NEURAL NETWORK BASED MODELING FOR THE GROWTH RATE OF ZnO THIN FILMS ON THE PULSED LASER DEPOSITION

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In this study the D-optimal design was used to make design matrix in this experiment. Neural networks (NNets) based on the back-propagation (BP) algorithm are applied to the pulsed laser deposition (PLD) process modeling in order to construct the model for the growth rate of the ZnO thin films.

The initial substrate of n-type InP has 3x10^{18} cm^{-3} doping concentrations. The chamber was evacuated by a turbomolecular pump to base pressure $1x10^{-6}$ Torr. Pulsed Nd:YAG laser was operated at a 355-nm wavelength with 2 Hz repetition rate and 2.5 J/cm² energy density. The ZnO films were deposited with varying, substrate temperature in the range of 350-450 °C and oxygen pressure in the range of 250-450 mTorr. A substrate holder was placed at 5 cm from the target. After ZnO thin films were deposited, the thickness was measured by using SEM (scanning electron microscopy).

The input factors, substrate temperature (T) and oxygen pressure (P), were explored via D-optimal experimental design with 17 runs. The sigmoid function in this NNets was used in each hidden layers as the transfer function, respectively [1]. The linear function used in output layer. The network was trained on 15 experimental runs with the learning rate of 0.0025 and the momentum coefficient of 0.95. The additional two trials were used for testing data in order to verify the fitness of NNets output for the results of the training data. The network training was completed when the root mean square error (RMSE) of training of 5% were achieved.

The $R$-squared values between the regression model and NNets were 73.8 % and 0.34 %, respectively. One of the assumptions in this analysis is that the residuals are both normally and randomly distributed [2]. The residual plot and the neural network results are shown in Fig. 1. It is observed that the residuals should be scattered evenly around zero and there is no special features or patterns in residuals.

It is verified that the linear relationship between the network output value and the experimental data. It is shown that the modeling output belongs to the range of prediction under the RMSE of training of 5%. The surface plot of response model is

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shown in Fig. 2. It also shows that the maximum condition of the growth rate for PLD-grown ZnO thin film is observed at temperature is 400 °C and pressure is 350 mTorr.

There is a marked increase in the growth rate of ZnO thin film around the maximum condition. It is observed that NNets can explain the constrained conditions for the growth rate, which can not be characterized by using regression model due to the nonlinearity of the process data.

The prediction of NNets exhibited good agreement with the measured values. The modeling can be used to find the maximum point of PLD process that has a different experiment condition. These results can lead to the conclusion that this methodology can be used to improve the manufacturability and the effectiveness of the semiconductor manufacturing processes.

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References


Fig. 1 (a) the residual plot. (b) neural network results for growth rate.

Fig. 2. The surface plot of response surface model.