Optimization of the collection of sprays by an enhanced electronic sensor

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Abstract: We propose the study of an electronic sensor allowing the collection of sprays in free space. The detector consists of three elements: a photodiode situated in the center of the structure to which is applied a bias voltage, an aluminum ring which referenced to a voltage higher than that of the photodiode and an insulating material disk (polyvinyl chloride). The total size of the structure is fixed by the diameter of the disk of insulating material. The electrostatic field created by this sensor has allowed an optimization of the collection of sprays. To obtain the biggest volume of possible detection, it's necessary to optimize dimensions of the various elements of the structure, geometries and voltages.

Keywords: sprays, collection, electrostatic field, charged particle

1. Introduction

The detection of emanation of potentially dangerous gas resulting from the basement becomes a sanitary major stake. Safety standards taking into account the volume activity (expressed in Bq / m^3) of gas (odorless and colorless) allowed to fix thresholds of air pollution. These thresholds take into account the number of particles electrically loaded per m^3. These harmful particles stemming from gas settle on an agglomerate of particles (not taken into account in our study). The group is called spray. To determine this volume activity and define the degree of pollution of the concerned middle, it is necessary to develop electronic sensors allowing the real-time collection of these sprays. The sensor that we present consists of two different parts. The first one is only dedicated to the collection and the second part realizes the counting of particles stemming from these sprays. The part dedicated to the collection will be presented here only.

2. First structure and results

The objective of this sensor is to optimize the collection of sprays thanks to an electrostatic field $\vec{E}$. This field is created between both electrodes of the structure. The first one corresponds to a photodiode situated in the center of the sensor and the second is a ring of aluminum. The chosen photodiode possesses specific characteristics for the detection of charged particles. The electrostatic field $\vec{E}$ appears thanks to the difference of potential created between both electrodes. It is calculable analytically thanks to the equation 1:

$$\vec{E} = -\overrightarrow{grad\,V} \quad (1)$$

To have an optimized volume of collection, it is necessary to adapt the dimensions of the various parts which constitute the sensor. The tensions applied to electrodes are imposed by normative constraints (ring aluminum) and technological constraints (circuit of counting). Initially, the shape chosen as the structure was circular and married so exactly the outline of the electrode of aluminum. Because of industrial constraints, the geometry of the insulating material became cubic. The structure is presented in figure 1:

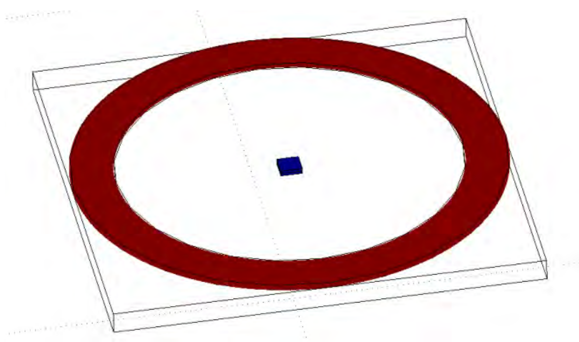


Figure 1 : Sensor's structure

The structure (figure 1) thus consists of a square photodiode of 2 mm of quoted and of 500 um of thickness. The insulating material is a cube of 4 cm of highly-rated and 2 mm in thickness. The aluminum electrode has an outside diameter of 4 cm and a 4 mm width. For a problem of robustness of the sensor, the photodiode is half pushed in the insulating material (polyvinyl chloride).

For the structure presented on the figure 1, a bias voltage of 3 V is applied to the superior face of the photodiode. The lower face serves as reference of potential and is in the ground. A voltage of 380 V is applied to the aluminum peripheral ring. We shall focus only on the lines of field being except the insulating material because they are the only ones to be able to optimize the collection. Those being inside do not influence the detection and will not thus be taken into account. The results are presented on figures 2a and 2b.

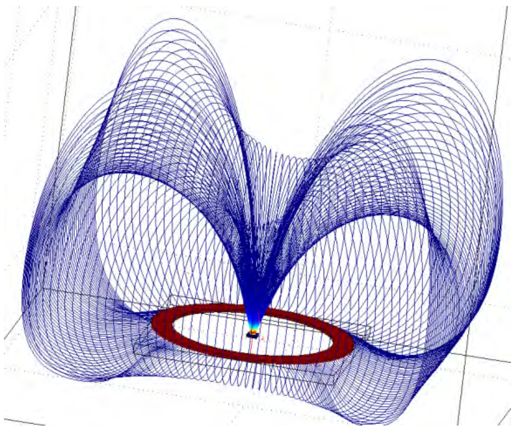


Figure 2a : E field's streamline (global view)

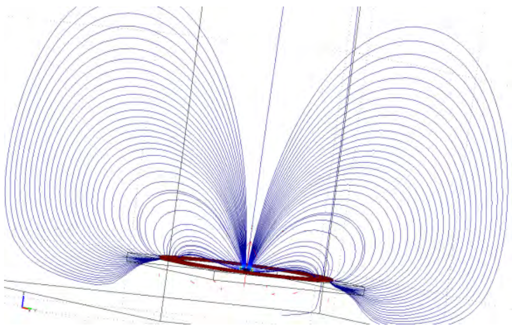


Figure 2b : E field's streamline (section view)

The values of the electrostatic field for a distance greater than 8 cm some structure what are of the order of 1 V/m and of $7{,}75.10^5$ V/m in closer what is in compliance with the values waited with regard to the equation 1. Considering the applied tensions, lines directed of the ring of aluminum to the photodiode. The majority of these lines are produced between the ring and the superior face of the photodiode (active area).

