapes appear. The crystal's surface appears to be a mesh after the sixth shock, but there are no visible breaks.

11. Anti-bacterial Activity

Preparation of medium:

In 1000 mL distilled water, dissolve 28.0 grams of nutritional agar. Bring to a boil, then completely dissolve the medium. Autoclave at 15 lbs pressure (121°C) for 15 minutes to sterilise. Pour into sterile Petri plates after thoroughly mixing.

Microorganisms
Gram – positive bacteria, Staphylococcus aureus (MTCC 3160), and Gram – negative bacteria, 
Escherichia coli, were used in the biological experiments (MTCC 732). Microbial type culture collection 
(MTCC) at Chandigarh, India's Institute of Microbial Technology (IMTECH).

**Preparation of 24 hours pure culture**

In a Roux bottle, a loop containing each of the bacteria was suspended in around 10ml of physiological 
saline. These were streaked onto the appropriate culture slants and incubated for 24 hours at 37°C. When 
growth was observed after the incubation period, the tubes were maintained at 2–8°C kept at room 
temperature.

**Preparation of samples solutions for the experiment**

Samples were prepared by dissolving 10 mg of chloramphenicol in 10 mL of distilled water and 
comparing them to a standard solution of chloramphenicol for bacteria (25 mg/mL pure water). Unless 
they were employed in the experiment, they were kept in the refrigerator.

**Agar well – diffusion method**

Antimicrobial activity was determined using the agar well diffusion method shown in Figure 15. With 24 
hour culture and 48hour old broth culture of respective bacteria, nutrient agar (NA) plates were swabbed 
(sterilized cotton swabs). Using a sterile cork borer, agar wells of 5mm diameter were drilled onto each of 
these plates. Using sterilized dropping pipettes, 50l, 100l, and 150l of the sample, control 30l, and 
standard 30l were added to the wells, and plates were left for 1 hour to allow for pre-incubation 
diffusion. For bacterial strains, the plates were incubated in an upright position at 37°C, 2°C for 24 hours to 
reduce the effects of variation in time between the applications of different solutions. The existence or 
absence of an inhibitory zone was reported as a result. The lack of the tested organism was indicated by 
the inhibitory zone surrounding the well. The zones’ sizes were measured on a diameter measurement 
scale. Antibacterial activity was measured in triplicates and the average values were recorded shown in 
Table 4.

**Table 4** Anti-bacterial activity of TPN Grown Crystal

| Bacterial strains         | Sample dose (µl) | Std. (30µl) | Control (30µl) |
|---------------------------|------------------|-------------|----------------|
|                           | 50µl             | 100µl       | 150µl          |
| **Gram positive**         |                  |             |                |
| *Staphylococcus aureus* (mm) | 3.10±0.21     | 5.40±0.37   | 9.25±0.64      | 11.15±0.78 | 0.00±0.00 |
| **Gram negative**         |                  |             |                |
| *Escherichia coli* (mm)   | 3.50±0.24      | 6.75±0.47   | 9.60±0.67      | 11.80±0.82 | 0.00±0.00 |
12. Conclusion

The slow evaporation solution growth approach, which uses water as a solvent, was used to effectively develop the optically transparent NLO single crystal TPN. The PWXRD investigation indicates that the formed crystal system is mixed phase monoclinic and orthorhombic. FTIR spectral analysis revealed the presence of all functional groups and their various vibrations. The UV-Vis NIR spectrum reveals that the crystal becomes transparent across the region, with a wavelength of 302nm. Because the formed crystal is transparent, it is suited for NLO applications. The calculated optical band gap was found to be 4.631eV using Tauc’s figure. The photoluminescence investigation revealed that the TPN Crystal has an excitation wavelength of 300nm. The chemical is thermally stable up to 379°C, according to TG-DTA and DSC tests. The mechanical properties of the material confirmed that it is a hard substance. TPN Crystal microhardness characteristics such as yield strength, elastic stiffness, fracture toughness, and brittleness were investigated. FE-SEM with EDAX was used to investigate the surface morphology and constituent elements. The TPN crystal's shock damage threshold was determined and noted. The growth mechanism of TPN crystal layer pattern with minimum dislocations is revealed by etching studies. The inclusion of meat atoms is accountable for the rise in antibacterial action. The efficiency of SHG is superior to Tricine, according to a study of NLO property.

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Figures
Figure 1

Photograph of TPN grown Crystal
Figure 2

The Powder XRD pattern of TPN grown Crystal

Figure 3

FTIR spectrum of TPN grown Crystal

Figure 4

(a,b) The UV-Vis transmittance spectrum and optical band gap spectrum of TPN grown Crystal.

Figure 5

The PL spectrum of TPN grown Crystal
Figure 6

Plot of Hardness Vs load for TPN grown Crystal
Figure 7
Plot of Yield Strength Vs Load for TPN grown Crystal

Figure 8
Plot of Load d VS Log p for TPN grown Crystal
Figure 9

TG/DTA Curve of TPN grown Crystal
Figure 10

The DSC Curve of TPN grown Crystal
Figure 11

Room Temperature M-H curve of TPN grown Crystal

Figure 12
(a, b) FE-SEM and EDAX of TPN grown Crystal

**Figure 13**

(a, b, c) Etching studies of TPN grown Crystal surface with time 10s, 20s, 30s respectively.

**Figure 14**

(a, b, c, d) Microscopic Images of SDT pattern of TPN grown Crystal

**Figure 15**

(a, b) Photographic view of zone of inhibition of TPN Grown Crystal against the *staphylococcus aureus* and *Escherichia Coli*