# Implementation of Artificial Neural Network for Detection of LPG through Pd-Doped SnO2 Based Thick Film Gas Sensor

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*Abstract*— Pd-doped SnO2 thick film sensor was produced on alumina substrate and their LPG sensing behavior was investigated. In the present paper studies have been made to analysis the sensitivity, response of SnO2 based with different Pd-doped thick gas sensor for LPG detection using different nonlinear ANN technique. To achieve this thick film Pd doped SnO2 sensor was fabricated on a 1” x 1” alumina substrate. LPG gas consists of sensitive layer SnO2 based with different Pd- doped, a pair of electrodes underneath the gas sensing layer serving as a contact pad for sensor and heater element is fabricated on the backside of the substrate. On both pure and Pd-doped samples measurements of conductance and capacitance have been made by fixed temperature at fixed gas concentration. The sensitivity of sensor has been studied at different Pd doped at a constant temperature of 350°C upon exposure to LPG. Sensing properties such as, sensitivity and selectivity measurement are carried out in the range 0- 5000 ppm at 350°C. The maximum response of 72.08% at 350°C was obtained under the explore of 0.5% of LPG. Practical Sensitivity of LPG is used to measure the sensitivity of different Pd- doped SnO2 based thick film gas sensors by using ANN algorithm. Two training algorithm of feed-forward algorithm namely Levenberg-Marquardt feed forward propagation and Random Weight /Bias Rule with adaptive learning rate were used. The performance of ANN models with different nonlinear algorithm is evaluated on practical sensitivity of sensor with different network transfer functions. Experimentally, we found that ANN model with training algorithm is more suitable for sensitivity of the sensor. Results present in the paper shows ANN as an effective tool in the area of SnO2 based thick film sensor design.

***Keywords:*** Thick film gas sensor, Artificial Neural Network, Levenberg-Marquardt algorithm, Random Weight / Bias Rule

## I. INTRODUCTION

As ecological supervision become more confine. To meet the industries demand, need to develop toxic gas sensor through the highly sensitive gas. To fair the demand of low level gas detection, gas sensors should be promoted in sensitivity, selectivity, and speed of response [1]. The sensors are recommended basically for assessment of physical quantities and for monitoring working environment. Concurrently, thick film gas sensor should be cost efficient and stable over long term [2]. Metal oxide semiconductor sensors principle based on electric conductivity assessment have been used extensively for toxic gas detection. $SnO_2$ is universally used material surrounded by semiconductor oxide for making sensors due to its cost-effective nature, long life and good reproducibility [3,4]. $SnO_2$ based thick film gas sensor devices are most applicable due to their prominent level of sensitivity, simple design, low weight and cost effectiveness. $SnO_2$ is an n–type, wide–band gap (3.6ev) semiconductor. It show the oxygen deficiency due to the non-stoichiometric compositions. The sensing substance of the thick film gas sensor are based on the adsorption of the gas molecules on it surface which produce changes in their conductivity .When unveiled outdoor, newly prepared tin-oxide particles adsorbed on the particle adsorb oxygen atoms on the surface . These oxygen atoms elevate the es from the conduction band of tin oxide and are adsorbed on the fragment surface as O ions. Each tin oxide fragment is wrapped with negatively charged O ions on the surface. On the other hand, due to depletion electron, there exists a layer of positively charged donor atoms equitably below the particle surface. When the sensor is exposed to reducing gases at elevated temperature, the O absorbents react with the gases and release the es to the conduction band. wherefore, the depth of the space –charge layer decreases, which results in a decrease in the height of the potential barrier for the electronic conduction at the grain boundaries. The LPG is a complex gas, the main constituents of LPG are propane or butane are flammable mixture of hydrocarbon. The Internet of Things (IoT) is the newborn evolution in the field of home automation system and indoor air quality monitoring expands the market demand for miniaturized gas sensors. Metal oxide gas sensors based on mostly used micro hotplates fabricated with micro-electro-mechanical system (MEMS) technology dominate the market due to their balance in performance and cost. Gas sensors have been widely applied in various fields, such as agriculture automotive industrial, indoor air quality monitoring and environmental monitoring.

The concept of ANN analysis have been discovered nearly 50 years ago, but in handing the practical problem it is used only from last 2 – decades [5]. ANN are collections of small individually interconnected processing units. Information is passed between these units along interconnections. An incoming connection has two value associated with it, an input value and a weight [6]. The output of the unit is a function of the summed value. Once an ANN is trained for a specify data it may be ready to be used then for the specify or classification [7]. ANNs can automatically learn to recognize pattern in the data real system or from physical models, or other sources. An ANN can handle much input and produce answer that is in a form suitable for designers [8].

