Structural and morphological analysis of hydrothermally fabricated ternary palladium alloys for use as efficient catalysts in dye sensitized solar cell counter electrodes

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Outline

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- Aims & Objectives
- Methodology
- Results
- References
- Acknowledgements

Background of Study

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- Greater demand for more energy necessitated by the rising world population and high global economic development[1].

- The need to limit the emission of toxic materials into the atmosphere

- Geopolitical instability causes fluctuation of oil prices

- Turn to renewable energy sources to fill the void created by depletion of fossil fuels as well as to fulfil the stringent environmental regulations enacted by various governments

- Potential alternatives include the DSSC technology which was invented by Gratzel in 1991 mimicking the conversion of sunlight into energy by plants[2].

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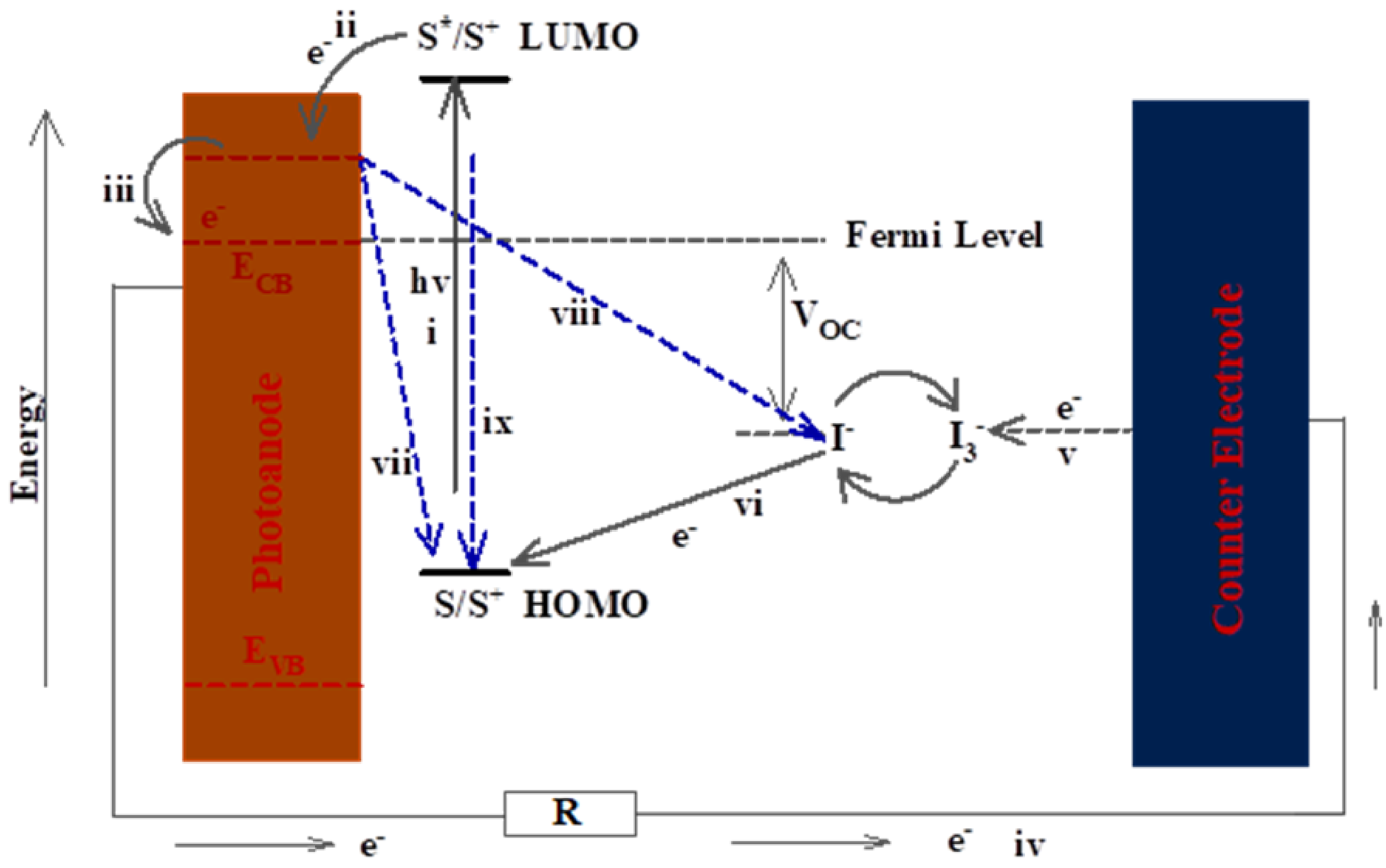

Fig 1: Operational procedure for a DSSC

Background of study

Advantages

- Produce energy from cleaner sources.
- Reduce emissions
- Reduce deforestation
- Simple operating procedure

Disadvantages

High fabrication costs associated with the expensive ruthenium and platinum metals.

Low conversion efficiency 13.4%

Possible improvements

- Elimination of liquid electrolyte.
- Replace ruthenium dye with other inorganic dyes
- Replace platinum counter electrode with core shell alloys whose efficiency is higher than that of platinum.