As we can notice it on figures above, the lines of field $\vec{E}$ have lengths between 2 electrodes are very variable. This variation can be penalizing during the collection of sprays. Indeed, the charged particles which compose sprays quickly lose their energy when they move in air. It is important to have a fast collection. To remedy it, two solutions are possible:

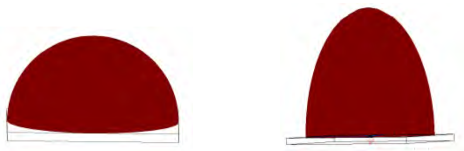
- increase the difference of potential between both electrodes to have a more intense electric field,

- define a zone of collection more restricted to obtain shorter lines of field.

The solution which we chose to develop takes into account electric safety standards towards the general public as well as the global dimension of the sensor. Thus, it is necessary to create a structure allowing satisfying the requirements linked to a zone of more restricted collection.

3. Modified structure and results

To optimize the zone of collection, the ring of aluminum was replaced by half an aluminum ellipsoid. Many length have been tested: 2 cm, 4 cm, 6 cm and 12 cm for the main line and the 4 cm in diameter for axes following the directions x and y figure 3.



a) b)

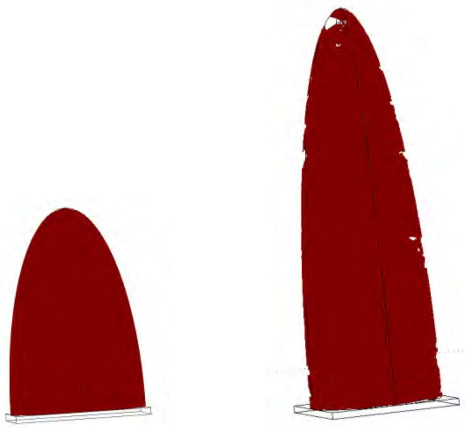


Figure 3 : Different ellipsoids tested: a) 2cm high; b) 4cm high; c) 6 cm high; d) 12 cm high

In each case, the ellipsoid is referenced to a unique potential identical to that of the ring of aluminum (380 V). In every simulation, the goal is to define if the collection of sprays could be optimized by the new structure.

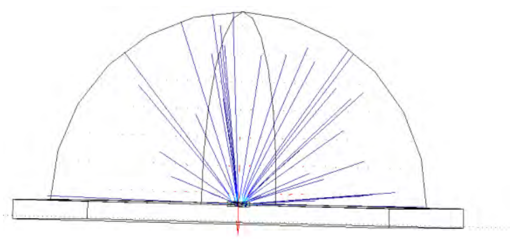


Figure 4 : E field streamline for 2 cm high ellipsoid

On figure 4, we could see that streamlines avec very direct between the peripheral electrodes and the photodiode. This aspect is very good for the collection. Furthermore, the field's intensity is powerful because the minimal value is close to 900 V/m and the maximum value is close to 7.10^5 V/m. This configuration of the ellipsoid allows optimizing largely the collection reporting the ring configuration (Figure 1).

The next figure reports the 6 cm high ellipsoid results.

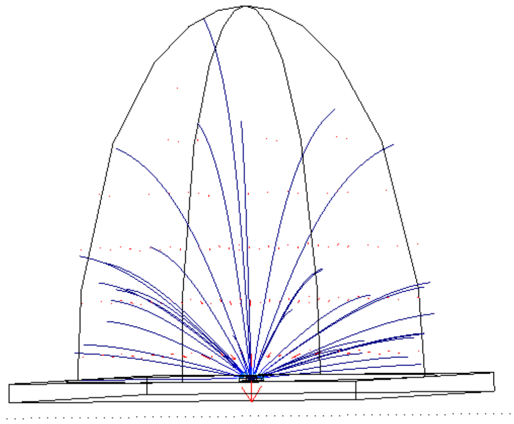


Figure 5 : E field streamline for 4 cm high ellipsoid

On figure 5 we could see the streamlines are a little less direct for the previous structure. Here, the electrostatic field intensity is included between 40 V/m and 7.10^5 V/m. The collection is also optimized and the detection's volume is larger than the previous case. But like the E field is less intense, collection in less fast.

