iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VII Month of publication: July 2023

DOI: https://doi.org/10.22214/ijraset.2023.54832

Fuzzy Interface System for the Prediction of Optical Properties of ZnO Thin Film

Nikam S. V.[1], B. T. Jadhav[2], S. M. Chiwate[3], G. S. Nhivekar[4]
[1]Rayat Institute of Research and Development, [2]Department of Nanoscience and Technology, [4]Department of Electronics, YCIS Satara
[3]Department of Electronics, Dr. Vishwanath Karad, MITWPU, Pune

Abstract: A fuzzy logic approach is widely used in predicting and controlling the process parameters. This paper presents FIS for the prediction of optical properties of aqueous ZnO thin film prepared by spray pyrolysis method. The impact of various process parameters such as precursor concentration, solution flow rate, substrate temperature and annealing temperature on transmittance and band-gap have been considered. FIS modeling and simulation carried out in Matlab using fuzzy logic toolbox. The results obtained from simulation shows good agreement with experimental results. It can predict 95.46% accurate transmittance and 99.45% accurate bandgap values.
Keywords: FIS, spray pyrolysis method, optical properties, modeling, simulation

I. INTRODUCTION

ZnO is highly transparent semiconductor material with wide band-gap energy. It has tremendous applications in optoelectronic devices and sensor technology. The thin films of oxides can be synthesized by various methods. The most common techniques used for preparation of thin films are Silar, CBD, CVD, electro-spinning, electrodeposition, spray pyrolysis, etc. [1].
The spray pyrolysis technique is most widely used to deposit thin films. Physiochemical properties of deposited film are greatly affected due to process parameters [2]. Therefore, to achieve the desire requirements of physiochemical properties one must know about the precise values of process parameters. Generally, researchers decide it by performing literature review and further performing experiments again and again. Hence it is time consuming as well as expensive too. Fuzzy logic simulation approach provides better solution for it [3]. It provides predictive model for the thin film properties [4].

II. MATERIAL AND METHODS

Zinc oxide thin films were deposited on glass substrate by using aqueous solution of Zinc acetate dehydrate, with the help of spray pyrolysis technique. The effect of various process parameters such as precursor concentration, spray rate, substrate temperature and annealing temperature on optical properties i.e., transmittance and band-gap were evaluated. Further, obtained experimental data was used to design fuzzy interface system for the prediction of transmittance and band-gap of ZnO thin film deposited by spray pyrolysis technique. The details of FIS are represented in this paper.

A. *Designing of Fuzzy Interface System*

The fuzzy interface system model was designed using Matlab fuzzy logic toolbox. Mamdani fuzzy interface model was most widely used due to its accuracy and rules that based upon linguistic variables [5]. Hence in this work also Mamdani fuzzy interface model was used to design the system. The optical properties such as transmittance and band-gap are significantly depending upon input process parameters of spray system, which include precursor concentration, substrate temperature, solution flow rate and annealing temperature. The structure of FIS is as shown in figure 1 given bellow. This figure 1 clearly indicate that inputs are get ANDed together to give desired output of fuzzy interface system.

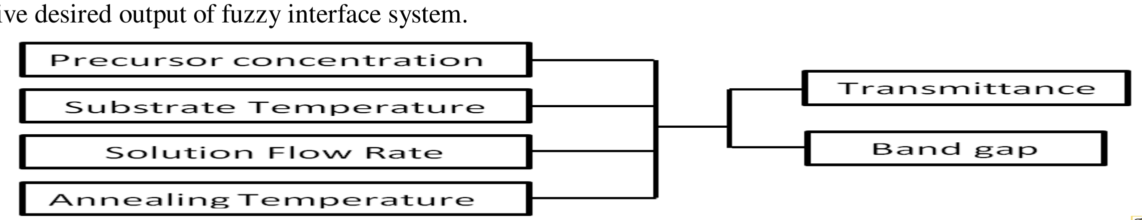


Fig 1. The Structure of FIS to predict optical properties of ZnO thin film.

The structure of FIS in Matlab fuzzy logic toolbox was depicted in fig. 2.

