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Tunnelling conduction process introduction during the degradation phenomena process in SnO_2 and ZnO varistors

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Abstract

An adjustment on the electrical degradation phenomena promoted by the application of low *dc* voltages on SnO_2 and ZnO based varistors is presented in this work. The electrical properties of varistors systems were highly damaged after treating the samples. Variations on the potential barrier height and width determined via impedance spectroscopy measurements are discussed on the basis of atomic defects at boundary regions and changes in the donor and surface states densities. Several authors consider thermionic conduction as the dominant process in SnO_2 and ZnO varistors but, for an appropriate barriers description, tunnelling current through the barriers must be considered.

The most studied varistor system, being currently used for commercial purpose, is based on a ZnO composition, as initially developed by Matsuoka *et al.* around 1970 [1]. Pianaro *et al.* [2] developed a SnO_2-based varistor composition, which has also been extensively studied and it is suggested to possess some advantages when compared to the ZnO-based compositions [3,4]. The purpose of this work is to gain knowledge in the degradation phenomena promoted by the application of a dc voltage and current pulses on SnO_2 and ZnO-based varistors. Variations on the potential barrier height and width determined via impedance spectroscopy analysis considering the thermionic and tunnelling conduction are discussed.

The ZnO-based varistor composition was 95.4% ZnO + 1.5% Sb_2O_3 + 1% NiO + 0.1% SiO_2 + 0.5%, whereas the SnO_2-based varistor composition was 98.9% SnO_2 + 1% CoO + 0.05% Nb_2O_5 + 0.05% Cr_2O_3. The high voltage circuit to generate the pulses of 8/20 μs was based on three capacitors having a total capacitance of 2.25 μF. Before and after the degradation process, each sample was electrically characterized by Impedance Spectroscopy (IS). In a first approach, a simple model considering the thermionic conduction was used. After that, experimental results were fitted using a sophisticated model which considers the contribution of the thermionic and tunnelling components to the electronic conduction. From Table 1, it can be seen that the barrier height is not greatly affected after degradation process even though an increase in C_{gb} was registered after each electrical stressing step.

Table 1: Grain boundary capacitance (C_{gb}) and resistance (R_{gb}) extracted from IS analysis, barrier height (φ) and donors concentration (N_d) obtained through different approaches to the electrical conduction.

Sample	Rgb (Ω)	Cgb (F)	Thermionic conduction		Thermionic plus tunnelling		J therm (A/cm^2)	J tun (A/cm^2)	J_{total} (A/cm^2)
			ϕ_b (eV)	N_D (m^{-3})	ϕ_b (eV)	N_D (m^{-3})			
ZnO before	$5{,}90 x10^{6}$	$3{,}82 x10^{-11}$	0,778	$4{,}19 x10^{21}$	0,810	$5{,}410 x10^{21}$	$6{,}5665 x10^{-8}$	$5{,}157 x10^{-8}$	$1{,}195 x10^{-7}$
ZnO after c.c	$5{,}10 x10^{5}$	$2{,}63 x10^{-10}$	0,716	$1{,}84 x10^{23}$	0,768	$3{,}365 x10^{23}$	$3{,}3652 x10^{-7}$	$2{,}176 x10^{-6}$	$2{,}512 x10^{-6}$
ZnO after-pulses	$5{,}70 x10^{3}$	$1{,}44 x10^{-9}$	0,600	$3{,}42 x10^{24}$	-------	---------	----------	------------	$2{,}234 x10^{-4}$
SnO_2 before	$3{,}77 x10^{6}$	$1{,}44 x10^{-10}$	0,749	$2{,}86 x10^{23}$	0,781	$7{,}417 x10^{22}$	$2{,}0229 x10^{-7}$	$4{,}999 x10^{-7}$	$7{,}028 x10^{-7}$
SnO_2 after c.c	$2{,}88 x10^{6}$	$1{,}620 x10^{-10}$	0,742	$3{,}58 x10^{23}$	0,776	$9{,}327 x10^{22}$	$2{,}465 x10^{-7}$	$7{,}064 x10^{-7}$	$9{,}528 x10^{-7}$
SnO_2 after pulses	$1{,}76 x10^{6}$	$3{,}46 x10^{-9}$	0,582	$6{,}81 x10^{25}$	0,595	$3{,}956 x10^{21}$	$2{,}8196 x10^{-4}$	$1{,}814 x10^{-4}$	$4{,}633 x10^{-4}$

References

[1] M. Matsuoka, *Jpn. J. Appl. Phys.* 10 (1971) 736.
[2] S.A Pianaro, P.R Bueno E. Longo, J.A Varela. *J. Mater. Sci. Lett.* 14(1995) 692.
[3] Bueno, P. R., Varela, J. A., Barrado, C. M., Longo, E. and Leite, E. R. *J. Am. Ceram. Soc.*, 2005, 88, 2629–2631.
[4] R. Parra, M.A. Ponce, C.M. Aldao, M.S. Castro, *J. Eur. Ceram. Soc.*, 27 (2007) 3907-3909. ISSN: 0955-2219.