Next, the detection's volume will be increase so it's possible to say that the minimum electrostatic field intensity will decrease.

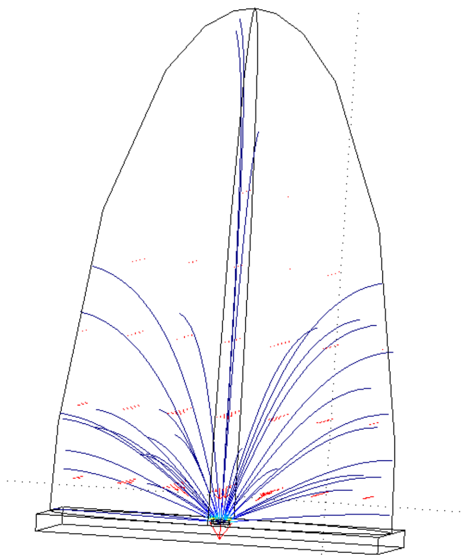


Figure 6 : E field streamline for 6 cm high ellipsoid

In this structure (figure 6), the E field lines are also less direct than previous cases. The minimum intensity of the electrostatic field is 1.5 V/m and the maximum is the same as before. This intensity is certainly sufficient to collect sprays but probably not so fast.

The next step is having an ellipsoid of 12 cm length. This simulation is used to have a bigger detection volume. Results are presented in figures 7a et 7b.

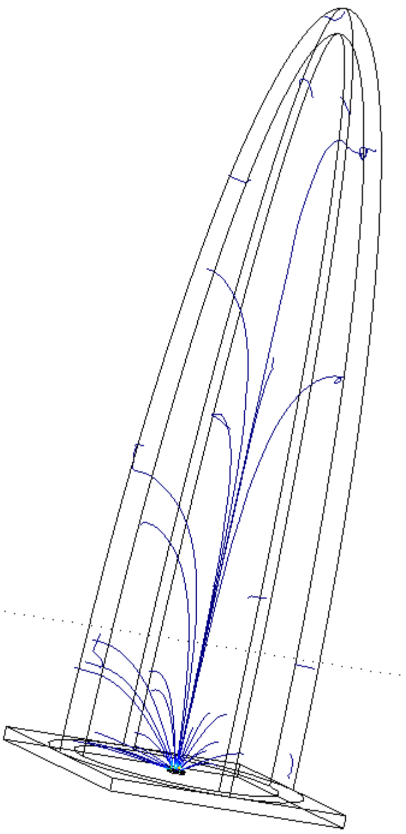


Figure 7a : E field's streamline (global view)

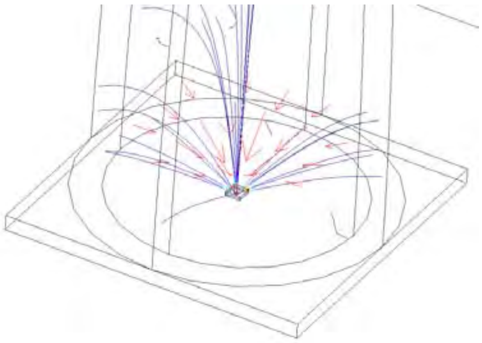


Figure 7b : E field's streamline (centered view)

On the figure 7a, we notice that the lines of field $\vec{E}$ are less direct between the electrode and the photodiode than for the first case (figure 4). The electrostatic field values are 1.10^{-3} V/m for the minimum (at the top of the detection area) and the maximum is always the same and is close to 7.10^{5} V/m.

On the figure 7b, we notice that the lines of field appear as previously between the peripheral electrode and the face activates of the photodiode. The orientation of the lines of field is also represented on this figure.

For this structure, several thicknesses of ellipse are tested (from 1 mm to 4 mm). We show that the influence of this thickness on the maximal value of the electrostatic field $\vec{E}$ is unimportant. This explains by the fact that the variation of thickness was weak. The variation of the electrostatic field depends directly on the distance between electrodes. The potential is constant on the whole ellipse. Thus the gradient of potential (dV / dx) is subjected to the only variations of x.

For this structure type, the route of sprays collected as well as the energy lost by charged particles is considerably reduced from the first one with the aluminum ring only (figure 2).

4. Conclusion

The objective of our study is to realize a system of collection of sprays. This system must return account of the volume activity of the considered gas in real-time. Considering the fast loss of energy by particles, a change of geometry of the electrode was necessary. The modification of the topology of the electrode allowed an improvement of the collection in a zone targeted and realized by the ellipse. This modification also allows having a system more strong and adapted to the industrial constraints. The perspectives during the next simulations are to introduce into the conception a hole at the top of the electrode which will allows an air flow in the structure, the thread of supply of the photodiode and the electrode to study their impacts on the structure of the sensor. In the same time, an armor plating box for the counting circuit. It is thus necessary to us to realize a study of electromagnetic compatibility.

5. References

[1]Thèse R. Abou-Khalil, 2008