

DEVELOPMENT OF MODIFIED STAINLESS STEEL ELECTRODE FOR ALKALINE WATER ELECTROLYSIS

Submitted to

GOVERNMENT OF INDIA

DEPARTMENT OF ATOMIC ENERGY

INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH



Submitted by

NANDHINI.K (40910006)

M.Sc., Chemistry (II Year)

Sathyabama Institute of Science and Technology

Semmancheri, Chennai-600119





भारतसरकार
GOVERNMENT OF INDIA
परमाणु ऊर्जा विभाग
DEPARTMENT OF ATOMIC ENERGY



सत्यमेव जयते

Dr Rajini P Antony
Scientific Officer –D
WATER AND STEAM CHEMISTRY DIVISION
भाभा परमाणु अनुसंधान केंद्र सुविधाएँ
BHABHA ATOMIC RESEARCH CENTRE
FACILITIES
कलपक्कम KALPAKKAM-603 102
Phone : 044-27480500-23349
Email : rajiniantony@igear.gov.in
raji.anna@gmail.com

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To whomsoever it may concern

Ms Nandhini K, Student, MSc Chemistry, Sathyabama Institute of Science and Technology did her internship under my supervision from 6th December 2021 to 21st December 2021 at water and steam chemistry division, Bhabha Atomic Research center, Kalpakkam facilities. This letter is issued for whatever official purpose it may serve.

Yours

Dr Rajini


21/12/21
SCIENTIFIC OFFICER / ENGINEER - E
WATER & STEAM CHEMISTRY DIVISION
Government of India
B. A. R. C. Facilities
DAE, KALPAKKAM - 603 102

ACKNOWLEDGEMENT

I want to thank my advisers Dr. Rajini. p. Antony (SO/E) and everyone at Water and Steam Chemistry Division, Bhabha Atomic Research Centre, Kalpakkam facilities for their patience and assistance during my on-site training. Thanks to their guidance, I was able to develop my industrial and research skills and learn about hydrogen production through water splitting techniques. These skills will help me to expand my resume and advance my career.

INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH

Indira Gandhi Centre for Atomic research [IGCAR], the second largest establishment of the Department of Atomic energy next to Bhabha Atomic Research Centre, was set up at Kalpakkam, in 1971 with main objective of conducting broad based multidisciplinary programme of scientific research and advanced Engineering, directed towards the development of sodium cooled Fast Breeder Reactor [FBR] technology, in India.

This is part of the second stage of Indian Atomic Energy Programme, which is aimed at preparing the country for utilization of the extensive Thorium reserves and providing means to meet the large demands of electrical energy in 21st century.

In meeting the objectives, a modest beginning was made by constructing sodium cooled Fast Breeder Test Reactor [FBTR], with nominal power of 40 MWt, based on the French reactor, RAPSODIE.

The reactor attained its first criticality on 18th Oct 1985 with maximum power level of 10.5 MWt with small core. It is the first kind in the world to use Plutonium Uranium mixed carbides as a driver fuel.

A 30 KWt, U233 fueled mini reactor [KAMINI] has been made operational for neutron radiography, neutron activation analysis etc., IGCAR utilizes its expertise and resource in enhancing its standing as a leading centre of research in various branches.

Apart from thrust areas related to nuclear technology, the centre has credentials as a leader of research in various frontiers and topical subjects like Quasi crystals, Oxide superconductor etc.

A modern library comprising 62,000 volumes of books, 28400 back volumes, about 785 journals and 1.95 lakhs reports in all disciplines caters.



WATER AND STEAM CHEMISTRY DIVISION

Head of division: Dr. T. V. Krishna Mohan

The mandate of the division is to carry out basics and applied research of excellence and relevance to Water cooled nuclear reactors to minimize corrosion to ensure integrity of structural materials in the primary, secondary and tertiary circuits, to minimize corrosion product and activity transport in the PHT circuits by stringent water chemistry control and modeling, decontamination of PHT system to reduce the man-rem problem of maintenance people of water cooled cooled reactors, to minimize Steam Generator fouling to maintain better heat transfer efficiency in secondary circuits and to minimize biofouling and its control in tertiary cooling water circuits to avoid the failure of condenser tube materials.

Advance the frontier of environmental sustainability of operational nuclear plant through biofouling research and development of spinoff technologies for societal benefits. Besides all these activities, based on R&D, wastewater treatment methodology developed and engineering facilities are devised to apply to societal needs.