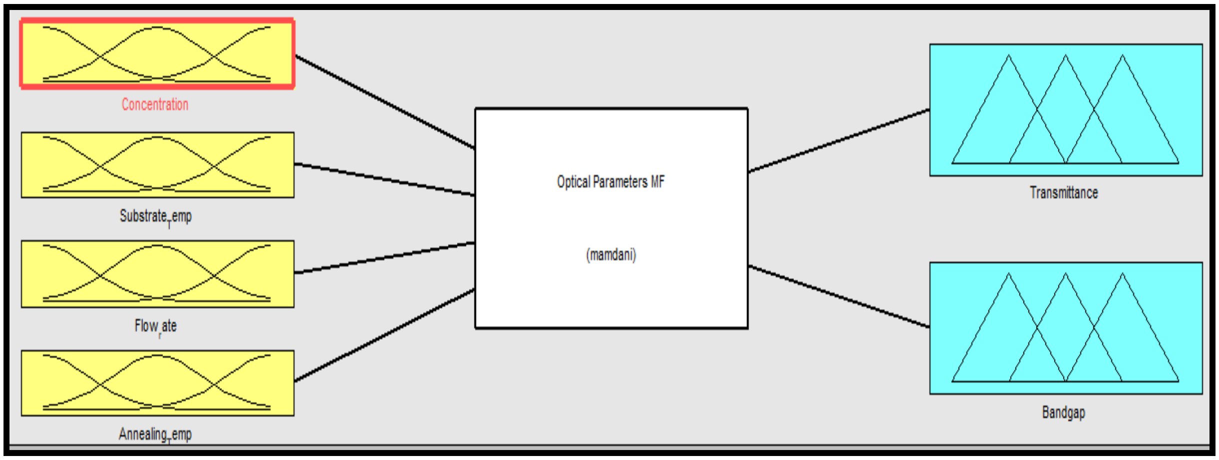


Fig 2. Structure of FIS in fuzzy logic toolbox for prediction of optical properties of ZnO thin film

B. Designing of Membership Function

There are six membership functions for each input and output constraint. To describe the fuzzy set triangular membership function were used. Each input was partitioned as per their defined experimental range of parameter [6]. Membership function for fuzzy set input precursor concentration, substrate temperature, solution flow rate, annealing temperature where as shown in figure 3 (a) – (d) and that for output transmittance and band-gap was illustrate in figure 3 (e) – (f).