DSSC

Background of Study

- Pure transition metal elements that have been explored up to date have only given low efficiencies leading to development of higher multi-metallic systems

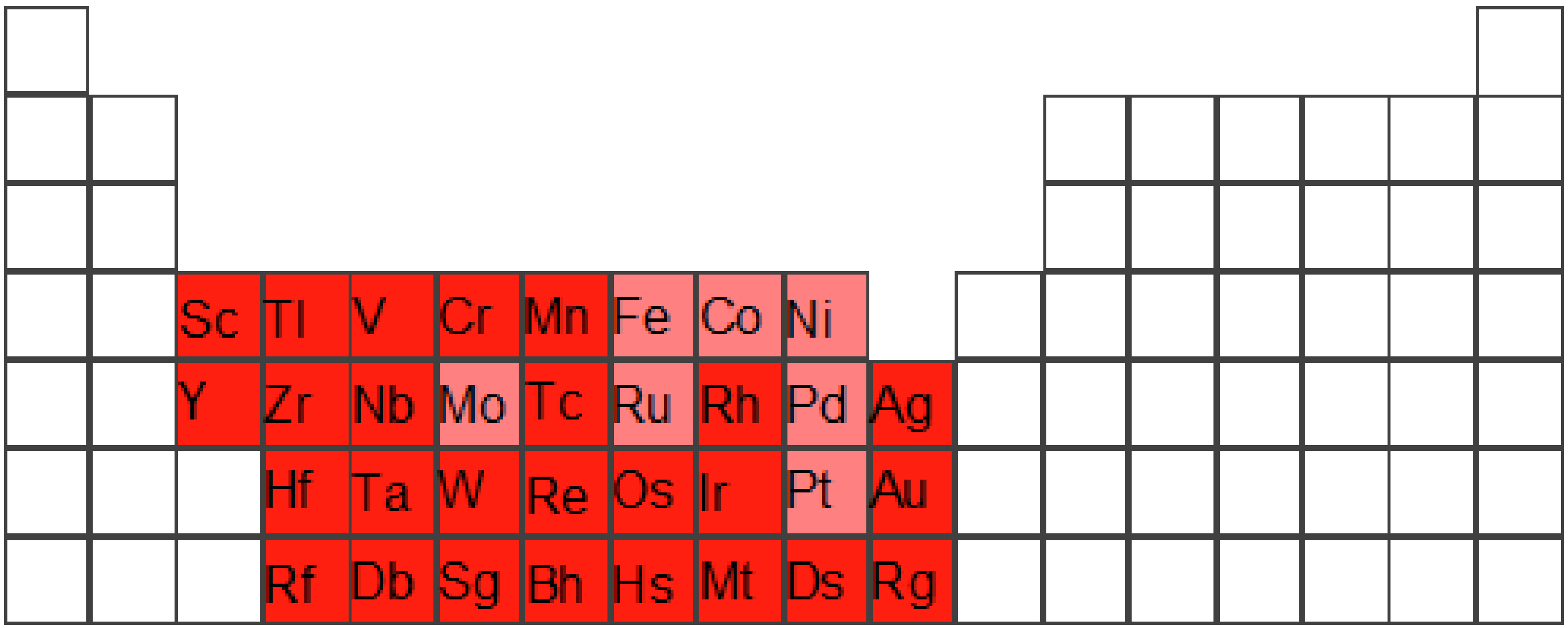

Fig 2:Periodic Table of elements

Background of Study

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- Use of ternary transition metal composites or alloys where each component serves a particular function. The more reactive metal would ideally occupy the outer part so as to partake in interfacial reactions.

- Ternary alloys possess excellent catalytic qualities which are due to the synergistic effect produced by the existence of three elements in a crystal structure.

- Synergy created by the interaction of two metals results in electron transfer which increases surface interaction with the electrolyte[3].

Aims and objectives

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Aim

- Synthesize ternary palladium alloy CE for DSSC use.

Objectives

- To synthesise PdNiCo, PdNiZn, ternary alloys
- Determine the structure and morphology of the synthesised counter electrodes using XRD and SEM respectively
- Evaluate the electrochemical properties of the developed catalyst samples using CV EIS and CD
- Determine the effect of varying the composition of the alloy on the performance of the counter electrode.

