Artificial intelligence technique in solving nano-process parameter optimization problem

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Keywords: Artificial intelligence; nano-process; optimization

ABSTRACT – This paper is proposing an Artificial Intelligence (AI) technique in solving the RF magnetron sputtering process parameter optimization problem. RF magnetron sputtering is a physical vapor deposition process which is widely used in the manufacturing of thin films. In this research, the optimization of the sputtering process parameters is to be solved computationally based on gravitational search algorithm (GSA).This study is concentrating on four process parameters of RF magnetron sputtering process, which are RF power, deposition time, oxygen flow rate and substrate temperature. As for the material, zinc oxide (ZnO) has been chosen due to its many significance characteristics. For the validation purpose, GSA performance was compared with particle swarm optimization (PSO). Based on the results, GSA has outperformed PSO in terms of the accuracy of the optimization performance, fitness value and processing time. The results showed that the AI approach in solving this nano-process parameter optimization problem has proven to be promising. This AI approach is expected to improve the trial and error method by reducing the number of experiments to be conducted in the parameter optimization process. The implementation of this computational technique could offer better time management and lower cost consumption in the thin film fabrication process.

1. INTRODUCTION

Artificial Intelligence (AI) is a branch of computer science which specializes in dealing with complicated problems through the use of knowledge, probabilities and other kinds of uncertainties [1]. This paper is proposing an AI technique in solving the RF magnetron sputtering process parameter optimization problem. RF magnetron sputtering is one of the physical vapor deposition technique which produce nanostructured thin films. In this research, the optimization of the sputtering process parameters is to be solved computationally based on gravitational search algorithm (GSA). GSA is an algorithm which is inspired from the Newtonian's laws of gravity and motion. Based on literature, the conventional method of trial and error process in the parameter optimization is time consuming and costly. Therefore, a more reliable and effective method is needed to improve the optimization process. In this study, the most optimized parameter combination should be able to produce the desirable nanostructured ZnO thin film properties.

2. METHODOLOGY

2.1 Experimental Data

The parameters to be optimized are the combination of RF power, deposition time, oxygen flow rate and substrate temperature. Table 1 shows the ranges of data to be optimized for each of the parameters. The material that has been selected in this research is zinc oxide (ZnO). This material is easily available due to its popularity and significant characteristics [2].

Table 1 Ranges of parameters to be optimized.

Parameters			
RF Power (watt)	**Deposition time (min)**	**Oxygen flow rate (sccm)**	**Substrate temperature (℃)**
50 - 400	15 - 120	0 - 10	27 - 500

2.2 AI Technique

GSA is represented by agents, which carry their own masses. Masses are calculated from the fitness values. An agent moves based on the amount of gravitational forces exerted from all other neighboring agents. The velocity of an agent is calculated based on its acceleration, which will contribute to its position updates. The position of the biggest mass is related to the solution of the problem, while the biggest mass is representing the optimum solution. Equation (1) and (2) shows the formula for the velocity and position of agents [3].

$$v(t+1) = rand\ x\ v(t) + a(t) \quad (1)$$

$$x(t+1) = x(t) + v(t+1) \quad (2)$$

Based on equation (1) and (2), v represents the velocity, a is the acceleration, t is the iteration, *rand* is the random numbers with [0,1] interval and x is the position.

3. RESULTS AND DISCUSSION

The performance testing of GSA is based on the mean fitness value and processing time. In this testing, GSA performance was compared with the performance of Particle Swarm Optimization (PSO) algorithm. PSO has been selected as the comparison algorithm based on its good performance in solving various engineering optimization problems. However, in this optimization problem, GSA has proven to outperform PSO based on the results shown in Table 2. Figure 1 represents the convergence graph, which shows that GSA has a more stable convergence characteristic than PSO.

Table 3 shows the results of the electrical properties from GSA and PSO parameters optimization. The computational optimization results are also compared with the most optimized result from the actual laboratory experiment. Table 4 shows the analyses from the computational optimizations based on the actual results.

Table 2 Average fitness value and processing time.

	Mean values	
	GSA	**PSO**
Fitness value	0.5359	0.4929
Processing time (s)	2.342	2.414

Table 3 Results of computational and actual laboratory optimizations.

	Laboratory Experiment Results		
	GSA	**PSO**	**Actual experiment**
Most optimized parameter combination	(300, 60, 0, 500)	(150, 60, 0, 500)	(200,60,0, 500)
Fitness value	0.9033	0.7852	1.000
Resistivity	0.0801	0.1055	0.0758
Conductivity measurement result (Sm^{-1})	12.479	9.477	13.2

Table 4. GSA and PSO optimization performance.

	Optimization Performance	
	GSA	**PSO**
Percentage error (%)	5.4621	28.2045
Accuracy (%)	94.5379	71.7955

4. CONCLUSION

The AI approach in solving this nano-process parameter optimization problem has proven to be promising. The accuracies of the optimizations from both of the AI techniques are acceptably high. Based on the results, GSA has outperformed PSO in terms of the accuracy of the optimization performance. GSA has also obtained higher mean fitness value and shorter processing time. This AI approach is expected to improve the trial and error method by reducing the number of experiments to be conducted in the parameter optimization process. The implementation of this computational technique could offer better time management and lower cost consumption in the thin film fabrication process. Future work could test other AI techniques with diverse sets of data to solve this parameter optimization problem.

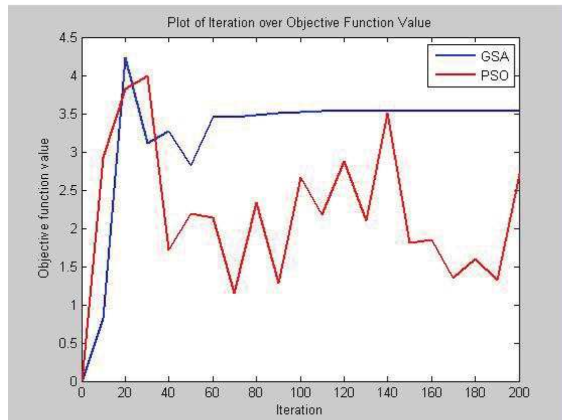

Figure 1 Average objective function values over iteration.

5. ACKNOWLEDGEMENT

The authors would like to express gratitude to Universiti Teknologi MARA (Terengganu) and NANO-Electronic Centre of Universiti Teknologi MARA for the continuous support given towards the completion of this project.

6. REFERENCES

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