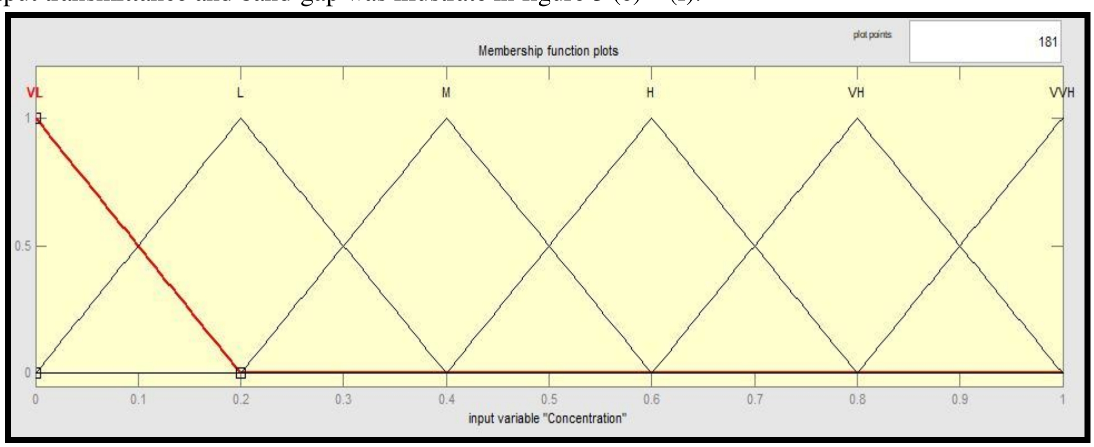


Fig. 3 (a) Membership function for precursor concentration

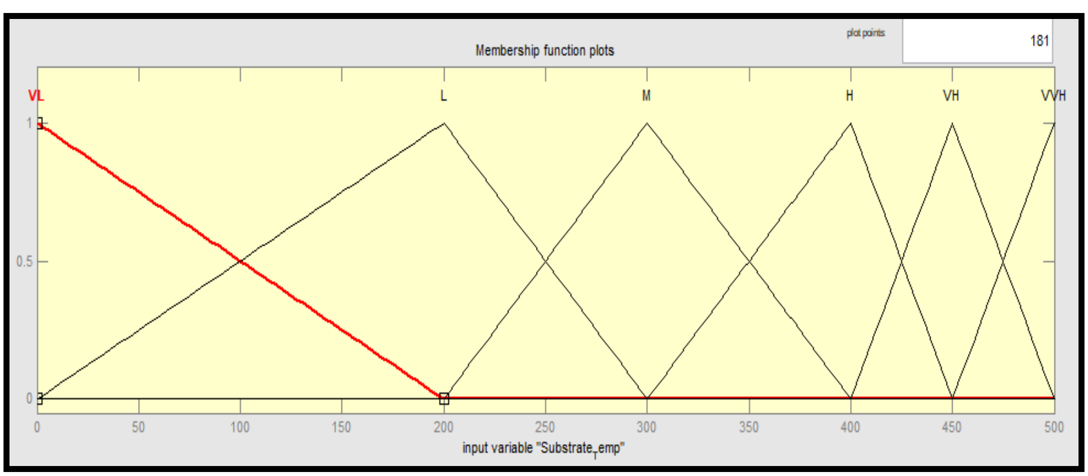


Fig. 3 (b) Membership function for substrate temperature

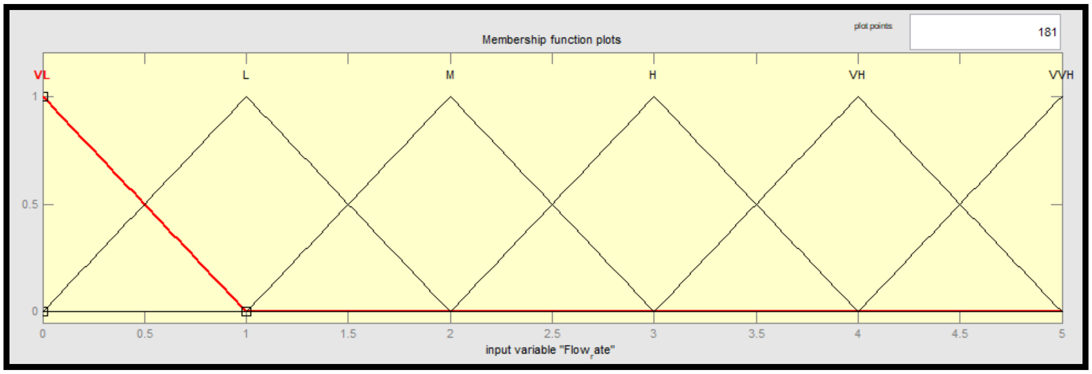


Fig 3 (c) Membership function for flow rate

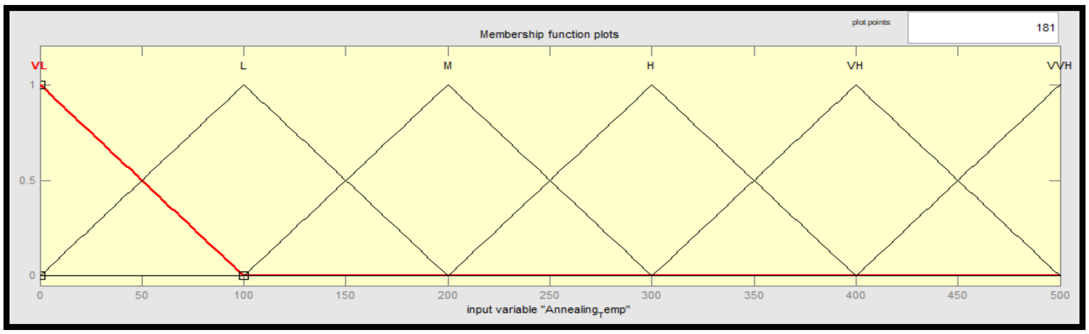


Fig 3 (d) Membership function for annealing temperature

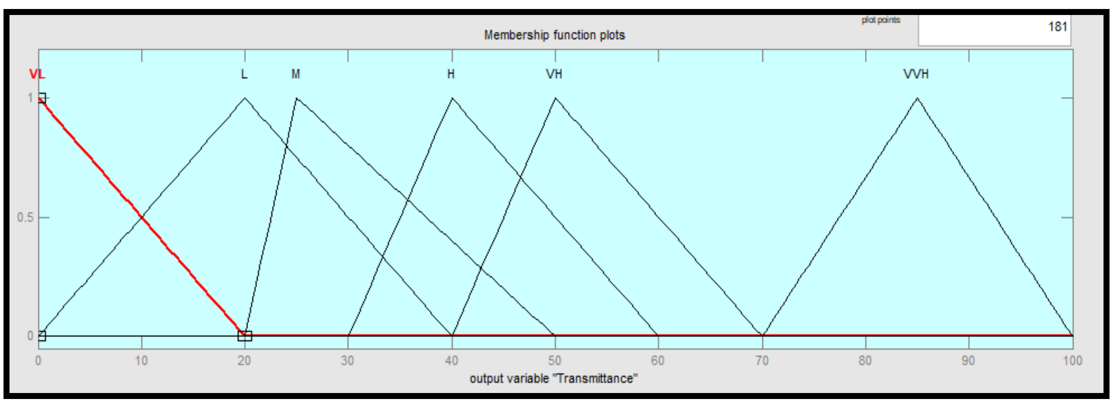


Figure 3(e) Membership function for transmittance

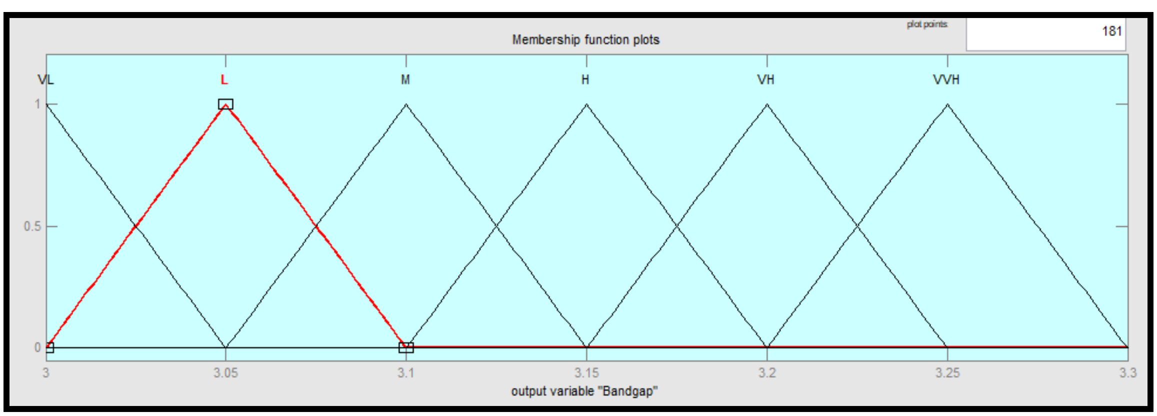


Figure 3(f) Membership function for band-gap

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VII Jul 2023- Available at www.ijraset.com

C. Fuzzy Rules

A set of 22 rules have been defined with the help of actual experimental data. These rules are defined as bellow.

1) If (Concentration is VL) and (Substrate_Temp is M) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
2) If (Concentration is VH) and (Substrate_Temp is M) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is M)(Bandgap is M) (1)
3) If (Concentration is M) and (Substrate_Temp is H) and (Flow_rate is M) and (Annealing_Temp is H) then (Transmittance is VVH)(Bandgap is VH) (1)
4) If (Concentration is M) and (Substrate_Temp is H) and (Flow_rate is M) and (Annealing_Temp is VH) then (Transmittance is VVH)(Bandgap is VH) (1)
5) If (Concentration is M) and (Substrate_Temp is H) and (Flow_rate is M) and (Annealing_Temp is VVH) then (Transmittance is VVH)(Bandgap is VH) (1)
6) If (Concentration is L) and (Substrate_Temp is M) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VH)(Bandgap is VH) (1)
7) If (Concentration is M) and (Substrate_Temp is M) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is H)(Bandgap is VH) (1)
8) If (Concentration is H) and (Substrate_Temp is M) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is M)(Bandgap is M) (1)