Methodology

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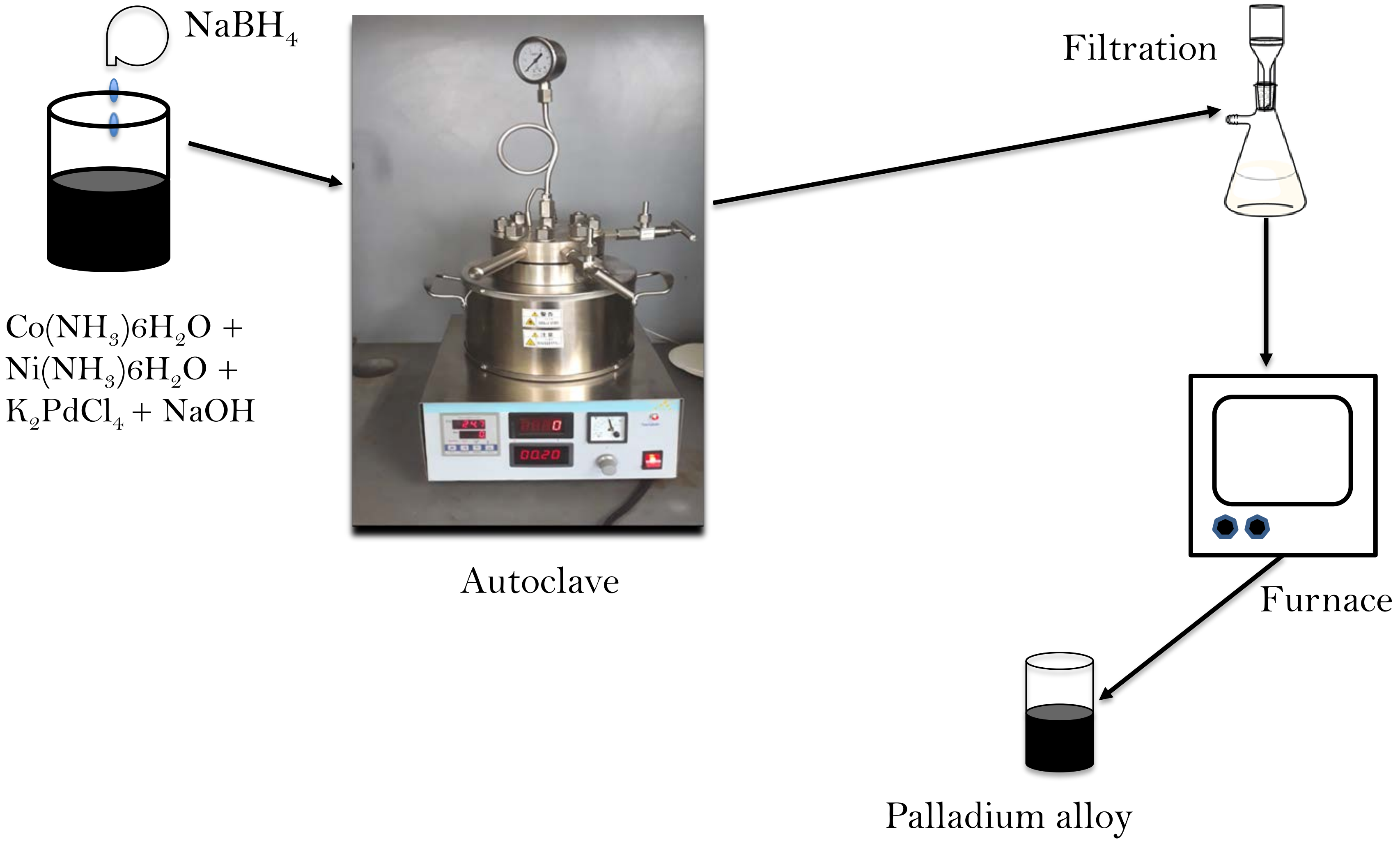

