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Electrodeposited Nickel Oxide Thin Film for Electrochemical Water Splitting

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Abstract: *Cheaper and capable electrocatalysts play an important role in electrochemical water splitting. Here, we have prepared nickel oxide (NiO) thin film as an electrocatalyst on the stainless steel substrate by electrodeposition method. XRD and FESEM techniques were used to study structural and morphological properties of prepared electrocatalyst. Further, obtained (NiO) thin film electrocatalysts are used for Oxygen evolution reaction (OER) by LSV in 1 M KOH. The electrodeposited (NiO) thin films exhibited overpotential of 212 mV at a current density of 5 mA cm^{-2}, and a Tafel slope of 75.7 mV dec^{-1}. This electrocatalyst is stable for at least 15 hrs. in the catalytic activity.*

Keywords: Thin film, Electrocatalyst, OER, Oxide, Alkaline

I. INTRODUCTION

Today's culture of human being creates large energy demand and hence it is essential to design proficient energy conversion devices and invention of alternative energy sources. [1-10]. Alternative energy sources can be applied as substitute in order to energy challenge issues. Although, the additional energy source like solar energy, wind energy maintains non-continuous energy due to its irregular cycle [11]. Consequently, the dependence on fossil fuels reduced by converting energy from renewable sources [12]. The supplementary auspicious source for fossil fuels is hydrogen (H_2) as a consequence of its high energy storing capacity in given volume [13-15]. Electrochemical water splitting is the best way for making hydrogen as a clean chemical fuel by using long-lasting energy resources [5, 9, 16]. Presently, noble electrocatalysts used as active electrocatalysts with lower overpotential for water splitting but however price and scarcity restricts on use [17, 18]. Hence, it is need to develop highly efficient and stable electrocatalysts towards OER by using cheap earth-rich elements. The transition metal based OER electrocatalysts are best alternatives due to abundance and very cheap in comparison to precious metals [19-23]. From last decades nickel (Ni) and Ni-based materials discovered the good catalytic nature regarding OER and economically abundant in earth crust [24-26]. The various catalytic properties of nickel oxides included in several useful devices [27-29]. These outcomes inspire the progress of simplistic production methods of the NiO metal electrodes as OER catalyst.

Herein, we report the synthesis of nickel oxide thin film on a stainless steel substrate. The prepared (NiO) thin film can be directly used for further structural, morphological and electrochemical characterizations. The stable and efficient electrocatalyst can be used in the large extent production of hydrogen via electrochemical water splitting.

II. EXPERIMENTAL

Nickel oxide thin films synthesized by electrodeposition method on a pure stainless steel substrate. Prior the deposition, stainless steel substrates polished by zero grade polish paper. Then cleaned with detergent, double distilled water and then ultrasonically cleaned with the mixture of ethanol and double distilled water for 15 minutes. Finally substrates were dried and then cleaned with acetone directly used for deposition. The precursor solution was formed using 0.05 M Nickel nitrate [Ni $(NO_3)_2.6H_2O$] and double distilled water (DDW). The electrodeposition experiment was performed in a potentiostat in which Pt, saturated calomel electrode (SCE) and stainless-steel substrates used as counter, reference and working electrode respectively. NiO films deposited on the (SS) substrate via potentiostatic mode at a fixed potential -0.9 V/SCE. After deposition films were annealed at 350 ^{0}C in muffle furnace for 60 minutes to form oxide phase. Structure and morphology were investigated by X-ray diffractometer and Field emission scanning electron

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microscope (FESEM). Electrochemical studies of prepared catalyst were performed by CHI (6002E) instruments with NiO thin film, Pt and Ag/AgCl electrode as working electrode, counter electrode and reference electrode respectively in 1M KOH solution at room temperature. All measured potentials were converted to the reversible hydrogen electrode (RHE) using following Nernst equation [30]:

$E_{RHE} = E_{Ag/AgCl} + (0.059 \times pH) + 0.197$

To determine the OER activity of prepared thin films, Linear Sweep Voltammetry (LSV) was performed at different scan rate of 5, 10 and 20 mVs^{-1}. Tafel slope was obtained by polarization curve. The stability of the electrocatalyst tested at constant current density of 5 mA cm^{-2} by chronopotentiometric measurement.

III. RESULTS AND DISCUSSION

The structural analysis of electrodeposited NiO electrocatalyst was investigated using XRD. Fig.1 shows the X-ray diffractogramms of as prepared and annealed NiO catalysts with 2θ range of 20 to 90° and it tells that the NiO has cubic crystal structure. The diffraction peaks of annealed NiO film were indexed at 37.28°, 43.6°, and 62.9° corresponding to planes (111), (200) and (220) respectively. This result is matched with the pattern of NiO cubic structure (JCPDS card no. 47-1049) [31].

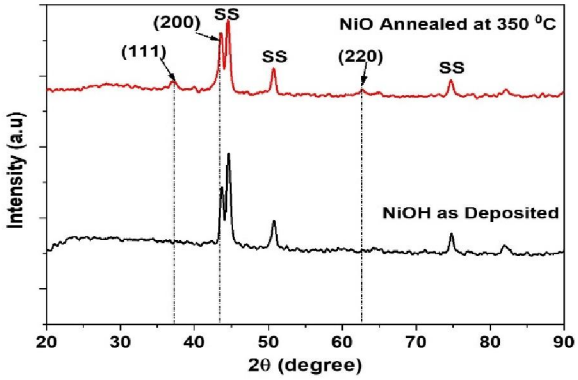

Fig.1 XRD pattern of NiO

The surface morphology of NiO was studied by FESEM and it is seen in the (Fig. 2). From these SEM micrographs we seen that NiO has porous nanowall like morphology and it enhances the active surface area which is helpful for catalytic water splitting [32].

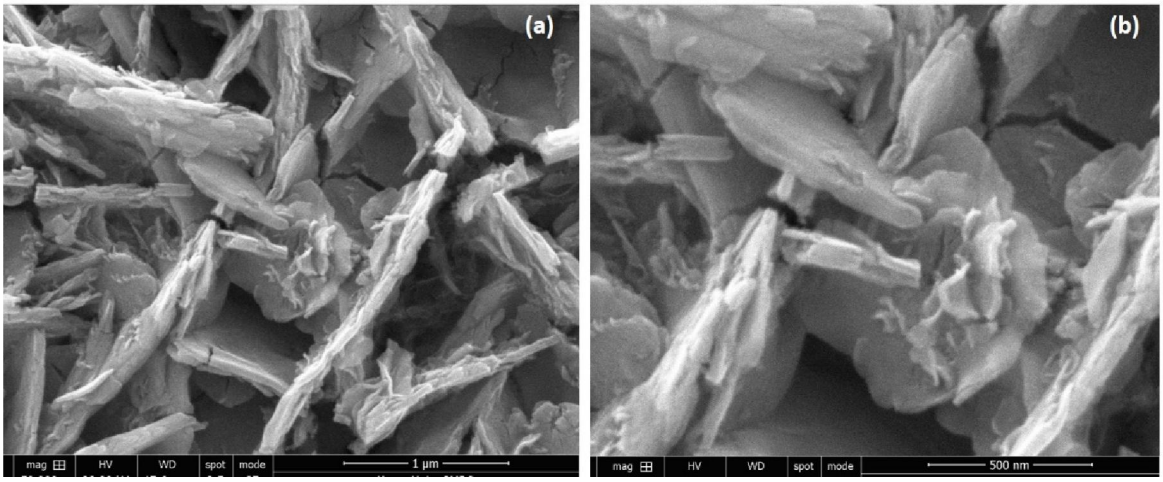

Fig. 2 SEM micrographs of (a) NiO and (b) High resolution SEM of NiO

OER activity was observed by (LSV) at different scan rate viz. 5, 10 and 20 mVs^{-1} in 1M KOH. Fig. 3(a) represents the LSV curves of NiO thin film catalyst at various scan rates. From these polarization curves it was clearly seen that onset potential 1.39 V vs. (RHE) and overpotential 212 mV to reach the current density of 5 mA cm^{-2}. Fig. 3(b) represents the

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Tafel plot of prepared NiO thin film. It shows the Tafel slope of 75.7 mV dec^{-1}. Low value of the overpotential and Tafel slope shows its better reaction dynamics for OER. Fig. 3 (c) shows the EIS Nyquist plot for NiO at different scan rate. The value of charge transfer resistance $R_{(s+ct)}$ is approximately equal to (5.8 Ω). This low value of $R_{(s+ct)}$ linked with faster charge movement process and hence enhanced the catalytic activity. Stability tested by the chronopotentiometric measurement in 1M KOH solution at 5 mA cm^{-2} for 16 hours. Fig. 3(d) shows potential vs. (RHE) versus time graph for stability test. NiO thin film catalyst showed stability of 15 hours without any loss in chronopotentiometric electrolysis.

