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“ENHANCEMENT OF OPTICAL AND STRUCTURAL PROPERTIES OF $SRTIO_3$ PEROVSKITE USING NATURAL STABILIZERS”

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Abstract. In this study, the synthesis of $SrTiO_3$ perovskite material via the sol–gel method in a DMSO medium and the influence of citric acid and yetmak plant extract used as stabilizers on its optical properties were investigated. The obtained samples were analyzed using photoluminescence (PL) spectroscopy. The PL spectra exhibited several emission maxima in the 400–1500 nm range. A strong emission band observed in the 550–600 nm region indicates the presence of defect states associated with oxygen vacancies and Ti^{3+} centers in the $SrTiO_3$ crystal lattice. The emission at higher wavelengths suggests the formation of deep energy levels and surface states. The results confirm that the use of citric acid and plant extract during synthesis increases the defect concentration in $SrTiO_3$ and significantly affects its optical activity.

Keywords: $SrTiO_3$, perovskite, sol–gel method, DMSO, photoluminescence, oxygen vacancies, defect states, plant extract.

Аннотация: данной работе исследован синтез перовскитного материала $SrTiO_3$ методом золь-гель в среде DMSO, а также влияние лимонной кислоты и экстракта растения йетмак, использованных в качестве стабилизаторов, на оптические свойства материала. Полученные образцы были проанализированы методом фотолюминесцентной (PL) спектроскопии. В спектрах PL в диапазоне 400–1500 нм наблюдались несколько максимумов излучения, при этом интенсивная эмиссия в области 550–600 нм указывает на наличие дефектных состояний, связанных с кислородными вакансиями и центрами Ti^{3+} в кристаллической решётке $SrTiO_3$. Эмиссия в области больших длин волн свидетельствует о формировании глубоких энергетических уровней и поверхностных состояний. Полученные результаты подтверждают, что применение лимонной кислоты и растительного экстракта способствует увеличению концентрации дефектов в структуре $SrTiO_3$ и существенно влияет на его оптическую активность.

Ключевые слова: $SrTiO_3$, перовскит, золь-гель метод, DMSO, фотолюминесценция, кислородные вакансии, дефектные состояния, растительный экстракт.

Annotatsiya: Mazkur ishda $SrTiO_3$ perovskit materialining DMSO muhitida zol-gel usuli yordamida sintezi hamda limon kislotasi va yetmak oʻsimligi ekstrakti stabilizator sifatida qoʻllanilishining materialning optik xossalariga ta’siri oʻrganildi. Olingan namunalar fotoluminessensiya (PL) spektroskopiyasi yordamida tahlil qilindi. PL spektrlarida 400–1500 nm oraligʻida bir nechta emissiya maksimumlari kuzatilib, 550–600 nm diapazondagi kuchli emissiya $SrTiO_3$ kristall panjarasida kislorod vakansiyalari va Ti^{3+} markazlari bilan bogʻliq defekt holatlari mavjudligini koʻrsatdi. Yuqori toʻlqin uzunliklari sohasida qayd etilgan emissiyalar chuqur energetik darajalar va sirt holatlarining shakllanganligidan dalolat beradi. Natijalar limon kislotasi va oʻsimlik ekstrakti ishtirokida sintez qilingan $SrTiO_3$ perovskit materialida defektlar konsentratsiyasining oshishini va bu holat uning optik faolligiga sezilarli ta’sir koʻrsatishini tasdiqlaydi.

Kalit soʻzlar: $SrTiO_3$, perovskit, zol-gel usuli, DMSO, fotoluminessensiya, kislorod vakansiyasi, defekt holatlar, oʻsimlik ekstrakti.

Introduction. In recent years, $SrTiO_3$ (strontium titanate) with a perovskite structure has attracted considerable scientific interest due to its high dielectric constant, chemical stability, wide band gap, and remarkable optical and photocatalytic properties. As a semiconductor material, $SrTiO_3$ is considered a promising candidate for applications in photoelectric devices, gas sensors, photocatalysis, and optoelectronic systems[1]. Its physicochemical properties strongly depend on the synthesis conditions, precursor materials, and stabilizing agents used during preparation.

Various synthesis methods have been employed for the preparation of $SrTiO_3$, including solid-state reaction, hydrothermal techniques, sol–gel processes, and other chemical approaches. Among them, the sol–gel method offers significant advantages such as molecular-level control of the reaction process, homogeneous composition, and phase formation at relatively low temperatures. [2].In this study, strontium nitrate ($Sr(NO_3)_2$) and titanium isopropoxide were selected as strontium and titanium sources, respectively. Dimethyl sulfoxide (DMSO) was used as a solvent to ensure good dissolution of metal ions and the formation of a homogeneous reaction medium.

To control particle growth and stabilize the gel formation process, citric acid was employed as a complexing agent and stabilizer. In addition, following an eco-friendly approach, yetmak plant extract was introduced as a natural stabilizing component. Organic compounds present in the plant extract can interact with metal ions, influencing particle morphology and surface states. [3-4].The incorporation of such green synthesis elements provides an opportunity to tailor the defect structure and optical properties of the material.

Therefore, the aim of this study is to investigate the optical properties of $SrTiO_3$ perovskite synthesized from $Sr(NO_3)_2$ and titanium isopropoxide in a DMSO medium in the presence of citric acid and yetmak plant extract, and to evaluate the influence of these stabilizers on the crystal lattice and defect states of the material. [5].