Fig 3:Schematic diagram of ternary palladium alloy fabrication

Results:XRD

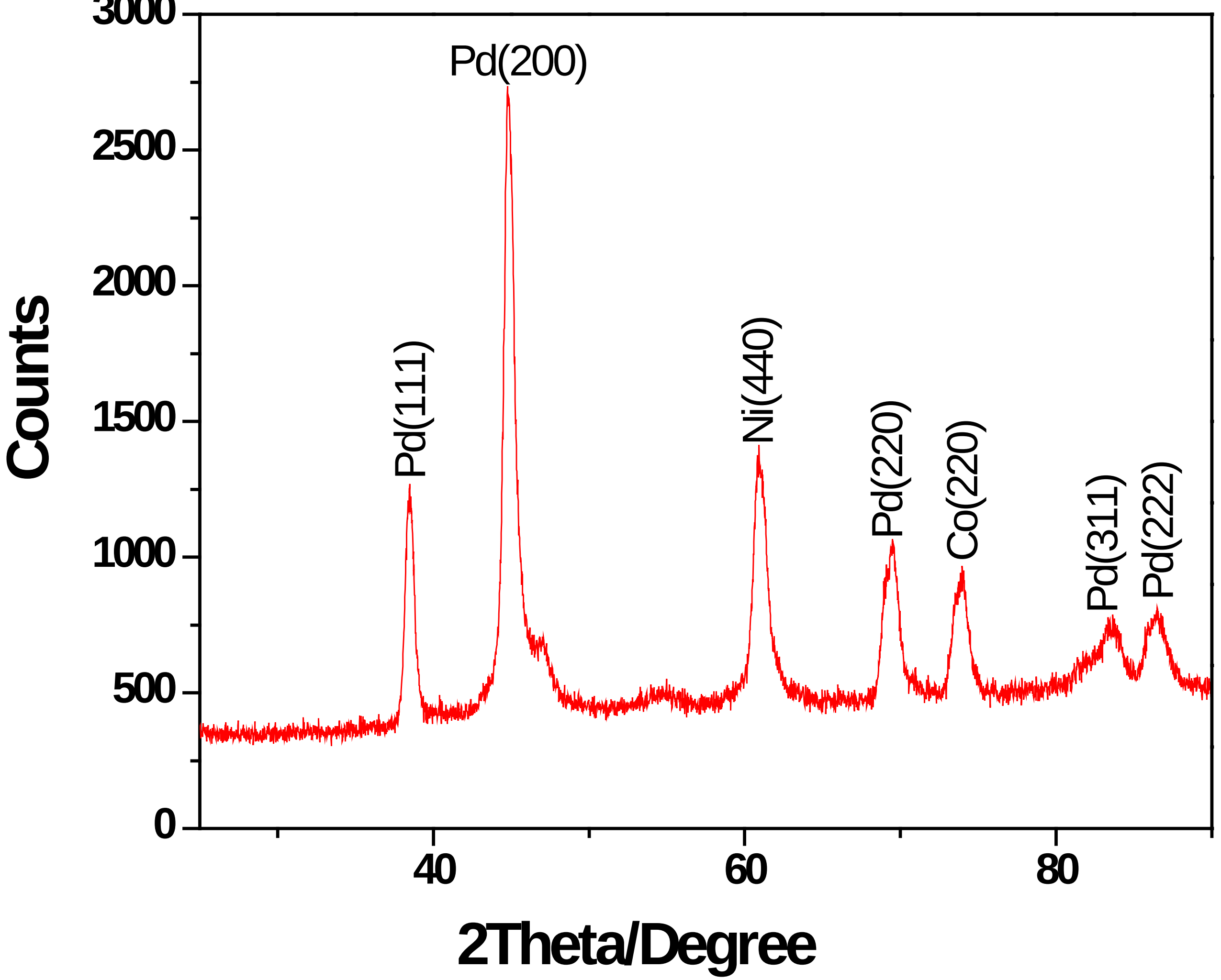

Figure 4: XRD image of PdNiCo

Results:XRD

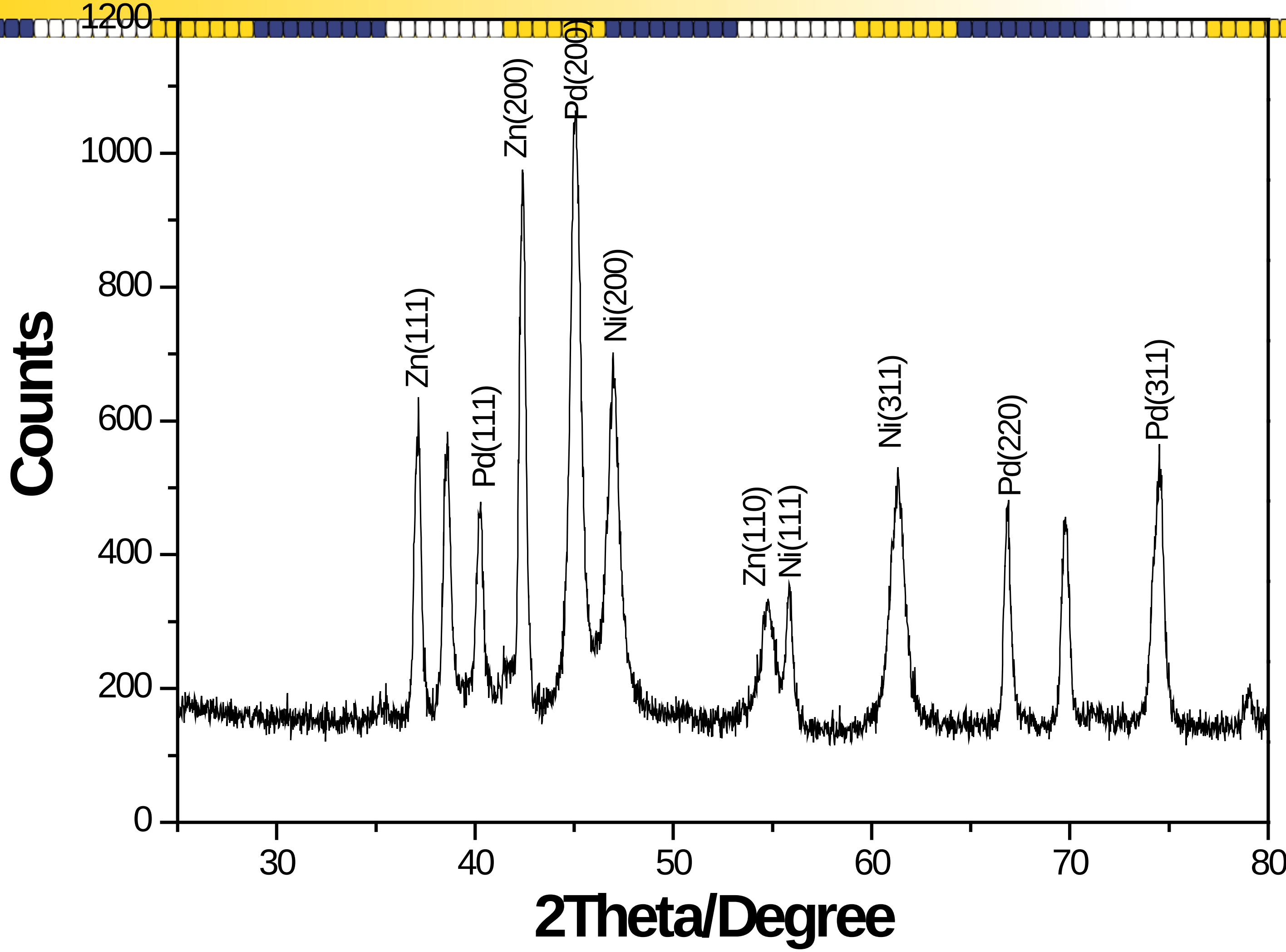

Figure 5: XRD image of PdNiZn