9) If (Concentration is VVH) and (Substrate_Temp is M) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is L)(Bandgap is L) (1)
10) If (Concentration is M) and (Substrate_Temp is VL) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VL)(Bandgap is VH) (1)
11) If (Concentration is M) and (Substrate_Temp is L) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is L)(Bandgap is VH) (1)
12) If (Concentration is M) and (Substrate_Temp is H) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VH)(Bandgap is VH) (1)
13) If (Concentration is M) and (Substrate_Temp is VH) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VH)(Bandgap is VH) (1)
14) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VH) (1)
15) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is VL) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
16) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is L) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
17) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is M) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
18) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is H) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
19) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is VH) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
20) If (Concentration is M) and (Substrate_Temp is VVH) and (Flow_rate is VVH) and (Annealing_Temp is M) then (Transmittance is VVH)(Bandgap is VVH) (1)
21) If (Concentration is M) and (Substrate_Temp is H) and (Flow_rate is M) and (Annealing_Temp is VL) then (Transmittance is L)(Bandgap is H) (1)
22) If (Concentration is M) and (Substrate_Temp is H) and (Flow_rate is M) and (Annealing_Temp is L) then (Transmittance is VH)(Bandgap is H) (1)

D. Defuzzification

It is the process of converting fuzzy inputs to the crisp output [6, 7].

