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Lanthanum Doped Strontium Titanate as photoanode by Pechini method for Dye Sensitized Solar Cell Application

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Abstract - *The high temperature synthesis results in coarsening of the particles which ultimately quenches the surface properties of a material. This will lead to poor performance of the Dye sensitized solar cell. Therefore we aim at synthesizing a single phase A-site deficient La doped $SrTiO_3$ (LST) by Pechini method at lower temperatures. It is expected to result in higher porosity and surface area which would aid for better adsorption of the dye molecules onto the material and the Lanthanum doping would contribute for more vacancies which are really important for increasing the conductivity. Thus, the LST powders synthesized by Pechini method would save the energy needed for calcination process and increase the porosity, active surface area, enhancing physical and electrochemical properties of DSSC anode in synergism with La doping.*

Key Words: Pechini, adsorption, surface area, porosity, doping, conductivity.

1.INTRODUCTION

The photovoltaic effect was discovered by Alexandre-Edmond Becquerel, who was a French physicist, in 1839. This was the beginning of the solar cell technology. Becquerel's experiment was done by illuminating two electrodes with different types of light. Dye-Sensitized Solar Cells (DSSCs) have attracted widespread interest since their first description by Grätzel and O'Regan [1] as an influential and low cost solar energy harvester. In a DSSC, solar energy is converted to electricity through light absorption by dye molecules attached to a mesoporous semiconductor, green leaves absorb the sunlight, in order to convert water and CO_2 to oxygen and carbohydrates. After light absorption by the dye molecule, the resulting excited dye injects an electron into the conduction band (CB) of the semiconductor, and the oxidized dye is in turn regenerated by a redox mediator, normally iodide/triiodide, in a surrounding electrolyte. The cycle is closed by the reduction of the redox couple at a platinized counter electrode [2, 3]. In a conventional DSSC, the photoanode consists of a TiO_2 layer (8-15 μm) deposited on a Transparent Conducting Oxide (TCO) covered glass substrate and sensitized with dye molecules (usually Ru complexes).

Over the last 20 years, ruthenium complexes gifted with thiocyanate ligands have achieved power conversion efficiencies beyond 11% and showed good stability [4-6]. An electrolyte containing I-/I3- redox couple acts as hole conductor and electrically regenerate the dye molecules. Another TCO covered substrate with a thin Pt layer (few nm) serves as counter electrode, to promote the reduction of the triiodide [7,8]. One of the crucial parts in DSSCs is the dye or photosensitizer. Generally, metal complexes photosensitizers consist of a central metal ion with ancillary ligands having at least one anchoring group. Light absorption in the visible part of the solar spectrum is due to a metal to ligand charge transfer (MLCT). The central metal ion is therefore a crucial part of the overall properties of the complexes. Ancillary ligands, typically bipyridines or terpyridines, can be tuned by different substituents (alkyl, aryl, heterocycle, etc.) to change the photophysical and electrochemical properties and thus improve the photovoltaic performance. In this study, LST(Lanthanum doped Strontium Titanate) powders were synthesized by Pechini method in order to increase surface area and reduce the calcination temperature at which pure perovskite structure can be obtained [9, 10].

2. EXPERIMENTAL PROCEDURE

$(La0.3Sr0.7)0.93TiO_3$ powders were synthesized by Pechini method. Titanium iso propoxide ($Ti(OCH(CH_3)_2)_4$) was dissolved in ethanol (99.9 %) for stabilization, and then distilled water was added to the solution. After stirring for 1 h, the stoichiometric amount of $La(NO_3)_3.6H_2O$ (Sigma Aldrich, 99 %) and $Sr(NO_3)_2$ (Sigma Aldrich, 99 %) was dissolved in the solution, and nitric acid (HNO_3) was added as a peptizing agent. The solution was stirred for 3 h, and citric acid ($C_6H_8O_7$) was added into the solution. Next, ethylene glycol ($C_2H_6O_2$) was added in the solution, and the solution was strongly stirred at 70° C for 1 h. The transparent solution was gradually changed to the LST gel. With the gel formation, the temperature increased to 180° C to obtain the LST powder. The LST powder was calcined at 600°C temperature for 5 h in air [11].

3. RESULTS & DISCUSSION

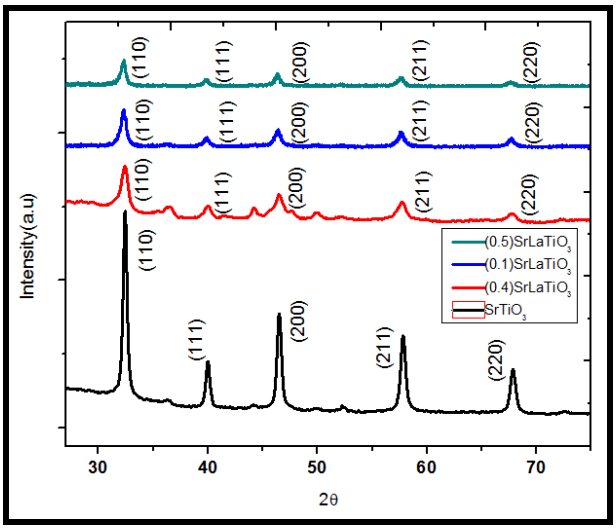

Fig -1: XRD patterns of $SrTiO_3$ $SrLaTiO_3$ powder calcined at 600˚C for 5h

The phase and crystallinity were examined by XRD over 2θ angle from 25˚ to 75˚ shown in (fig.1). As the Lanthanum percentage increases, the major peak at 32º corresponding to (110) plane broadens and this is due to the reduction of crystallite size on doping with Lanthanum. Crystallite size is calculated using Scherrer equation, crystallite size of $SrLaTiO_3$ is 6nm [11].