Results: SEM

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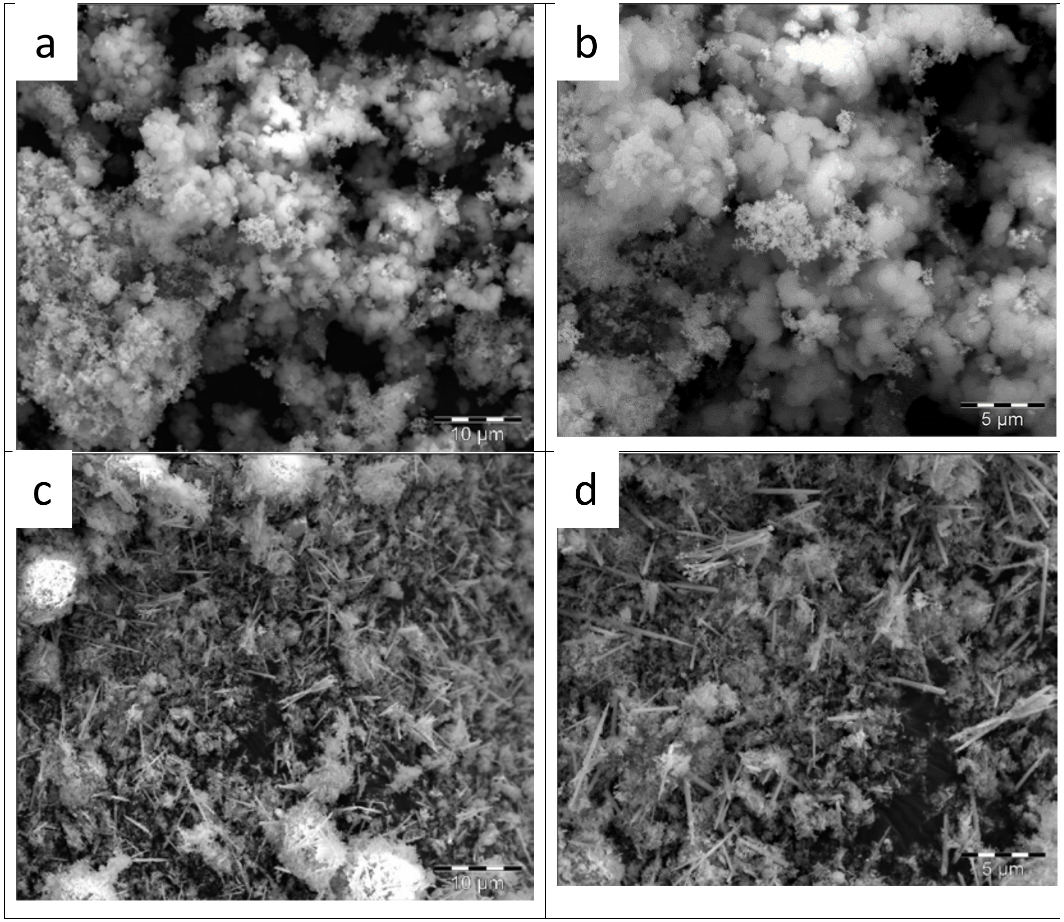

Figure 6: SEM images of (a and b) low and high magnification of PdNiCo respectively (c) and (d)PdNiZn