Different kind of defuzzifyng methods are available some of them are centroid, Mean-Max Membership, Centre of Sums, Centre of Largest Area, Weighted Average Method. To achieve the accuracy of fuzzy reasoning model selection of defuzzification method plays vital role. The 'centre of area' method is widely used due to its more accurate and precise results as compared to other methods. Therefore in this work centre of area method was employed [8, 9].

III. RESULTS AND DISCUSSION

The simulation of proposed fuzzy interface system is as shown in fig. 4 Matlab FIS rule viewer.

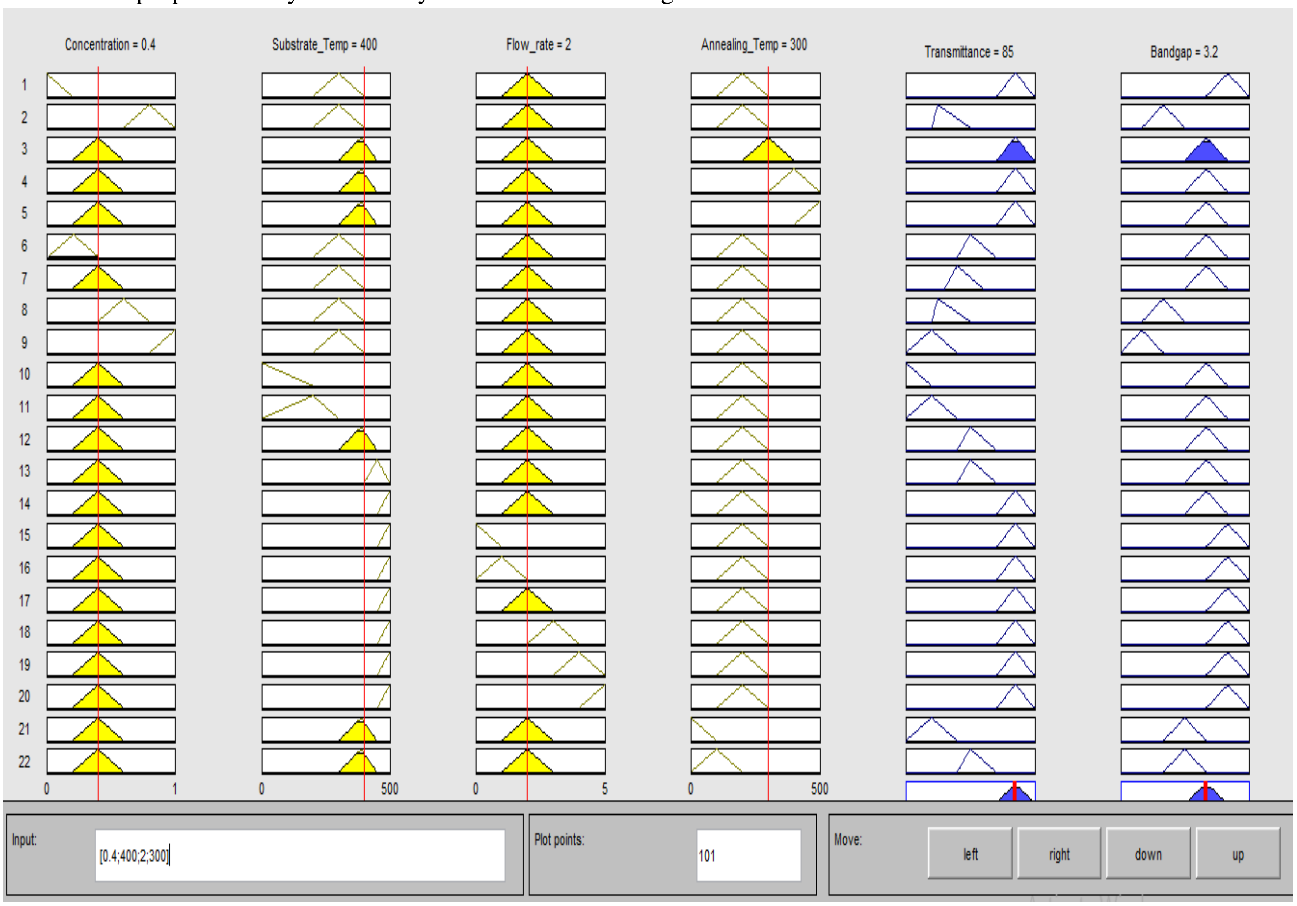


Fig. 4. FIS Rule Viewer

Following table 1 and 2 shows the FIS evaluation results for various input parameters and corresponding outputs. Further the system accuracy was calculated by finding average accuracy of total number of data sets evaluated.

