Prediction of performance degradation and lifetime for semiconductor devices using Markov chain model

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Abstract: We study on a method to predict performance degradation and lifetime of semiconductor devices under the assumption that the device characteristics can be monitored periodically. By using the Markov chain model, degradation and lifetime of the MOSFET are predicted based on measured values of gate leakage current. MOSFET degradation states are classified into discrete states or classes according to its gate leakage current. State transition probabilities are obtained from measured gate leakage current data. In our study, gate leakage current data are obtained by simulation based on the percolation model instead of actual device measurement. Experiments to predict degradation and lifetime of MOSFETs are carried out. In the experiments, gate leakage current data obtained by simulating 1000 devices are used. The experimental results show that device monitoring can enable us to elongate lifetime of system.

Keywords: Time-to-failure modeling, Time-to-failure statistics, Markov chain model, degradation prediction, lifetime prediction, gate leakage current

1. Introduction

The lifetime of semiconductor devices are estimated usually by using a Weibull distribution model. For example, in JEDEC standard [1], x% lifetime is defined as 0.1%, which is the time at which the cumulative failure rate reaches to 0.1%. That is, there is one failure device among 1000 devices. Thus the life time of devices are estimated statistically. If the characteristics of devise under operation is monitored and the lifetime is estimated from the monitored data, the deteriorated device can be replaced by a new one so that the lifetime of system is elongated. And there is the advantage that the stock quantities of maintenance parts (devices) can be reduced.

The degradation estimation for Infrastructure system has been reported [2], [3]. However, as far as we know, there is no report regard to the electronic system that is composed of semiconductor devices.

In this paper we try to predict the degradation or the lifetime of devices from the periodically monitored data by using Markov chain method. We assume that the device characteristics can be monitored periodically. The leakage current in the gate oxide of MOSFET is used as device characteristics.

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2. Research method

2.1 Gate leakage current simulation

2.1.1 An overview

The leakage current characteristics is obtained by simulation that uses the percolation model[4], [5].

In this model, the gate oxide is represented by cubic lattice. Let us suppose a 3-dimensional mesh graph whose node is located at the center of each cube and is connected by edges with six adjacent nodes. Let the coordinate of the mesh node be (x, y, z) where $x = 0, \cdots, N_x - 1$, $y = 0, \cdots, N_y - 1$, and $z = 0, \cdots, N_z - 1$. The MOSFET surface is on y-z plane and the x-axis is perpendicular to the surface. This 3D mesh graph is implemented as a 3D array on the simulation program.

3. Some examples of NANOTS proceeding format

In this section, some examples of NANOTS proceeding format are shown. This section is independent of the other part of this manuscript.

Figure 1 shows an example of figure. Table 1 shows an example of table. Figures and tables must be referred in the main text.

Here is an example of equation:

$$F(\omega) = \frac{1}{\sqrt{2\pi}} \int_{\infty}^{\infty} f(t) e^{j2\pi\omega t} dt. \qquad (1)$$

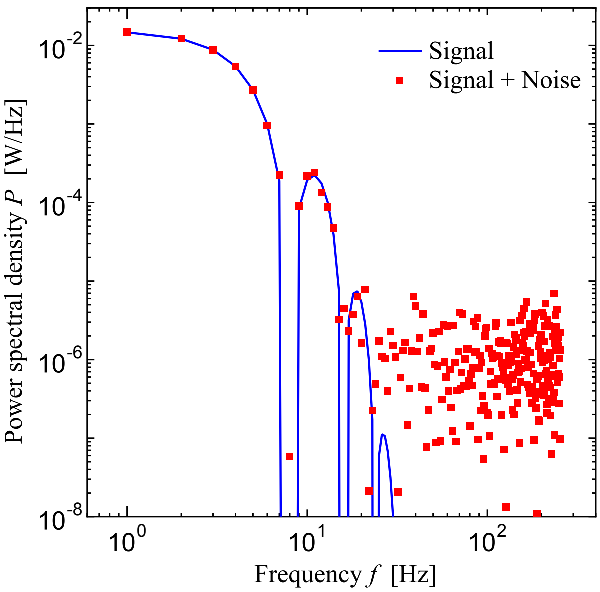

Fig. 1 An example of figure. Figures must be referred in the main text.

Table 1 An example of table. Tables must be referred in the main text.

Class	t_{RET} [sec]	t_{SFT} [sec]	Δt [sec]
C_5^{3000}	3215	3650	435
C_4^{3000}	3329	4027	698
C_3^{3000}	3621	4555	934
C_2^{3000}	4027	5643	1616
C_1^{3000}	4672	6863	2191

The following show an example of itemization.

- item 1,
- item 2,
  - sub-item 2(a),
  - sub-item 2(b), and
- item 3.

The following show an example of enumeration (numbered list).

1. item 1,
2. item 2,
   (a) sub-item 2(a),
   (b) sub-item 2(b), and
3. item 3.

4. Conclusions

We have studied on a method to predict performance degradation and lifetime of semiconductor devices under the assumption that the device characteristics can be monitored periodically. By using the Markov chain model, degradation and lifetime of the MOSFET are predicted based on measured values of gate leakage current. MOSFET degradation states are classified into discrete states or classes according to its gate leakage current. State transition probabilities are obtained from measured gate leakage current data. In our study, gate leakage current data where obtained by simulation based on the percolation model instead of actual device measurement. Experiments to predict degradation and lifetime of MOSFETs were carried out. In the experiments, gate leakage current data obtained by simulating 1000 devices were used. The experimental results show that device monitoring can enable us to elongate lifetime of system.

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Appendix A

If you want to write some non-essential things of your research such as proofs of theorems, write them in appendix sections.