Results

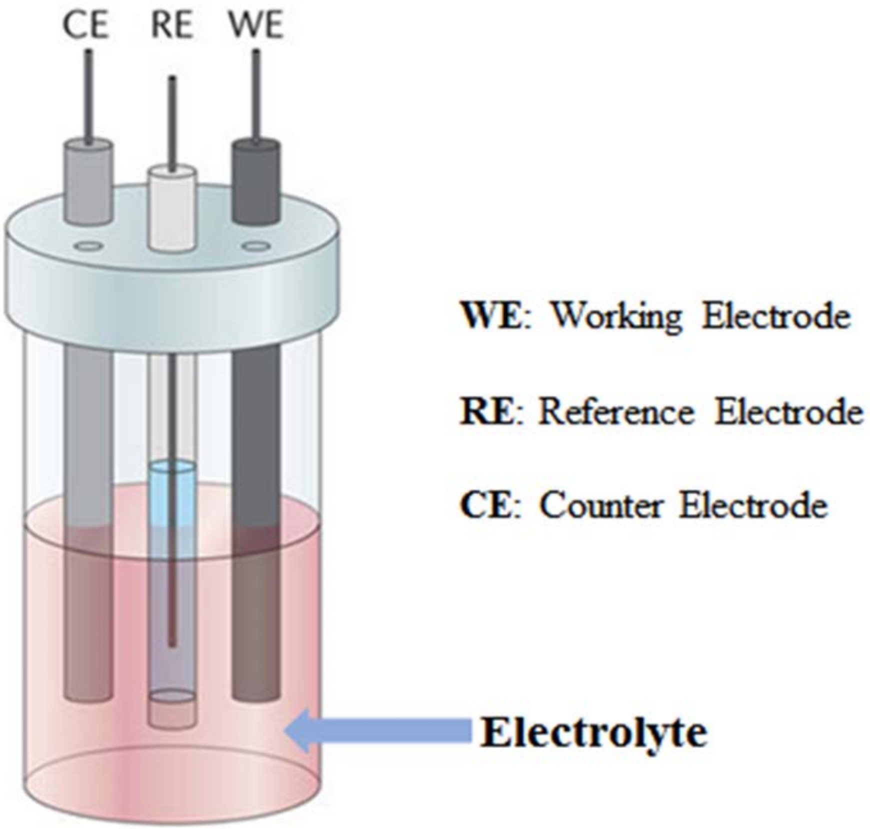

Fig:7 Three electrode cell configuration

Results: CV

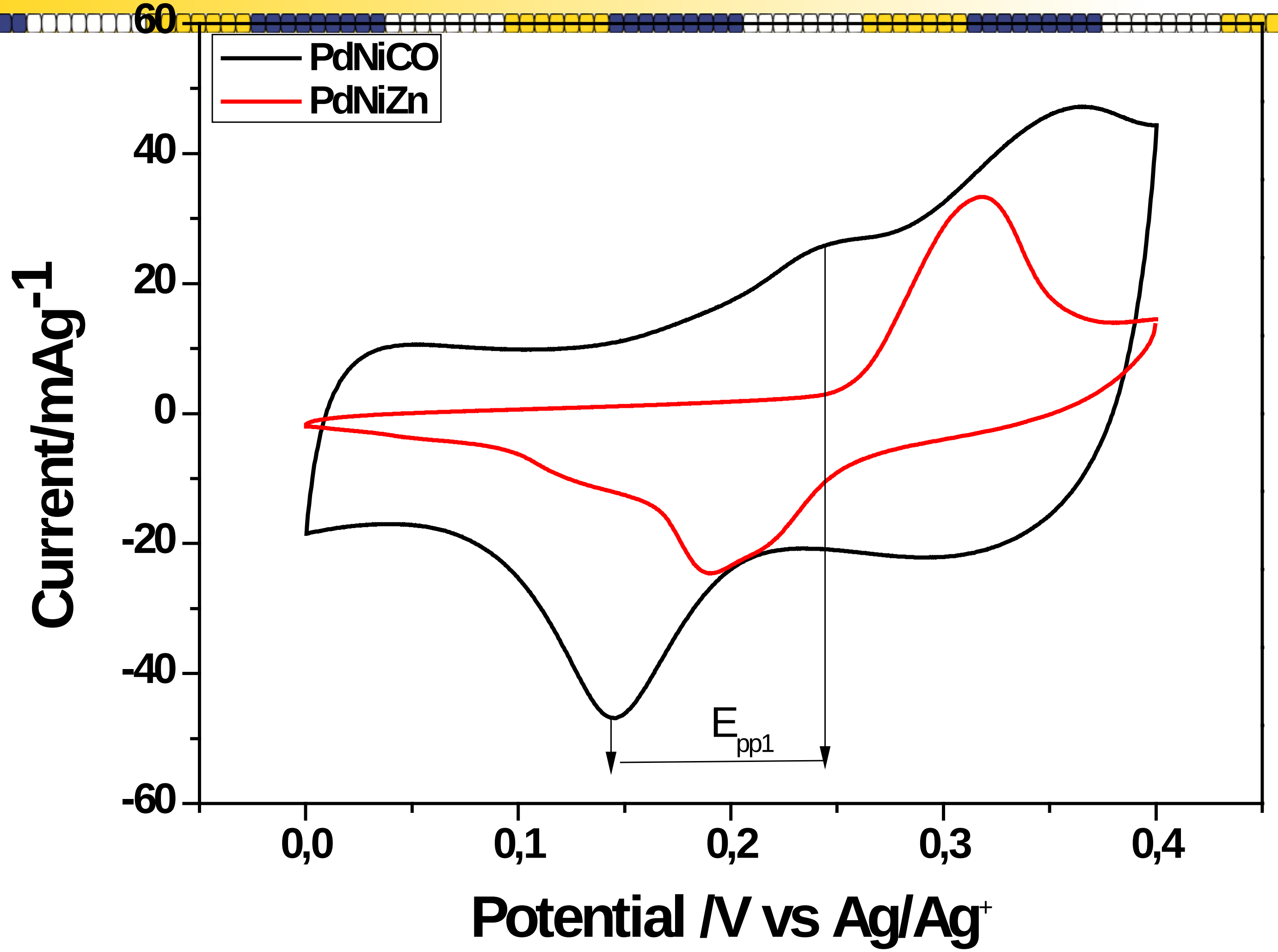