The Levenberg-Marquardt algorithm combination of two minimization methods such as the gradient descent method and the Gauss-Newton method. The Gradient descent method was the sums of the squared errors were reduced by updating the parameters in the steepest-descent direction. The

Gauss-Newton method was the sum of the squared errors was shortened by assuming the minimum squares function was locally quadratic, and finding the minimum of the quadratic. The Levenberg- Marquardt method move more like a gradient-descent method when the specification were far from their excellent value, and move more like the Gauss-Newton method when the specification were close to their excellent value.

Random Weight /Bias Rule for each epoch, all training vectors (or sequences) are each presented once in a different random order, with the network and weight and bias values updated accordingly after each individual presentation. In Random Weight / Bias Rule define the weights and biases of hidden nodes certain the nonlinear mapping were set randomly and were not learned. This method achieve the specification of the hidden nodes in such approach that nonlinear fragments portion of the activation functions were located in the input space regions with data and can be used to create the surface approximating a nonlinear target function. The weights and biases were dependent on the input data range and activation function type.

## II. Results and Discussion:

The maximum sensitivity recorded for undopped Pd doped $SnO_2$ based thick film gas sensor was 19.78% at 350°C in figure 1. When the sensitivity was tested by matlab software neural network tool through Levenberg-Marquardt algorithm with adaptive learning rate network function, the maximum sensitivity for purelin network transfer function was found to be 19.14% at 350°C compare to other transfer network function in Fig.2.When the sensitivity was tested by matlab software neural network tool through Random Weight/Bias Rule, the maximum sensitivity in purelin network transfer function was found to be 19.78% at 350°C (Fig.3) compare to various network transfer function.

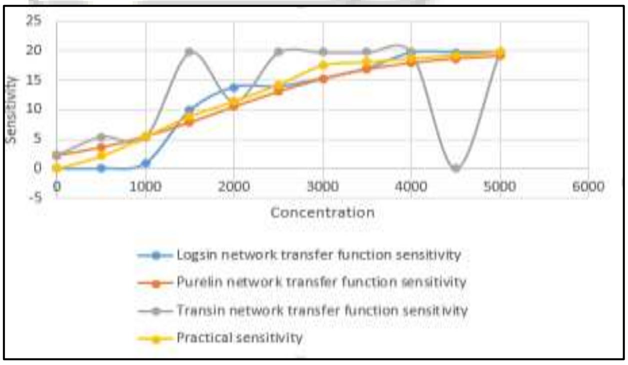


Fig. 1: Sensitivity graph for undoped PdLPG for Levenberg-Marquardt at $350^0$C

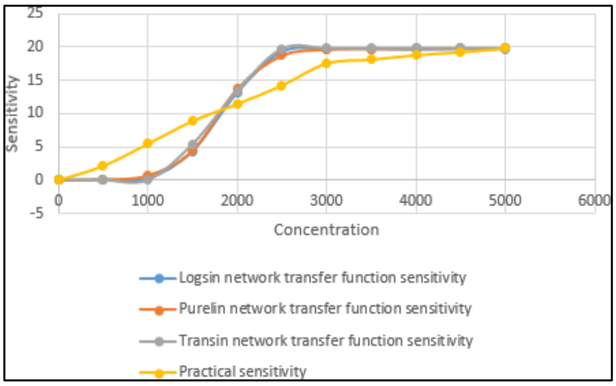


Fig. 2: Sensitivity graph for undoped Pd LPG for Random Weight /Bias Rule at $350^0$C

The maximum sensitivity examined for 0.25% Pd doped $SnO_2$ based thick film gas sensor was 38.45% at 350°C (Fig.3). Using Levenberg -Marquardt feed forward propagation with adaptive learning rate algorithm network function in Transin network transfer function, the maximum sensitivity for network was found to be 37.619% at 350°C (Fig.3). Random Weight/Bias Rule as compared to algorithm in transin network transfer function, the maximum sensitivity for network was found as 38.45 % at 350°C (Fig. 4).

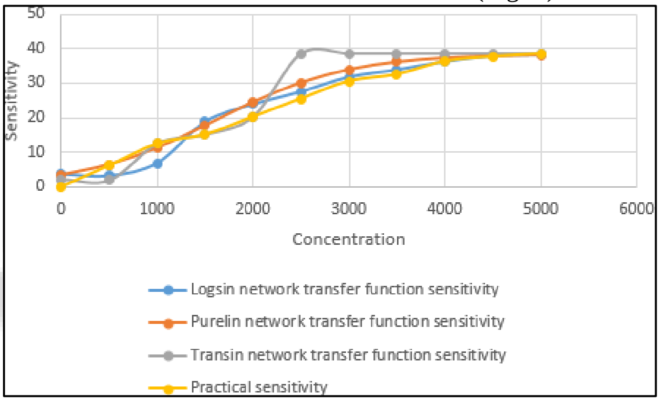


Fig. 3: Sensitivity graph for 0.25% Pd LPG for Levenberg-Marquardt at $350^0$C

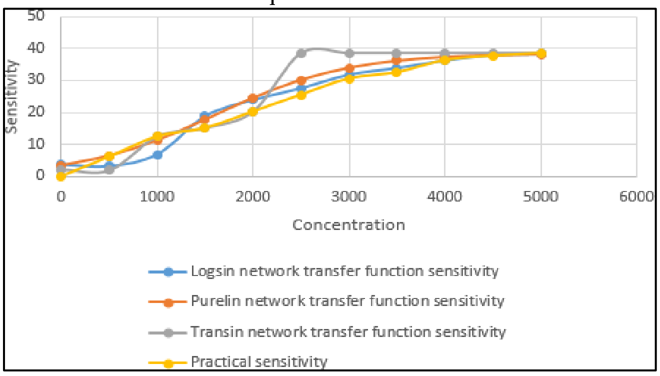


Fig. 4: Sensitivity graph for 0.25% Pd LPG for Random Weight /Bias Rule at $350^0$C

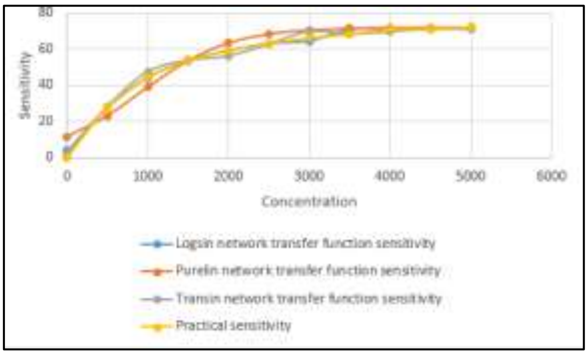


Fig. 5: Sensitivity graph for 1% Pd LPG for Levenberg-Marquardt at $350^{0}$C

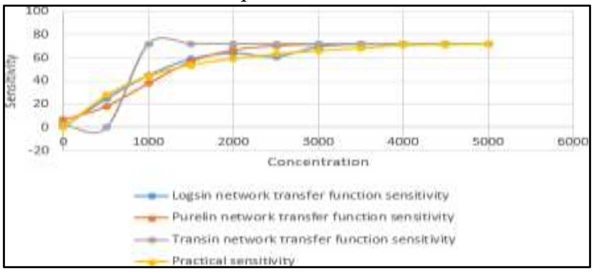


Fig 6: Sensitivity graph for 0.25% Pd LPG for Random Weight /Bias Rule at $350^{0}$C

The maximum sensitivity was practically demonstrated for 1% Pd doped SnO2 based thick film gas sensor by 72.08% at 350°C (Fig.5). Levenberg -Marquardt feed forward propagation algorithm, the maximum sensitivity in logsin network transfer function was found to be 71.854% at 350°C (Figure 5) as compared to network other transfer function.). Random Weight/Bias Rule as compared to algorithm in transin network transfer function, the maximum sensitivity for network was found as 72.08 % at 350°C (Fig. 6).

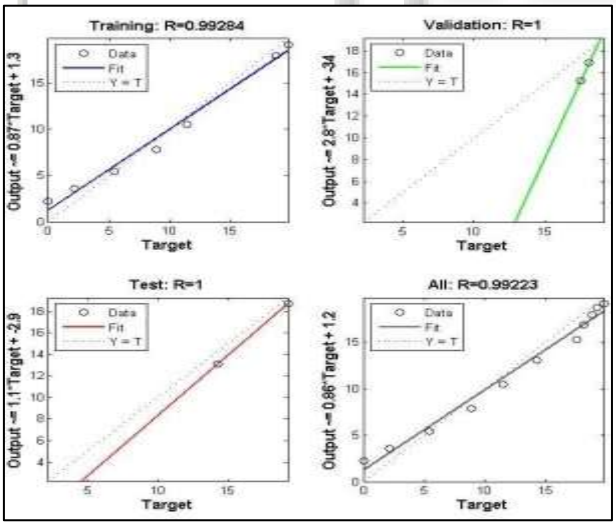


Fig. 7: Maximum Sensitivity of undoped LPG for Levenberg-Marquardt of Purelin transfer function at $350^{0}$C.