Table I:
COMPARATIVE RESULTS OF ZNO THIN FILM TRANSMITTANCE BASED ON ACTUAL EXPERIMENTAL RESULTS AND PREDICTED BY FUZZY MODEL.

Sr. No.	Input parameters				Output (Transmittance)		%Error	% Accuracy
	Conc.	Substrate Temp	Flow Rate	Annealing Temp	Experimental	Predicted by Fuzzy Model		
1	0.2	300	2.5	200	51.77	53.9	-4.11	95.89
2	0.4	400	2.5	200	55.44	53.9	2.78	97.22
3	0.4	500	5	200	77.3	85	-9.96	90.04
4	0.4	400	2	400	86.1	85	1.28	98.72
System Accuracy for transmittance prediction =								95.46

Table II

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VII Jul 2023- Available at www.ijraset.com

COMPARATIVE RESULTS OF ZNO THIN FILM BANDGAP BASED ON ACTUAL EXPERIMENTAL RESULTS AND PREDICTED BY FUZZY MODEL.

Sr. No.	Input parameters				Output (Bandgap)		%Error	% Accuracy
	Conc.	Substrate Temp	Flow Rate	Annealing Temp	Experimental	Predicted by Fuzzy Model		
1	0.2	300	2.5	200	3.18	3.20	-0.63	99.37
4	0.4	400	2.5	200	3.19	3.20	-0.31	99.69
7	0.4	500	5	200	3.27	3.25	0.61	99.39
9	0.4	400	2	400	3.22	3.20	0.62	99.38
System Accuracy for Bandgap prediction =								99.45

It is observed that Fuzzy Interface system shows good agreement with experimental results. It can predict 95.46% accurate transmittance and 99.45% accurate Bandgap values for aqueous ZnO thin films deposited by spray pyrolysis method.
The input variables 'concentration' vs 'substrate temperature' was plotted against transmittance and bandgap to find the relation between both attributes in the prediction of transmittance and bandgap as shown in figure 5 and 6.

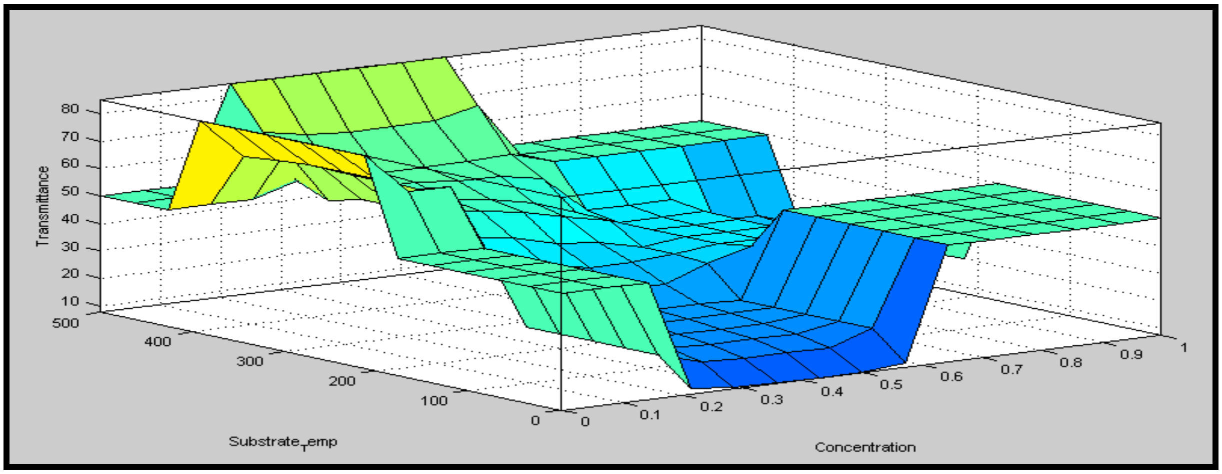


Figure 5: Surface view plot for Concentration Vs Substrate Temperature against Transmittance

From figure 5 it is observed that if the values of precursor concentration is in the range of 0 to 1 molar and for substrate temperature in the range of 0 to 500°C then transmittance is in the range of 10 to 80%.