Fig 8: Cyclic Voltammetry graphs for ternary palladium alloys at 50mVs

Results :EIS

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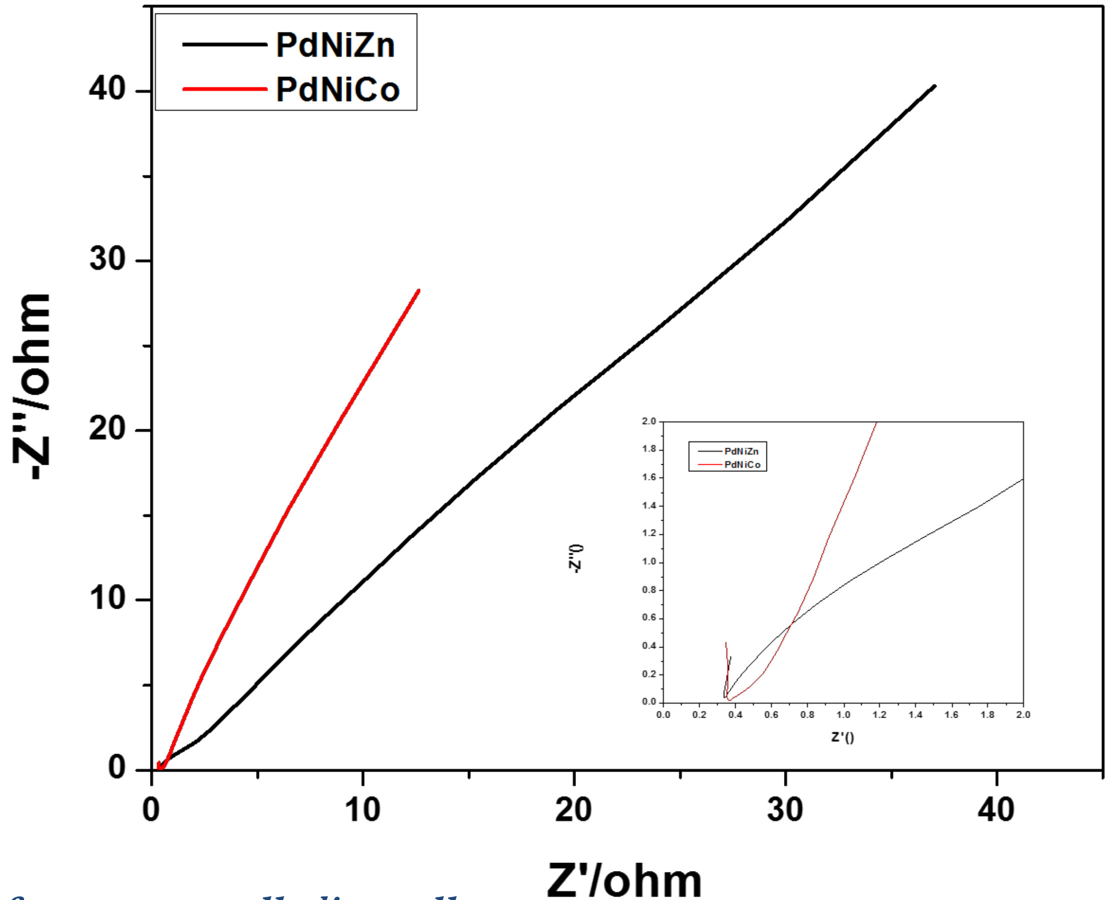