FACILITIES AVAILABLE IN WSCD

- **UV-VISIBLE SPECTROPHOTOMETER**
- **HIGH PERFORMANCE LIQUID CHROMATOGRAPHY**

HPLC-Ultimate 3000, Water

- **ICP-AES and ASS**

Inductively couple atomic emission spectroscopy covering spectral range of 190 nm-700 nm

- **ZETA SIZER**

Particle size and zeta-potential measurement (ZS nano Malvern)

- **CONFOCAL LASER RAMAN MICROSCOPE**

532nm and 785nm Laser with CCD detector covering a spectral range of 190-700nm

- **ATOMIC FORCE MICROSCOPE**

An essential tool for Micro structural analysis.

ALKALINE WATER ELECTROLYSIS

Alkaline water electrolysis is used to split water into gases of hydrogen and oxygen using electricity.

At cathode, water molecules are reduced by electron to hydrogen and negatively charged hydroxide ions.

At anode, hydroxide ions are oxidized to oxygen and water while releasing electrons.

Overall, water molecules react to hydrogen and oxygen in the ratio of 2:1

The alkaline water electrolysis is advantageous related to polymer membrane water electrolysis because the non precious inexpensive electrode is used for both anode and cathode.

However currently the energy efficiency of hydrogen production using alkaline water electrolysis is insufficient and should be improved from an economical perspective.

The anode material used in alkaline water electrolysis is exposed to an oxidative atmosphere and continuous evolution of oxygen micro bubbles inducing chemical and biological degradation.

Therefore, highly active and durable novel electrodes are required to improve the efficiency of alkaline water electrolysis.

The first row transition element and their oxides have attracted significant attention.

In particular, the nickel which is deposited in a stainless steel electrode which act as an anode in alkaline electrolysis because of its high OER performance among other transition metal.

ELECTRODEPOSITION

Electrodeposition which is also known as electrolytic deposition is the conventional process of coating a thin layer of one metal on top of a different metal to modify its surface properties.

Based on the principle of electrolysis, it is a process that uses electrical current to reduce the cation of a desired material from an electrolyte and coat those materials as a thin film onto a conductive substrate surface.

This is done to achieve the desired electrical and corrosion resistance, reduce wear and friction, improve heat tolerance and for decoration.

Hence the surface properties of a material can be tailored and new materials for a variety of application can be explored through this technique.

ELECTRODEPOSITION BY DIFFERENT METHOD

- Chronoamperometry
- Chronopotentiometry
- Cyclic Voltammetry

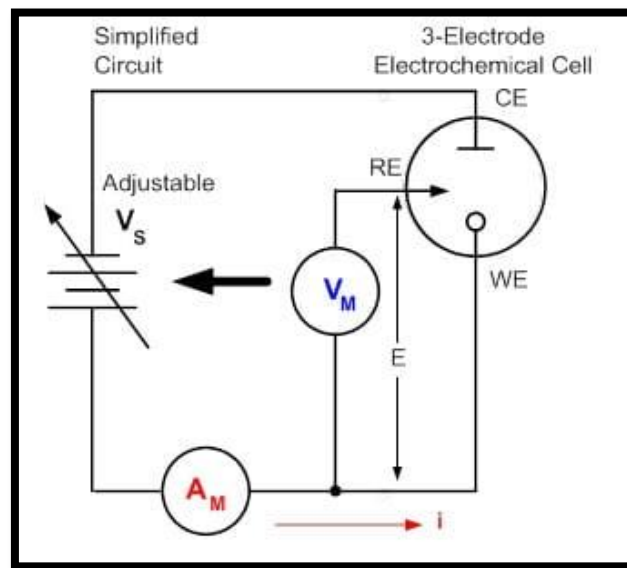
CHRONOAMPEROMETRY

Chronoamperometry is an electrochemical technique in which the potential of the working electrode is stepped and the resulting current from faradic processes occurring at the electrode is monitored as a function of time.

The functional relationship between current response and time is measured after applying single or double potential step to the working electrode of the electrochemical studies.

Limited information about the identity of the electrolyzed species can be obtained from the ratio of the peak oxidation current versus the peak reduction current.

Most commonly a three electrode system is used. Since the current is integrated over relatively longer time intervals, chronoamperometry gives a better signal to noise ratio in comparison to other amperometric techniques.