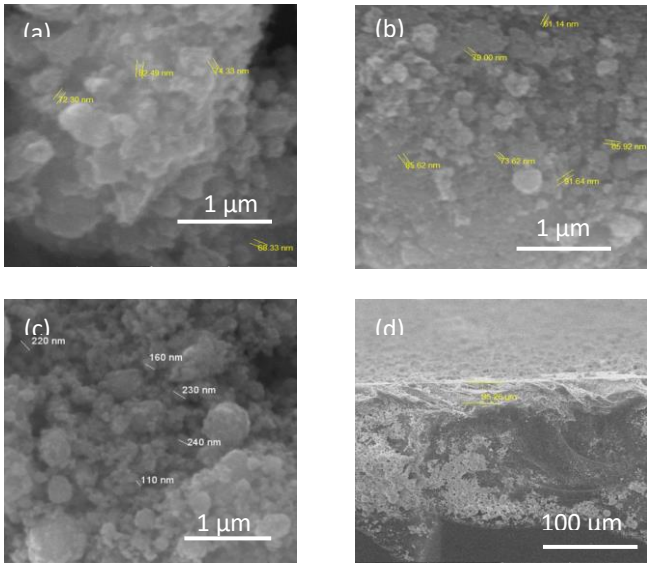

Fig -2: SEM images of (a) TiO_2; (b) $SrTiO_3$; (c), (d) $SrLaTiO_3$

SEM images of (a), (b) and (c) confirms the formation of Spherical morphology of TiO_2, $SrTiO_3$ and $SrLaTiO_3$ nanoparticles respectively and SEM image of (d) shows the cross sectional SEM image of $SrLaTiO_3$ respectively.

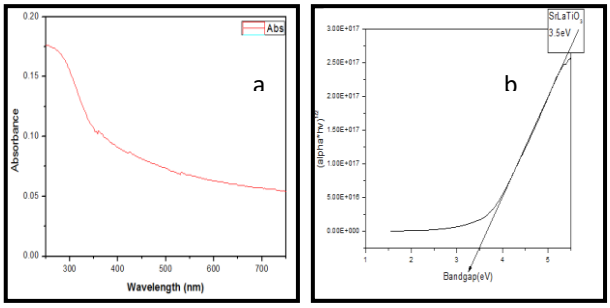

Fig -3: (a), (b) UV-Visible Spectroscopy for $SrLaTiO_3$ at 254nm and Tauc plot for $SrLaTiO_3$

It shows the Bandgap of $SrTiO_3$ is 3.2eV. On doping the Lanthanum nitrate hexahydrate to the strontium titanate the bandgap of the material increased to 3.5eV, the wide bandgap which is required for photo anode of dye sensitized solar cell.

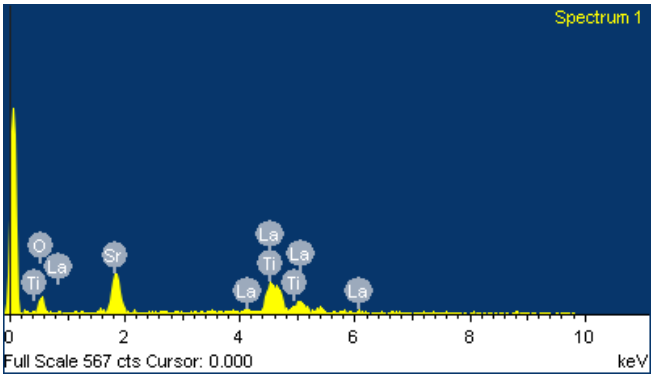

Fig -4: EDS result for $SrLaTiO_3$

Element	Weight %	Atomic %
O	25.47	64.96
Ti	15.47	13.18
Sr	26.30	12.24
La	32.76	9.62

Table -1: EDS result for $SrLaTiO_3$

The figure and table shows the quantitative analysis of $SrLaTiO_3$ which confirms the presence of Lanthanum, Strontium, Titanium and Oxygen.

Parameters	Value Obtained
Surface Area	35.0236m^2/g
Pore Volume	0.002845cm^2/g
Mean Pore Diameter	11.12nm

Table -2: BET-BJH results for $SrLaTiO_3$

Table 2 shows the BET-BJH analysis, it was clear that the Lanthanum doped Strontium titanate has the surface area

(**35.0236m²/g**), the pore volume (**0.002845cm³/g**), and the mean pore diameter (**11.12nm**). It shows the prepared anode material has sufficient surface area for Dye sensitized solar cell application [11].

4. CONCLUSION

The narrow diffraction peaks are observed at 32°, demonstrates the crystalline Lanthanum doped strontium titanate and the SEM image confirms the spherical morphology of $SrLaTiO_3$. The UV-Vis Spectroscopy of $SrLaTiO_3$ shows 3.5eV wide bandgap which is necessary for the photo anode material of the DSSC. EDS result shows that the quantitative analysis of the elements present in the sample and confirms the presence of Lanthanum and BET-BJH results shows high surface area, pore volume and pore diameter of $SrLaTiO_3$ which improves the adsorption of dye and hence increases the efficiency due to the increase in light absorption.

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