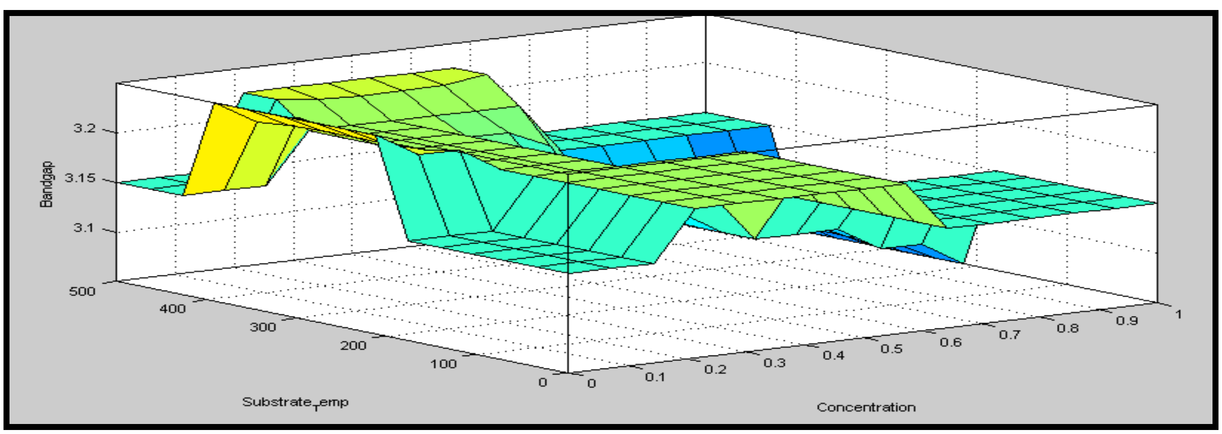


Fig 6: Surface view plot for Concentration Vs Substrate Temperature against Bandgap

From figure 6 it is observed that if the values of precursor concentration is in the range of 0 to 1 molar and for substrate temperature in the range of 0 to 500°C then bandgap is in the range of 3 to 3.25eV.

IV. CONCLUSIONS

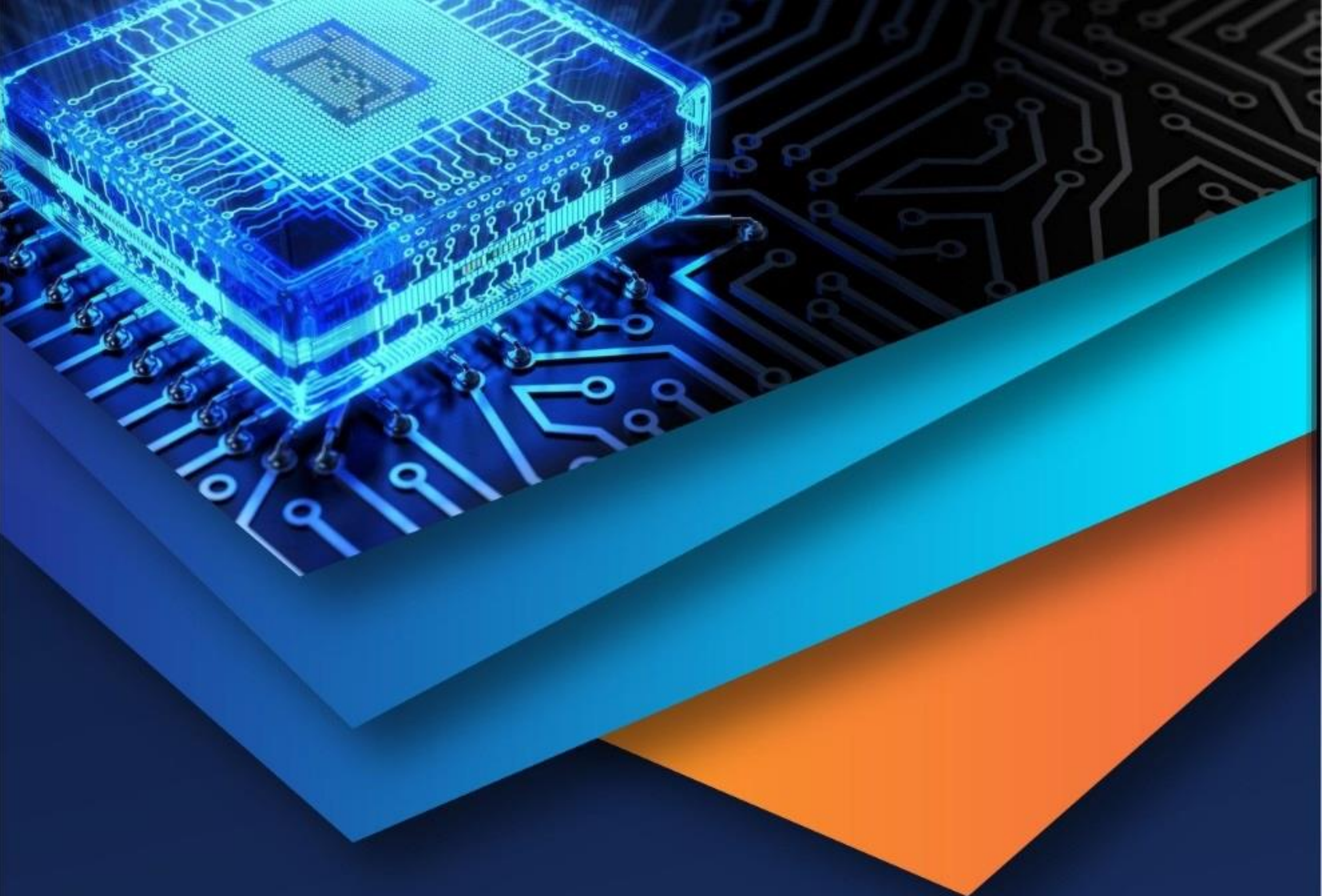
A fuzzy logic model for the prediction of transmittance and bandgap of aqueous ZnO thin film deposited via spray pyrolysis technique was successfully designed with Matlab fuzzy logic toolbox. The effect of process parameters on optical properties i.e. transmittance and bandgap was investigated by performing actual experiments. Triangular membership functions were defined for input and output. Fuzzy logic rule base has been constructed by using experimental data which shows the relation between input attributes i.e. precursor concentration, substrate temperature, solution flow rate and annealing temperature with output attributes transmittance and bandgap. For defuzzification 'Centroid Area Method' was implemented. The FIS was tested with four data sets of experiments and it shows good agreement with actual experimental data. The prediction results obtained for transmittance of ZnO film shows 95.46% accuracy and that of for bandgap shows 99.45% accuracy. Hence, the fuzzy logic approach can provide cost effective solution for the thin film synthesis with desire optical properties.