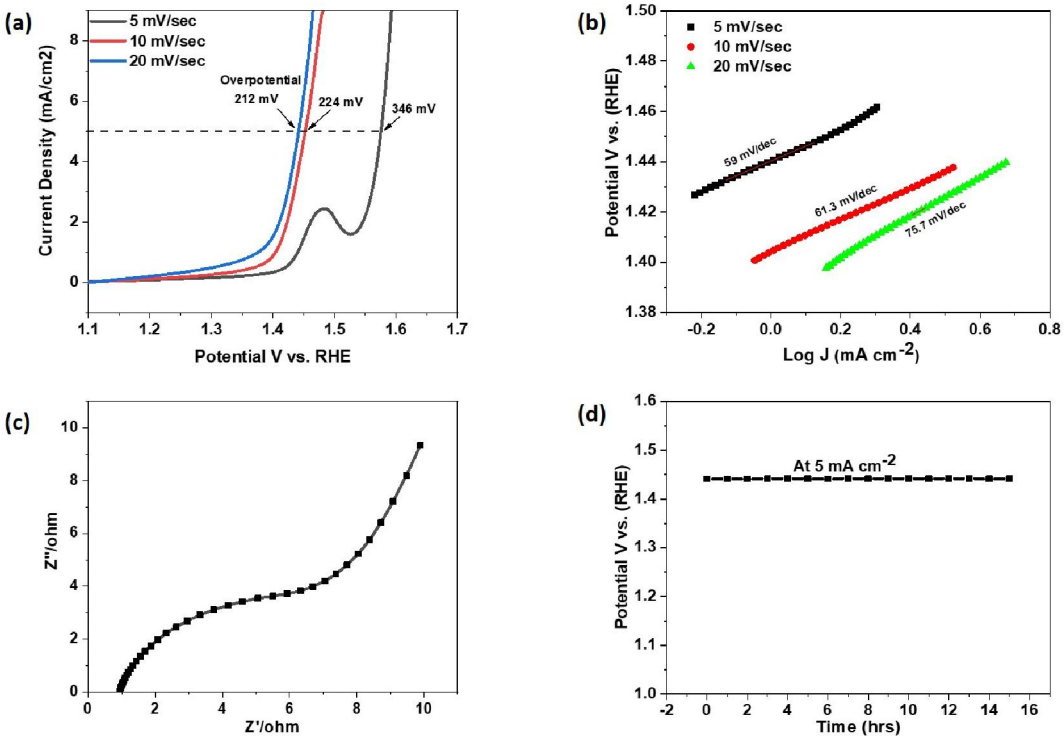

Fig.3 (a) LSV of Nio, (b) Tafel plot of NiO at various scan rate
(c) Nyquist impedance plot & (d) Stability Test of NiO at 5 mA cm^{-2}

Electrocatalyst	Synthesis Process	Electrolyte	OER(overpotential) (mV)	Tafel slope (mV dec^{-1})	Reference
NiO	Electrodeposition	1M NaOH	450	136.7	[33]
NiO	Electrodeposition	1M NaOH	450	120	[34]
NiO/NiNDs@NF	Electrodeposition	1M KOH	360	90	[35]
NiO	Chemical Bath Deposition	1M KOH	345	48	[36]
NiO	**Electrodeposition**	**1M KOH**	**212**	**75.7**	**This work**

Table 1: A comparability of OER activity with other published literature

A comparability of OER activity in this work with other published literature NiO electrocatalyst is given in Table 1. Hence electrodeposited NiO thin film electrocatalyst exhibits the excellent OER kinetics and stability in the electrochemical water splitting.

IV. CONCLUSION

We have reported NiO thin film for OER electrocatalyst in the catalytic water splitting. The NiO thin film electrocatalyst exhibited excellent OER performance and required very small overpotential 212 mV to hold the current density of 5 $mAcm^{-2}$. The small Tafel slope of 75.7 mV dec^{-1} in 1M KOH solution. This OER performance enhanced due to porous assembly and high surface area of catalyst. Hence the competent electrocatalyst with high stability and excellent catalytic behavior emphasize as an auspicious material for water splitting application.

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