CHRONOPOTENTIOMETRY

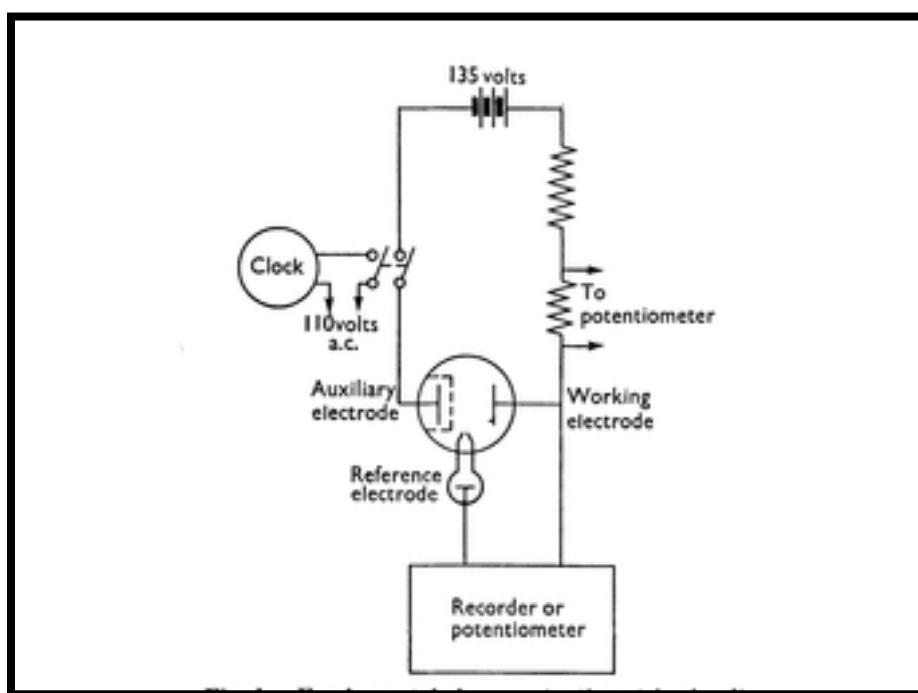
Chronopotentiometry is a galvanostatic method in which the current at the working electrode is held at a constant level for a given period of time.

The working electrode potential and current are recorded as a function of time.

This method is used to study chemical reaction mechanism and kinetics.

It is also frequently used to study batteries and electrodeposition.

Typically, current is held constant between working and counter electrodes while potential is measured at the working electrode, relative to the reference electrode.



CYCLIC VOLTAMMETRY

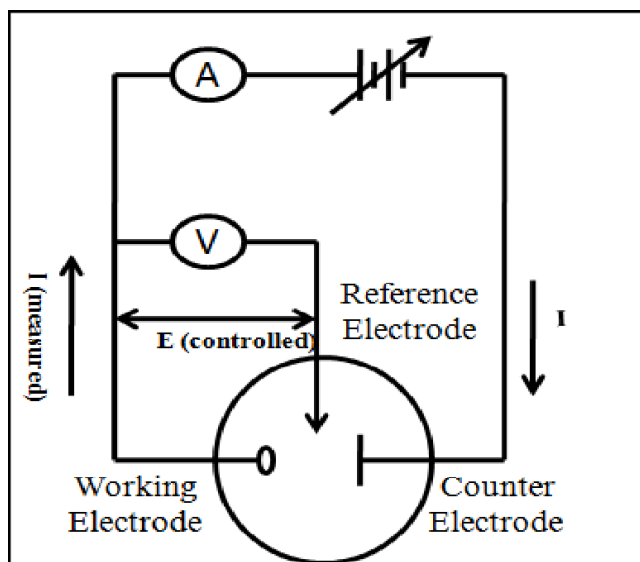
Cyclic voltammetry is a type of potentiodynamic electrochemical measurement.

In a cyclic voltammetry experiment, the working electrode potential is ramped linearly versus time.

Unlike in linear sweep voltammetry, after the set potential is reached in a CV experiment, the working electrode potential is ramped in the opposite direction to return to the initial potential.

The current at the working electrode is plotted versus the applied voltage to give the cyclic voltammogram trace.

Cyclic voltammetry is generally used to study the electrochemical properties of an analyte in solution or of a molecule that is adsorbed on to the electrode.



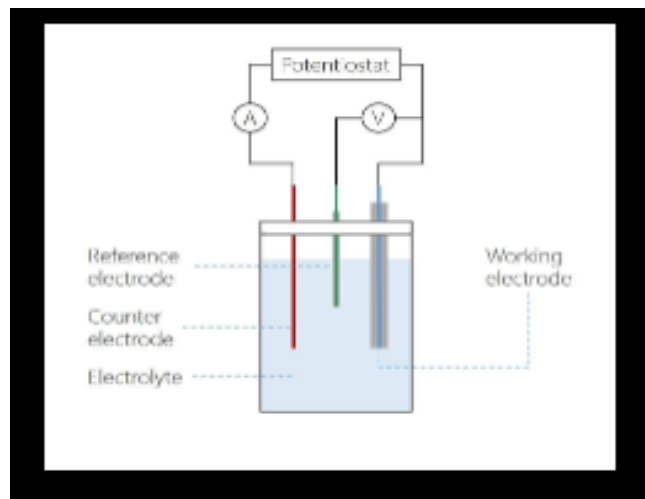
STUDIES MADE DURING MY INTERNSHIP

Using these three methods the electrodeposition was done in a stainless mesh.

