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MATHEMATICAL MODELING IN INTEGRATED CIRCUIT TECHNOLOGIES

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Abstract — This paper deals with the questions concerning mathematical treatment of statistical information about the parameters of integrated circuit (IC) crystals in order to obtain mathematical description in form of regression model considering peculiarities of technological process. The elaborated method of modeling is based on the classical method of least squares with preliminary orthogonalization of factors. Method is highly efficient, especially in the case of *passive information* when the main preconditions of regression analysis are violated and no other method does give accurate and correct results.

***Key words*: microelectronics, mathematical treatment, regression model.**

1. Introduction

The technological process (TP) of integrated circuit production is very complicated and multifactor one. On different stages of this process output parameters have quite great dispersion which leads to decreasing of quality of future production. To avoid this situation according to the peculiarities of IC TP it is suggested to control the process with the help of mathematical model describing the dependence of output parameters of IC crystals on technological factors. To obtain such model realization of special experiments is needed. In conditions of mass production realization of active experiment is quit difficult and needs great outlays. The only possible way to get information about TP parameters is using passive information, gotten by suitable measurements. In treatment of passive experimental statistical data about multifactor objects while obtaining its mathematical model a number of difficulties appear. Well-known classical method, such as method of least squares (MLS), has some properties, which constrain its application. In passive data experiments a number of preconditions of regression are violated, these are: orthogonality, linear independence, rotatability etc. Because of that MLS usage gives such estimates of model coefficients, which are mixed characteristics of all factors. Thus, operative test and control of the object by this model with suitable efficiency become impossible.

2. MLS with preliminary orthogonalization of factors

To eliminate above mentioned constraints the modification of classical MLS is suggested [1]. It is based on the preliminary orthogonalization of initial factors. According to this idea instead of regression model of the form

$$\mathrm{Y} = \mathrm{b}_0 + \sum_{i=1}^{p} \mathrm{b}_i \mathrm{X}_i + \sum_{i<j}^{p} \mathrm{b}_{ij} \mathrm{X}_i \mathrm{X}_j + \sum_{i=1}^{p} \mathrm{b}_{ii} \mathrm{X}_i^2 + \ldots, \qquad (1)$$

where p is the number of initial factors, the mathematical description of the object is presented by special polynoms $\Psi_k(z)$ with their weights A_k

$$Y \sum_{k=0}^{m} A_k \Psi_k(z) \qquad (2)$$

Thus the model is found in new orthogonal reference frame, where all preconditions are fulfilled due to preliminary transformation of factors to orthogonal form.

Corresponding polynomials are as follows:

$$\Psi_0(z) = 1; \quad \Psi_k(z) = z_k - \sum_{r=0}^{k-1} \frac{\sum_{j=1}^{N} z_{kj} \Psi_{rj}(z)}{\sum_{j=1}^{N} \left[\Psi_{rj}(z)\right]^2} \cdot \Psi_r(z); \quad A_k = \frac{\sum_{j=1}^{N} y_i \Psi_{kj}(z)}{\sum_{j=1}^{N} \left[\Psi_{kj}(z)\right]^2},$$

where k = 0…m; (m + 1) - number of terms of regression equation.

$\mathbf{A}_i$ are orthogonal and independent coefficient which characterizes the influence of initial factor on output value Y.

In contrast to classical MLS where no any statistical estimation take place in method with preliminary orthogonalization (MLSO) the test of statistical significance of coefficients A_k is realized as well as the test of model adequacy to experimental data. According to these procedures some coefficients of the model (2) may be admitted to be insignificant and be excluded from the model without worsening its accuracy and recalculation of the rest coefficients.

After that statistical analysis the inverse transformation to initial coordinates is performed by expressions

$$b_i = A_i - \sum_{r=i+1}^{m} b_r \cdot \frac{\sum_{j=1}^{N} z_{rj} \Psi_{ij}(z)}{\sum_{j=1}^{N} \left[\Psi_{ij}(z)\right]^2}; \quad i = m,\ldots,0.$$

These coefficients correspond to regression equation (1).

3. Conclusion

The suggested MLSO has the following advantages:

1) on base of orthogonal coefficients A_k method permits to evaluate the influence of each factor on Y and define independent contribution of each factor to corresponding coefficient b_i which hold no information about influence of each factor and is simply some number in equation. This property of MLSO increases its resolving capacity;
2) owing to preliminary orthogonalization method works effectively even if initial factors are correlated;
3) MLSO is the best method for obtaining mathematical models on base of **passive data** in conditions of real functioning of multifactor objects. It obtains much higher accuracy than any other modeling method in regression analysis;
4) MLSO can be used also in any field of science, economy, medicine and industry, solving the problem of control and diagnostics. Thus MLSO is successfully used in microelectronics, radio-technique, ophthalmology, and agriculture. It was realized as a computer program and is a part of software package of mathematical methods for treatment of passive statistical information about multifactor objects [2].

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