V. ACKNOWLEDGMENT

The Authors are thankful for Rayat Institute of Research and Development for supporting this work.

REFERENCES

[1] G. Temesgen, "Thin film deposition and characterization techniques," Journal of 3D Printing and Applications, Vol. 1, pp 1-24, April 2022
[2] M. Chaudhari, "Thin film Deposition Methods: A Critical Review," International Journal for Research in Applied Science and Engineering Technology, Vol 9, pp 5215-5232, June 2021.
[3] M. Jaya, A. Hashim, Siti, Rahman and Nizam, "Fuzzy logic-based for predicting roughness performance of TiAlN coating," Proc. of the 2010 10th Int. Conf. on Intelligent Systems Design and Applications, ISDA'10, pp 91-96, Nov.2010.
[4] O. O. Abegunde, E. T. Akinlabi, O. P. Oladijo, S. Akinlabi and A. U. Ude. "Overview of thin film deposition techniques," AIMS Materials Science, Vol. 6, pp 174-199, March 2019.
[5] K. Hamidi, Jafar, Shahriar, Kourosh, Rezai, Bahram, Bejari and Hadi, "Application of fuzzy set theory to rock engineering classification systems: An illustration of the rock mass excavability index," Rock Mechanics and Rock Engineering, Vol. 43, pp 335-350, May 2009.
[6] Zalnezhad, Erfan, Sarhan and Ahmed, "A fuzzy logic predictive model for better surface roughness of Ti–TiN coating on AL7075-T6 alloy for longer fretting fatigue life," Measurement, vol 49, pp 256–265, March 2014.
[7] D. R. Unune, B. M. Marani, S. S. Mohite and et al, "Fuzzy logic-based model for predicting material removal rate and average surface roughness of machined Nimonic 80A using abrasive-mixed electro-discharge diamond surface grinding," Neural Comput & Applic, Vol.29, pp. 647–662, May 2018.
[8] J. Arghavani, M. Derenne and L. Marchand, "Fuzzy logic application in gasket selection and sealing performance," Int J Adv Manuf. Technol, Vol. 18, pp 67–78, July 2001.
[9] K. Hashmi, I. Graham and B. Mills, "Data selection for turning carbon steel using a fuzzy logic approach," Journal of Materials Processing Technology, Vol. 135, pp 44-58, April 2003



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY