11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

ICAM2009

Modeling of the Growth of Quantum Dots by Neural Network

O. P. Vilela Neto[(1)(4)] ,A. P. Singulani[(1)(4)] ,M. A. C. Pacheco*[(1)(4)] ,M. B. R. Vellasco[(1)(4)] ,M. P. Pires[(2)(4)] ,P. L. Souza[(3)(4)]

(1) ICA - DEE, Pontifícia Universidade Católica do Rio de Janeiro, e-mail: marco@ele.puc-rio.br.
(2) IF, Universidade Federal do Rio de Janeiro.
(3) LABSEM, Pontifícia Universidade Católica do Rio de Janeiro.
(4) DISSE - Instituto Nacional de Ciência e Tecnologia de Dispositivos Semicondutores
* Corresponding author.

Abstract – We have applied a computational intelligence technique, namely, artificial neural network (ANN) to model the growth of self-assembled quantum dots. The ANN was used to associate the growth input parameters with the density and size dispersion of the deposited quantum dots. The method relies on an existing database of growth parameters with a resulting quantum dot characteristic to be able to later obtain the growth parameters needed to reach a specific value for such a quantum dot characteristic. Trends of the quantum dot density and size dispersion behavior as a function of growth parameters were correctly predicted.

The last decade has witnessed the development of semiconductor quantum dot (QD) structures for application in a variety of optoelectronic devices [1,2]. QDs are structures on the nanometer scale, which confine the electrons in all three dimensions, leading to the full quantization of the electronic energy levels. In a previous work, we have used computational intelligence techniques to predict trends in the InAs QDs' mean height behavior as a function of different growth parameters [3]. In this work we extend the prediction to the density and size dispersion of these QDs.

Artificial neural network are widely used in problems of series prediction, recognition of standards and function approximation [4]. It is a non-linear mathematical model used to find complex relationships between input and output. The main advantage of ANN over other interpolation methods is its capability of modeling systems with a very strong non-linear behavior.

The investigated samples contain one layer of free standing self-assembled InAs QDs deposited by metalorganic vapor phase epitaxy (MOVPE) at 100 mbar on top of InP, InGaAs or InGaAlAs, where the alloys are all lattice matched to the InP substrate. The QD height and density of the grown samples were determined by atomic force microscopy (AFM). The six different growth parameters of each set used as input to create the ANN are: the indium flux in the reactor, the growth temperature, the deposition time, the thickness of the buffer layer which the dots are nucleated, the aluminum and indium contents of this layer material. We have used three different materials for the buffer layer, namely, InP, InGaAs and InAlGaAs. Two ANNs were developed: one to predict the density of QDs and other one to the size dispersion.

The experimental data are shared in three different groups: training, validation and test. Figure 1 and 2 show the results for the density and size dispersion prediction, respectively. It can be seen that the ANNs were able to predict the characteristics behavior as a function of input parameters.

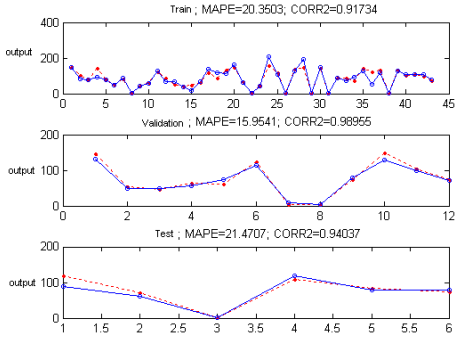

Figure 1: Prediction of density of QDs. The blue line is the experimental data.

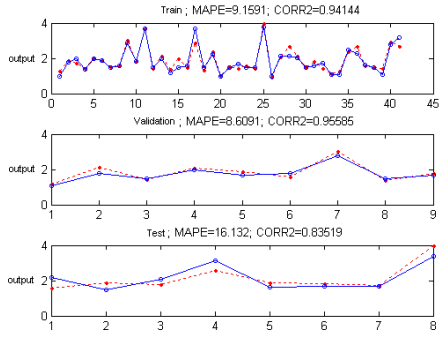

Figure 2: Prediction of size Dispersion of QDs. The blue line is the experimental data.

References

[1] P. Bhattacharya, Z. Mi, Proc. IEEE 95 (2007) 9.
[2] D. Bimberg, M. Grundmann, N.N. Ledentsov, Quantum Dot Heterostructures, Wiley, New York, 2001.
[3] A. P. Singulani, O. P. Vilela Neto, M. A. C. Pacheco, M. B. R. Velasco, M. P. Pires, P. L. Souza, J. Crys. Grow. 310 (2008) 5063
[4] S. Haykin, Neural Networks: A Comprehensive Foundation. Prentice Hall PTR Upper Saddle River, NJ, USA, 2nd ed., 1994.