A Nanocoloumbmeter for Triboelectric Charge Testing of Garments

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Abstract - It is shown a nanocoulombmeter (NC) of Faraday Cup (FC) type used for electrostatic charge (q_x) measurement on cloth (gown, waistcoat, etc) of the working personal in the microelectronic industry. Unlike existing equipments of this type, the NC proposed by the authors has the advantage that measurement of q_x may be done without contact with active electrode of FC, which allows not to use the elimination of connection cable (disturbing and expensive component) between FC and displaying device of the measuring instrument for q_x.

1. Research's motivation

The technological experience of the last few years shows that the main generator of dangerous electrostatic charge in the electronics and computers industry is operator's human body (HB) [1, 8]. It may charge in each of the 3 base sequences that can be met in the working space: walking on the floor to the working table, changing of some garments pieces (GP) (taking off a cloth, putting on a gown), activity at the working table. The authors' researches focus on the second sequence only, because it has been found that in this sequence the HB charging is much greater than in the others cases, reaching 0.5 ÷ 1.2 μC [2, 7]. At such values, the HB discharge (ESD, fig.1) may produce hardware breakings (components breaking through) and software malfunction (false triggers) [4, 8].

In our days, the measurement of the electrostatic charging of the HB is realized (standard) by "Walking" method, which can not be used to the measurement of the charging on GP. For this type of measurement can be used a nanocoulombmeter, for example the Monroe Electronics 284/22B system of [6]. In this case there are two inconveniences: (**1.**) the volume of the Faraday's cup (FC) is too small (3 dm^3), and (**2.**) transmission of charge (q_x) to the output equipment (electrometer) is done with a triaxial cable (TC), which is too expensive and perturbing (at flexure or torsion may generate parasitic charge). To avoid these inconveniences, the authors have developed a coulombmeter, which has a volume of FC much greater (17 dm^3) and where the measurement of q_x is done without contact (by means of the E_x field emitted by q_x), which permits the elimination of TC from the measuring circuit.

2. Physical phenomenon which basis the nanocoulombmeter

It is known that by rubbing of two electro-isolated pieces, A and B (fig.2a), they load with charges of opposite sign but same size ($q_A = |-q_B|$). In this case the measurement of q_x, can by done either on A or B.

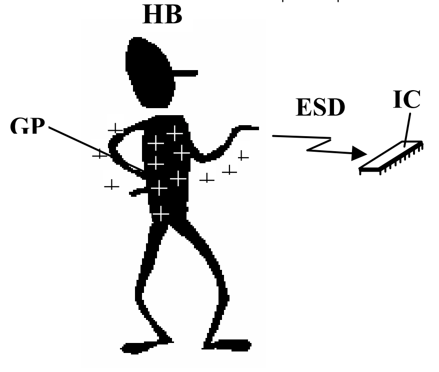

Fig.1

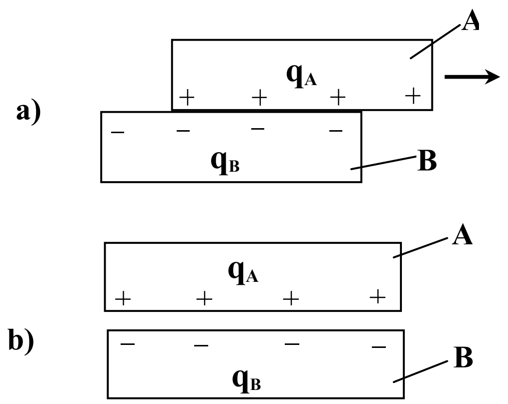

Fig.2

Based on this assumption, the authors are proposing the replacement of the measurement of the electrostatic charge (appearing on HB when taking of a GP) by the measurement of the accumulated charge on the GP (q_x) which is dropped (at normal speed) in to the FC of nanocoulombmeter.

3. Description of nanocoulombmeter

The functional and block schemes of the nanocoulombmeter are represented in fig.3a and fig.3b respectively. Its function is: Because of q_x on GP (in FC), between cylinder electrodes 1 and 2 of the C_{12} capacitor, appears a potential difference:

$$V_x = q_x / C_{12}, \qquad (1)$$

V_x, voltage is measured with a Fieldmill electrostatic voltmeter (FM) [8] which displays the following:

$$N = aV_x, \qquad (2)$$

proportional with V_x, and q_x also.
Combining (1) with (2) results the expression (m = constant):

$$N = mq_x \qquad (3)$$

which represents the *functional equation of NC*, where:

$$m = \frac{k}{C_{12}} \qquad (4)$$

is its sensitivity.