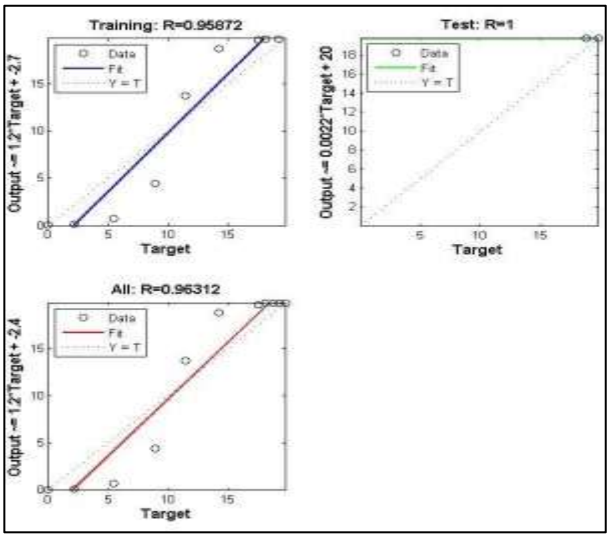


Fig 8: Maximum Sensitivity of undoped LPG for Random weight/bias Rule of Purelin transfer function at $350^{0}$C.

The maximum sensitivity recorded for undopped Pd doped SnO2 based thick film gas sensor was 19.78% at 350°C in Fig. 3 and 4. The Levenberg -Marquardt feed forward propagation algorithm with adaptive learning rate algorithm was used regression parameter of train data (0.99284) and output target train data (0.99223) in purelin network transfer function as shown in Figure 7.The Random Weight/Bias Rule algorithm was used regression parameter of train data was (0.9587) and outpu ttarget data (0.9631) are shown in figure 8.

In Pd doped SnO2 based thick film gas sensor was 38.45% at 350°C in Figure 3 and 4. The Levenberg -Marquardt feed forward propagation algorithm with adaptive learning rate algorithm was used regression parameter of train data (0.99255) and output target train data (0.99359) as shown in Figure 9.The Random Weight/Bias Rule algorithm was used regression parameter of train data was (0.98069) and output target data (0.95861) are shown in Figure 10.Amongst the three transfer function network, transin is most suitable function as at zero epoch maximum validation performance was achieved for Levenberg -Marquardt feed forward propagation.

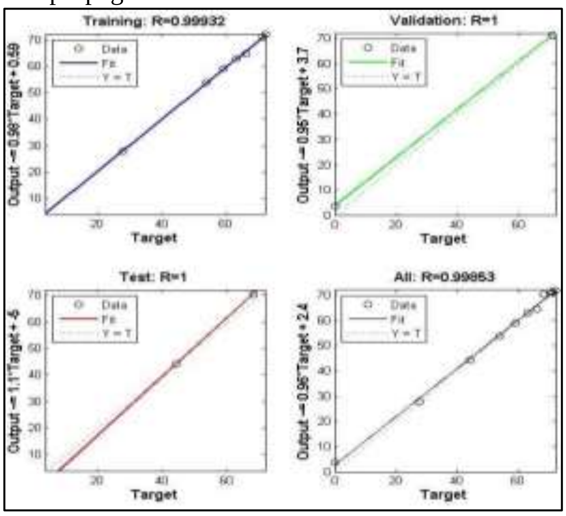


Fig. 9: Maximum Sensitivity of 0.25% Lpg for Levenberg-Marquardt of Transin transfer function at $350^{0}$C

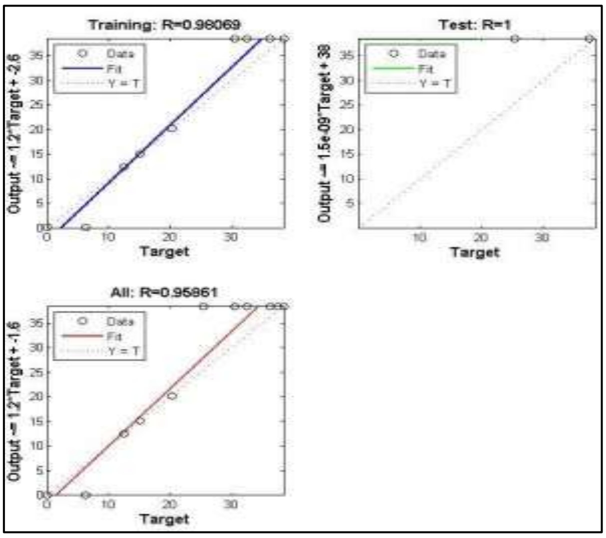


Fig. 10: Maximum Sensitivity of 0.25% Lpg for Random weight/bias Rule of Transin transfer function at $350^{0}C$

