Analysis of temperature influence on titanium-dioxide memristor characteristics at pulse mode

Extended abstract

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***Abstract* — The main goal of this paper is to analyze the temperature influence on memristor parameters and characteristics at impulse mode. A relationship between ionic mobility and temperature is deduced based on experimental data. Then the dependencies between resistances of the memristor in opened and closed states and the temperature are given in analytical and graphical form. The influence of the temperature on memristor characteristics are presented using MATLAB models in pulse mode. At the end some concluding remarks about the inner memristor diffusion are presented.**

Keywords—titanium-dioxide memristor; charge carriers mobility; temperature dependence; impulse mode.

I. INTRODUCTION

The memristor was predicted in 1971 by Professor Leon Chua [1]. The first physical prototype of the memristor was invented in 2008 by Stanley Williams of Hewlett-Packard [3, 4, 9]. That memristor consists of two sub-layers of titanium dioxide, sandwiched between two platinum electrodes. The basic unique property of this nonlinear element is to memorize the full amount of charge which has passed through it [2]. Many research results and simulations on the memristor investigation have been made in last few years [2, 4, 5, 6]. The main properties and the principle of operation of Williams's memristor have been described. Some physical relationships between the basic electrical quantities of the memristor are presented. The resistances of the memristor in opened and closed states, respectively R_{OFF} and R_{ON} are very important parameters for its operation [7, 8]. The charge carrier's mobility μ_v is also one of the basic parameters of the element. These parameters are dependent on the memristor temperature but in the papers published so far no data on this topic have been found. The basic purpose of this paper is to propose adequate model of these temperature dependencies in titanium-dioxide memristor.

In section II the relationship between charge carriers mobility and the temperature of the memristor is described. The temperature dependence of resistances of the titanium-dioxide memristor in opened and closed states is depicted in Section III. The main formulae and SIMULINK model and results taken of a simple memristor circuit with temperature influence accounting are given in Section IV. Final conclusions and remarks are presented in Section V.

II. DEPENDENCE BETWEEN CHARGE CARRIERS MOBILITY AND CELSIUS TEMPERATURE

In [11] an experimental diagram of the relationship between holes mobility and temperature of pure titanium dioxide is given. It is interesting that in this type of material the derivative of the experimental curve is positive. The holes mobility at room temperature is $\mu_v = 1.10^{-14}$ ($m^2/V.s$). Using these experimental data an extrapolation polynomial of 20^{-th} power is created in MATLAB environment. This polynomial is given with (1):

$$\mu_v = 1.10^{-54}(-0{,}0005T^{18} + 0{,}2394T^{17}) \qquad (1)$$

The graphical expression of this polynomial is presented in Fig. 1, where the absolute temperature T is replaced by the Celsius temperature: $t = T - 273{,}15$ [^{0}C]. It is clear that the charge mobility increases rapidly with increasing the memristor temperature.

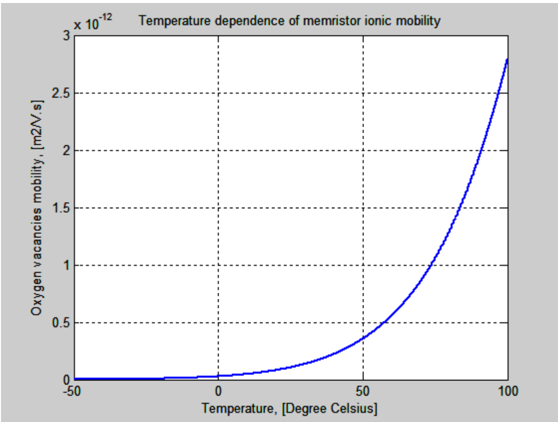

Fig. 1. Dependence between charge carriers' mobility and temperature

III. DEPENDENCE BETWEEN RESISTANCES OF THE MEMRISTOR IN OPENED AND CLOSED STATES AND THE CELSIUS TEMPERATURE

An experimental relationship between specific conductivity of titanium-dioxide and the absolute temperature is presented in [10]. The quantities at the axes are in logarithmic scale. The dependence between them is given with (2):

$$lg\sigma = 5{,}72lgT - 9 \qquad (2)$$

After processing (2) and expression of specific conductivity with the resistance R_{OFF} we obtain the next formula (3):

$$R_{OFF} = 2{,}06.10^{18} T^{-5{,}72}\ [\Omega] \tag{3}$$

The resistance of the memristor in closed state has more steep temperature relationship, expressed with (4):

$$R_{ON} = 6{,}3271.10^{16} T^{-6}\ [\Omega] \tag{4}$$

In Fig. 2 the dependence between R_{OFF} and the Celsius temperature t is presented.

