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Thiourea Metal Complex crystal for AR coating in solar thermal devices

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Abstract

The thiourea metal complex (TMC) NLO crystals with index of refraction near 1 are used for antireflection coating on solar cells to enhance the efficiency by reducing the reflection. The said crystals are also useful for coatings on camera lenses and on some components used for optical experiments with lasers. Present communication concentrates on the synthesis, crystal growth and application of Thiourea zinc sulphate (ZTS) crystal doped with 1 M % Ammonium dihydrogen phosphate (ADP) crystal for antireflection coating. Superior quality non-linear optical crystals of ZTS + ADP were grown from aqueous solution by slow evaporation method in a constant temperature bath at 35˚C. UV-visible spectral analysis ascertained in the range of 200–900 nm affirmed the 80% transmittance. Linear optical property refractive index determined by using transmittance data, required for antireflection coating.

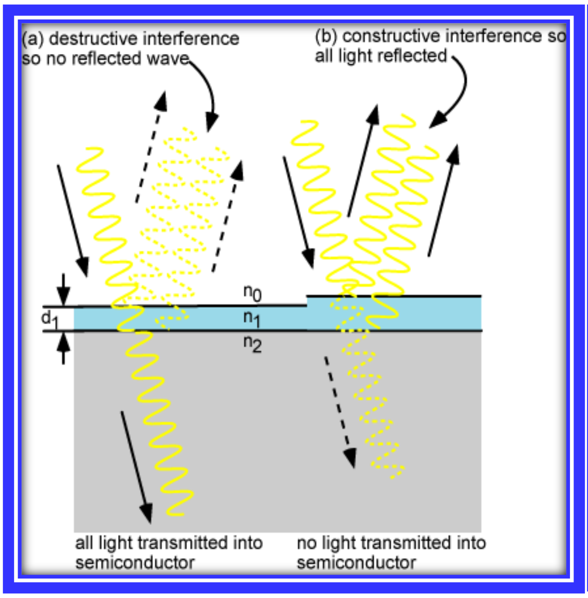
Keywords: Crystal growth, refractive index, S-R method

Introduction

Thiourea metal complex (TMC) crystals have been very rapidly developed due to their appealing features such as large optical transparency, high nonlinear response, huge laser damage threshold, high thermal stability and improved mechanical properties. These qualities advocate TMC crystals suitable for applications in electro-optic modulation, optical data storage devices, high-tech NLO and telecommunication devices **[1-4].** Zinc Thiourea sulphate (ZTS) is a nonlinear optical material (NLO) which has combined property of high optical nonlinearity and chemical flexibility of organics along with physical ruggedness of inorganic. ZTS is a material with non-centrosymmetric orthorhombic crystal system. It exhibits a low angular sensitivity, high laser damage threshold, wide optical transparency, and exceptionally wide acceptance angle for second harmonic generation (SHG), SHG efficiency 1.2 times of KDP **[5-12].**

Approximately 4% incident light from uncoated glass substrate gets reflected at each interface, resulting in total transmission of only 92% of the incident light. Antireflection coating (AR) coating on each surface will increase the throughput of the system and reduce hazards caused by reflections traveling backwards through the system (ghost images). Anti-reflection coatings are especially important if the system contains many transmitting optical elements. Also, many low-light systems incorporate AR coated optics to allow for efficient use of light **[13, 14].**

Anti-reflection coatings on solar cells are similar to those used on other optical equipment such as camera lenses. They consist of a thin layer of dielectric material, with a specially chosen thickness so that interference effects in the coating cause the wave reflected from the anti-reflection coating top surface to be out of phase with the wave reflected from the semiconductor surfaces. These out-of-phase reflected waves destructively interfere with one another, resulting in zero net reflected energy. In addition to anti-reflection coatings, interference effects are also commonly encountered when a thin layer of oil on water produces rainbow-like bands of color **[15, 16].**



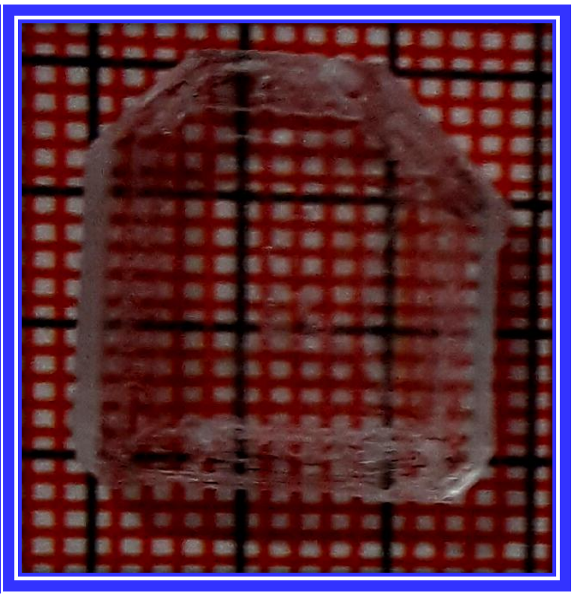


Fig.1 AR-thickness d1 and refractive index n1 Fig.2. ZTS + ADP crystal

The transmission properties of a coating are dependent upon the wavelength of light being used, the substrate's index of refraction, the index of refraction of the coating, the thickness of the coating, and the angle of the incident light.