The maximum sensitivity recorded for 1% Pd doped SnO2 based thick film gas sensor was 72.08% at 350°C in figure 5 and 6. The Levenberg -Marquardt feed forward propagation algorithm with adaptive learning rate algorithm was used regression parameter of train data (0.99932) and output target train data (0.99853) as shown in Figure 11.The Random Weight/Bias Rule algorithm was used regression parameter of train data was (0.89481) and output target data (0.88671) are shown in Figure 12.Amongst the three transfer function network, logsin is most suitable function as at zero epoch maximum validation performance was achieved for Levenberg -Marquardt feed forward propagation.

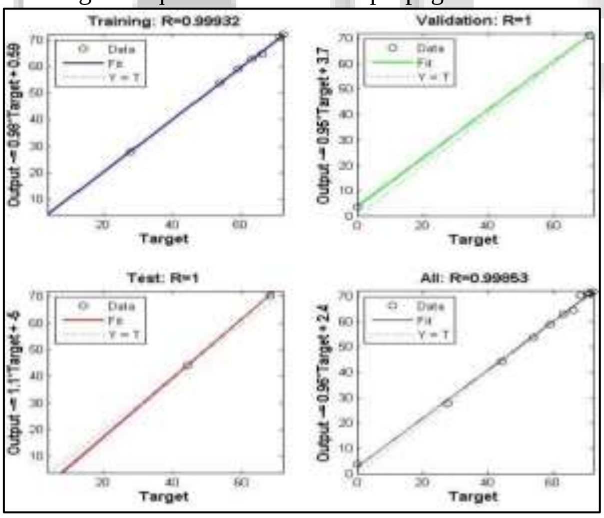


Fig. 11: Maximum Sensitivity of 1% LPG for Levenberg-Marquardt of Logsin transfer functionat $350^{0}C$

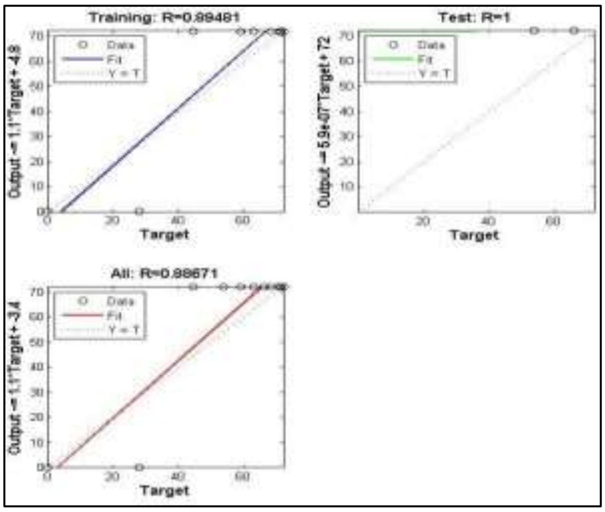


Fig. 12: Maximum Sensitivity of 1% LPG for Random Weight/Bias Rule of transin transfer functionat $350^{0}C$

## III. CONCLUSION

The maximum sensitivity recorded for undopped Pd doping $SnO_2$ based thick film gas sensor was 19.78% at 350°C. This shows that Levenberg -Marquardt feed forward propagation with adaptive learning rate algorithm is the best suitable technique in comparison to Random Weight/Bias Rule algorithm in purelin network transfer function Fig. 7 and 8. The maximum sensitivity examined for 0.25% Pd doped $SnO_2$ based thick film gas sensor at 350°C was found 38.45%. This shows that Levenberg-Marquardt feed forward propagation algorithm is the best suitable technique in comparison to Random Weight/Bias Rule with adaptive learning rate algorithm transin network transfer function in figure 9 and 10.

The maximum sensitivity recorded for 1% Pd doping SnO2 based thick film gas sensor was 72.08% at 350°C. This shows that the Levenberg -Marquardt feed forward propagation algorithm in logsin network transfer function the best suitable technique in comparison to Random Weight/Bias Rule algorithm in Fig. 11 and 12.

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