Nickel is deposited in a stainless steel electrode using chronoamperometry and chronopotentiometry under different experimental conditions in a three electrode configuration.

The three electrode configuration consists of working, counter and reference electrode and electrolyte.

- Working electrode: SS mesh
- Reference electrode: Ag-AgCl (3M)
- Counter electrode: Platinum electrode
- Electrolyte: Nickel sulphate hexa hydrate



Experimental condition

Chronoamperometry:

Potentials: -0.9V, -1V, -1.3V, -1.5V

Time for deposition: 120s

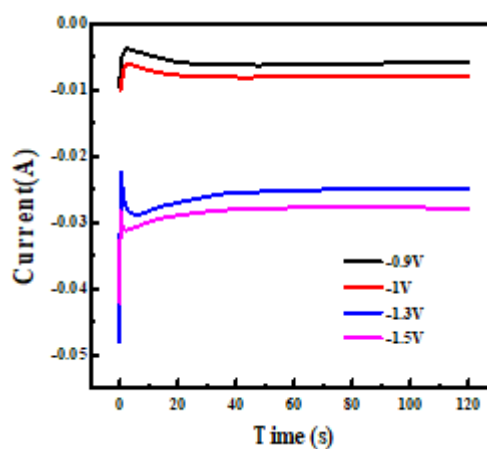
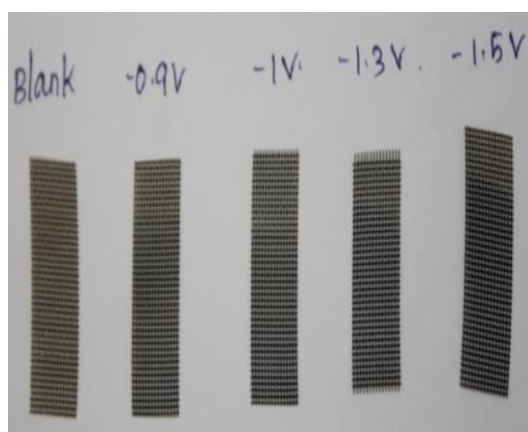
Chronopotentiometry:

Current: -0.02A, -0.03A, -0.05A, -0.07A

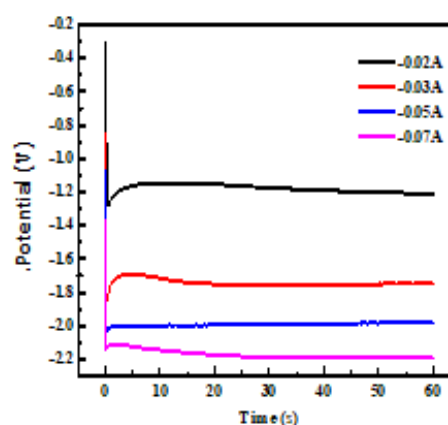
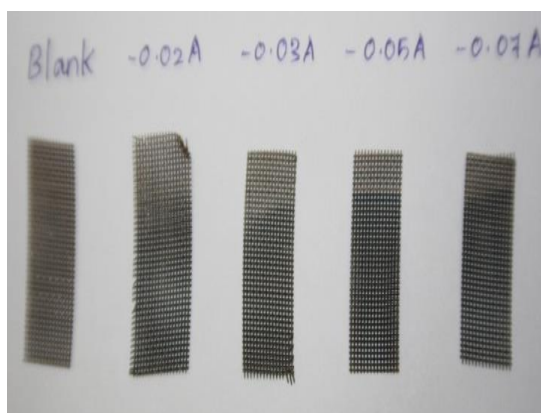
Time for deposition: 60s

The electrode after deposition of nickel:

Chronoamperometry



Chronopotentiometry



Thus with the help of data the deposition will be best for chronoamperometry is -1.5V and for chronopotentiometry is -0.007A.

That is when the potential or current increases the deposition is also increase.

CONCLUSION

Thus the electrodeposition is a cost effective and high through-put method for fabricating low dimensional electrodes.

With the help of electrodepositing the nickel in SS mesh increases the efficiency of alkaline water electrolysis.

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IIT Kharagpur

Jul-Oct 2021
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