The coating is designed so that the relative phase shift between the beam reflected at the upper and lower boundary of the thin film is 180°. Destructive interference between the two reflected beams occurs, cancelling both beams before they exit the surface. The optical thickness of the coating must be an odd number of quarter wavelengths (λ/4, where λ is the design wavelength or wavelength being optimized for peak performance), in order to achieve the desired path difference of one half wavelength between the reflected beams, which leads to their cancellation as shown in **Fig.1.**

The equation for determining the index of refraction of the crystal or thin film needed for complete cancellation of the two beams is **[17, 18]:**

$n_f = (n_o n_s)^{1/2}$ Where n_f is RI of AR, n_0 is RI of air (or the incident material), n_s is RI of substrate.

Experimental procedure

The ZTS metal complex has been synthesized by dissolving Zinc Sulphate (1mole) and thiourea (3 mole) in double distilled de-ionized water. The ZTS metal complex salt was repetitive recrystallized to gain highest possible purity for further synthesis. To achieve doping of 1 M % ADP the supersaturated solution of purified ZTS was prepared. The measured quantity of of 1 M % of ADP was gradually added to the supersaturated solution of ZTS with continuous stirring process to attain homogeneous doping throughout the mixture. The 1 M % ADP doped ZTS solution was then filtered in a rinsed beaker and kept for slow solution evaporation in a constant temperature bath at 35˚C. The grown ZTS + ADP crystal is shown in **Fig.2.**

Results and discussion

For photonics and NLO device applications the optically transparent crystals are readily demanded **[20, 21].** In present study the optical transmittance of 2 mm thick pure ZTS +ADP crystal was ascertained in the wavelength range of 200 to 900 nm using the spectrophotometer (Shimadzu make UV-2450). The recorded transmittance spectrum is shown in **Fig.3**. The UV-visible spectrum of the grown crystal exhibits the enhanced transmittance up to 80% in entire visible region. Refractive index is calculated by using transmittance data and applying the formula reported by Nabeel A Bakr et al and plotted in **Fig.3 [6, 19].** The calculated value of refractive index (RI) was found to be **1.65** in visible region for grown crystal. The lower RI procured by ZTS+ADP crystal makes it more suitable for antireflection coating in solar thermal devices and optical device fabrications **[6, 22-25].**

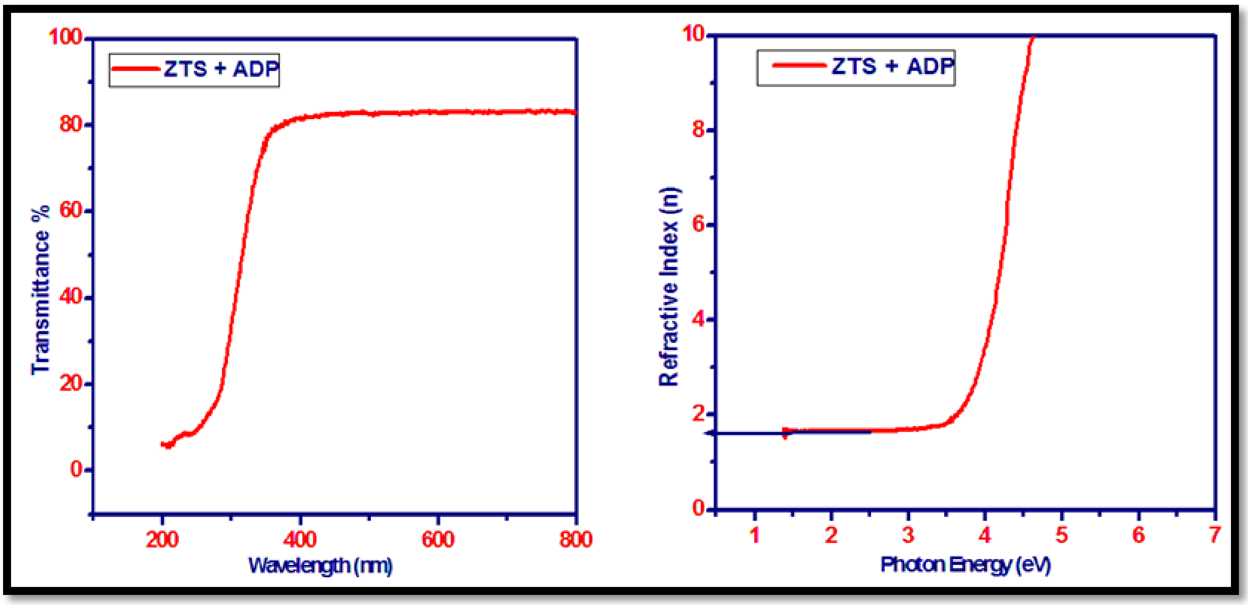


Fig.3. Transmittance and Refractive index of grown crystal

Conclusion

ZTS+ADP crystal have been grown by slow solution evaporation technique at 35˚C. The optical studies revealed higher transmission(80%) , wider range of transmittance and improved optical parameters favoring its suitability for solar thermal device fabrication, nonlinear optical and laser applications. The lower value of refractive index (1.65) of was ascertained in the visible region of interest. Decisive results of present studies are (a) ZTS+ADP crystal offers high optical transparency (b) the lower value refractive index 1.65 Hence under the extended umbrella of photonic device applications, ZTS+ADP crystal holds strong status for the antireflection (AR) solar thermal coating.

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