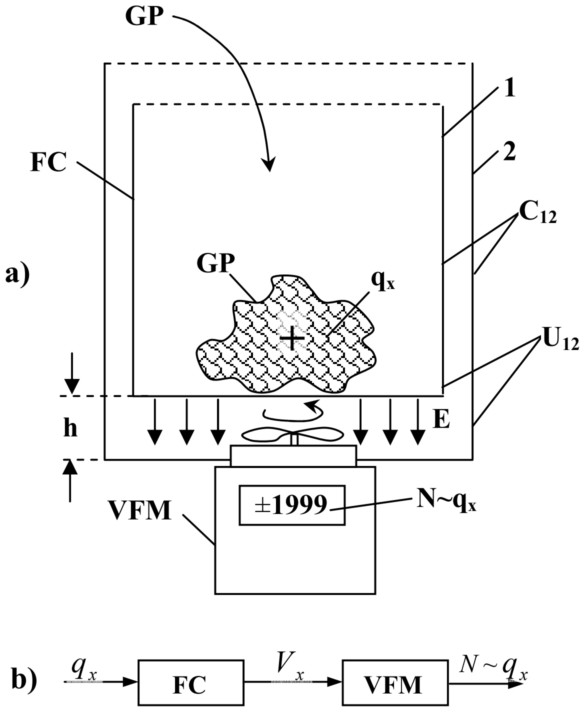

Fig.3

4. Technical Caracteristics of NC

Ranges for q_x. The NC has 3 measuring ranges for q_x: 20, 200 and 2000 *nC* respectively.

Capacity C_{12} of FC has been adjusted (by modification of *h*, fig.3a) to meet $C_{12} = 200pF \pm 0,5\%$, measured with a digital Faradmeter, having accuracy of 0,02%. For $C_{12} = 200pF$, at 20, 200 and 2000 *nC* ranges the according output voltages (V_{xn}) of FC are: 200, 2000 and 20000*V*.

Other characteristics of FC. The volume of active electrode 1 (cylindrical): 17*dm*^{3}, isolation resistance $R_{iz} > 10^{14}\,\Omega$, breaking voltage $V_{12str} = 30kV$.

Fieldmill voltmeter (VFM) has the displaying function realized by a digital milivoltmeter of 7106 type, with displaying device 1999 ($N_{\max} = 2000$) and base accuracy 1,3 %.

5. Measuring uncertainty of NC

Examining functioning equation of NC (3) we can see that for q_x = constant, NC indication (N) can be affected by error because of *m* instability. Therefore the analysis of measurement uncertainty of NC can be reduced to the analysis of the uncertainty that affects the sensitivity of $m = a/C_{12}$.

In order to simplify notation, during the analysis of the uncertainty related to m, C_{12} will be denoted as C, thus (4) will be used in the following form:

$$m = \frac{a}{C} \tag{5}$$

5.1. Evaluation criteria

Following GUM [5], the maximum uncertainty related to *m* is expressed as the extended uncertainty:

$$U_m = ku_{cm} \tag{6}$$

where *k* is the extension factor and u_{Cm} is the standard composed uncertainty related to *m*. This last uncertainty is defined by the expression;

$$u_{cm} = \sqrt{{u_{Am}}^2 + {u_{Bm}}^2} \tag{7}$$

where u_{Am} and u_{Bm} are standard uncertainties of type A and B respectively. None of the two quantities that define *m* is obtained by repetitive measurements, therefore results that u_{Am} = 0 and only u_{Bm} must be evaluated. In this case, results that $u_{Cm} = u_{Bm}$.

5.2. Evaluating B type uncertainty

Starting from (5), the expression of u_{Bm} can be expressed as following:

$$u_{Bm} = \sqrt{\left(\frac{\partial m}{\partial a} u_{Ba}\right)^2 + \left(\frac{\partial m}{\partial c} u_{Bc}\right)^2} \tag{8}$$

or, using normalized values:

$$\frac{u_{Bm}}{m}100 = \sqrt{\left(\frac{u_{Ba}}{a} \cdot 100\right)^2 + \left(\frac{u_{Bc}}{c} \cdot 100\right)^2} = u_{Bm}\% \tag{9}$$

where (u_{Ba}/a)100 and (u_{Bc}/c)100 are the uncertainties of VFM (1.3%) and C_{12} (0.5%). Replacing these values in (9) we obtain $u_{Bm}\% = u_{Cm}\% = 1,38\%$.

5.3. Computation of extended uncertainty

NC is considered for measurements of medium accuracy, therefore we have chosen a confidence level of 95% which in Gauss statistics corresponds to an extension factor *k* = 2. Under these considerations from (6) we obtain $u_m = 2 \cdot 1{,}38 = 2{,}76\%$ which means that the base uncertainty of the proposed nanocoulombmeter is $BU = U_m = 2{,}76\%$. This result indicates that NC enters in the accuracy class 3. The value BU is in accordance with the experimental results (2,7%) given in [2].

6. Conclusions

In this paper it has been shown a nanocoulobmeter (NC) of Faraday Cup (FC) type, used for measurement of triboelectric charge (q_x) which may be produced on cloth (gown, waistcoat, etc) taking off by the human operator, instrument useful for cloth testing of the working personal in the microelectronics.

Unlike the existing instruments of this type, the proposed NC has the advantage (important one) that measurement of q_x is done without electrical contact with FC, which permits elimination of the connection cable (disturbing and expensive component) between this and displaying device of the measuring instrument for q_x.

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