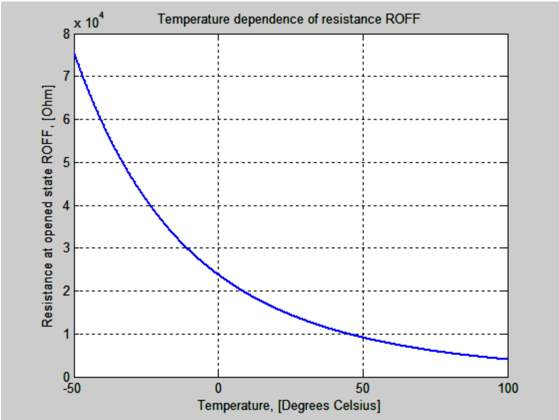

Fig. 2. Dependence between memristor resistance R_{OFF} and temperature

In Fig. 3 the relationship between R_{ON} and the Celsius temperature t is shown.

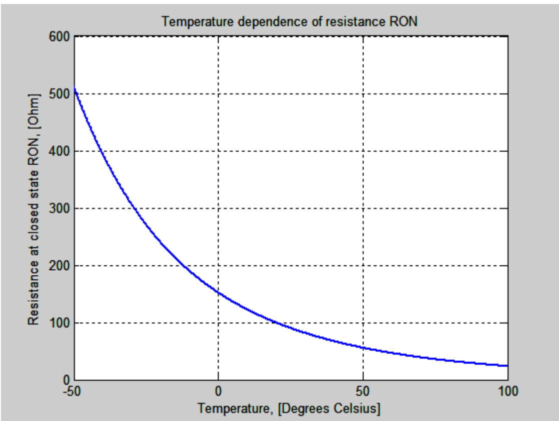

Fig. 3. Dependence between memristor resistance R_{ON} and temperature

IV. Synthesis and Analysis of SIMULINK Model of a Simple Memristor Circuit at Impulse Mode

The basic relationship between memristor current $i(t)$ and voltage across it $u(t)$ is presented with (5) [4]:

$$i(t) = \frac{u(t)}{R_{OFF}\sqrt{\left(1 - \frac{q(t_0)}{Q_D}\right)^2 - \frac{2\eta}{Q_D R_{OFF}}\int u(t)dt}} \tag{5}$$

where $q(t_0)$ is the initial charge in the doped region, and Q_D is the quantity of charges which the memristor can memorize in its whole volume. This quantity Q_D is presented with (6) [4, 8]:

$$Q_D = \frac{D^2}{\mu_v R_{ON}} \tag{6}$$

The constant D is the length of the whole memristor.

Based on these formulae presented above a SIMULINK model of memristor circuit with one memristor and with a pulse voltage source is created. The time diagrams of current and charge accumulated in the memristor are presented at different temperatures.

V. Conclusions

From the results presented above it is clear that with increasing the temperature the charge carriers' mobility increases too but the resistances of the memristor at opened and closed states decrease. As a result at Celsius temperature $t = 127\ ^0C$ the whole charge of the memristor that it can memorize is about 100 times less than its value at room temperature. The current through the memristor investigated is bigger than the current at a room temperature. So the quickness of the memristor increases too and the operational state changes. But the characteristics of the memristor as an electronic switch are worse at high temperature.

Acknowledgments

The research results presented in the paper are financed from Contract № 121PD0072-08 for scientific projects for help of PhD Students of Scientific – research sector of Technical University – Sofia for 2012 - 2013 years.

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