Fig 9: EIS graphs for ternary palladium alloys

Results :CD

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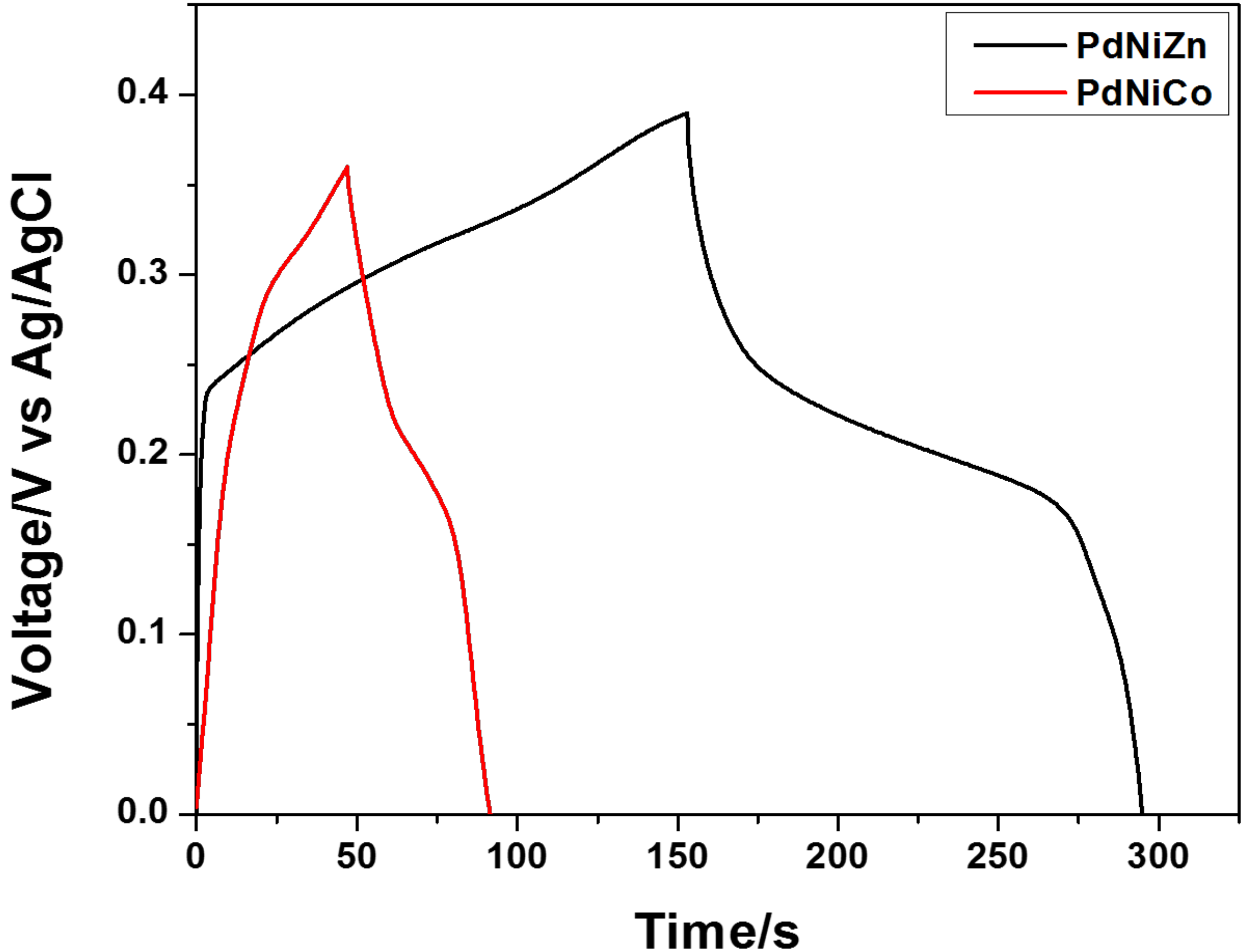

Fig 10: CD curves for PdNiZn and PdNiCo

Conclusion

- XRD has shown 5 dominant peaks at 2 theta values of 40°, 46.2°, 63.2,° 71.2°,75.1°,83.3° and 86.1° for PdNiCo whereas PdNiZn had peaks at 43.2° , 46.4° ,45.6°, 62.3°, 67.4° and 75.2°.
- SEM identified spherical densely packed PdNiCo particles whereas PdNiZn was composed of nanoneedles.
- CV results showed that PdNiZn had more reduction current density however it also possessed a higher peak to peak potential difference signifying a lower rate of reduction intensity.
- From EIS analysis PdNiZn possessed the least charge transfer resistance at 0.32ohm with PdNiCo not performing any worse at 0.36 ohm.
- Charge discharge graphs show that PdNiZn slowly discharges electrical energy hence it is a potential material for use in capacitors.

References

- 1.Ali N.,Hussain A.,Ahmed R.,Wang MK., Zhao C.,Ul Haq B., Fu Y.Q.Renew.Sust. Energ. Rev. 59 (2016) 726-737.
- 2. Theerthagiri J., Senthil A., Madhavan J., MaiyalaganT,.Review on recents progress in non platinum counter electrode materials for Dye-Sensitized solar cells, ChemEletroChem 2 (2015) 928-945.
- 3.O'Regan B, Gratzel M. A low-cost, high-efficiency solar cell based on dye sensitized colloidal TiO2 films. Nature 1991; 353, 737–40.
- 4. Dong, J., Wu, J.H., Jia, J.B., Hu, L.H., Dai, S.Y., 2015. Sol. Energy 122, 326–333.
- 5. Cocking JL., Johnson GR., Richards PG. Platinum Metals Rev 1985, 29 (1)17- 26
- 6. Bond GC, 'Catalysis by Metals', Academic Press, London, 1962, 206,573
- 7. Sun L., Lu L.,Bai Y., Sun K. Alloys and compounds 654 (2016) 196-201.

Acknowledgment

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