Results and discussion. $SrTiO_3$ perovskite material was synthesized via the sol–gel method using strontium nitrate ($Sr(NO_3)_2$) and titanium isopropoxide as precursor sources in a DMSO medium. Citric acid was employed as a complexing and stabilizing agent to ensure homogeneous distribution of metal ions and controlled gel formation. In addition, yetmak plant extract was introduced as a natural stabilizer within a green synthesis approach. The combined effect of these components is expected to significantly influence the crystal lattice, surface states, and defect structure of the resulting $SrTiO_3$ perovskite.

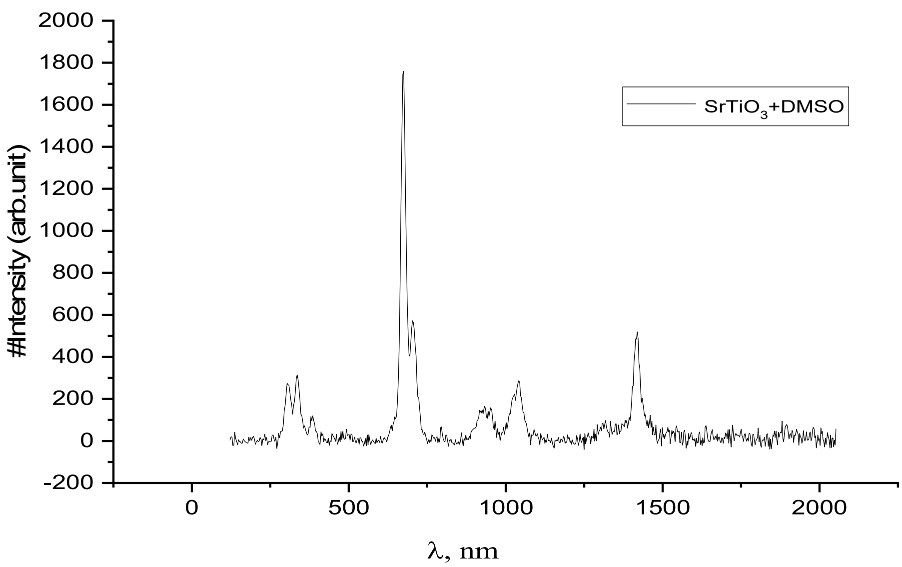

Figure 1

The optical properties of the synthesized samples were investigated using photoluminescence (PL) spectroscopy. The PL spectra exhibited several emission bands in the wavelength range of 400–1500 nm, indicating the presence of multiple energy levels and defect centers within the $SrTiO_3$ structure. A relatively weak emission observed in the short-wavelength region (400–450 nm) can be attributed to surface states and oxygen vacancies, which are associated with high-energy radiative recombination processes.(figura-1) Such emissions typically indicate local lattice distortions and surface-related defects in the crystal structure.

A strong and prominent emission band was detected in the 550–600 nm region, representing one of the key findings of this study. This emission is mainly attributed to radiative recombination processes involving defect levels associated with Ti^{3+} centers and oxygen vacancies. During the sol–gel process, citric acid forms complexes with metal ions, while organic constituents present in the yetmak plant extract may not completely decompose during calcination. As a result, additional defect states and oxygen vacancies can be generated within the $SrTiO_3$ lattice, leading to a significant enhancement in PL intensity.

Furthermore, emission bands observed at wavelengths above 1000 nm suggest the presence of deep energy levels and charge carrier trapping states (trap states). These deep-level defects can slow down charge transfer processes and increase the complexity of recombination mechanisms within the material. The adsorption of biologically active organic molecules from the plant extract onto the $SrTiO_3$ surface may further modify surface states, contributing to the formation of additional energy levels within the band structure.

The relatively high PL intensity indicates rapid electron–hole recombination within the material. While this behavior may be advantageous for light-emitting and optoelectronic applications, it may limit charge carrier separation efficiency in photocatalytic systems. Nevertheless, the presence of controllable defect states provides an opportunity to tailor the optical activity and emission characteristics of $SrTiO_3$ perovskite for specific technological applications.

Overall, the results demonstrate that $SrTiO_3$ synthesized in a DMSO medium in the presence of citric acid and yetmak plant extract exhibits a complex defect structure and enhanced optical activity. These findings highlight the potential of such materials for applications in optoelectronic devices, light-emitting systems, and advanced photocatalytic technologies.

Conclusion. $SrTiO_3$ perovskite was successfully synthesized via the sol–gel method in DMSO using citric acid and yetmak plant extract, which promoted homogeneous gel formation and controlled crystallization. Photoluminescence analysis revealed multiple emission bands, indicating the presence of surface states, Ti^{3+} centers, oxygen vacancies, and deep-level trap states, all of which contributed to the material’s enhanced optical activity. The strong emission in the 550–600 nm range highlights defect-mediated radiative recombination, while longer-wavelength emissions suggest the formation of deep energy levels that may influence charge carrier dynamics. Overall, the results demonstrate that controlled defect engineering through the combined use of citric acid and plant extract can tailor the optical properties of $SrTiO_3$, making it a promising candidate for optoelectronic and light-emitting applications.

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