STATISTICAL PARAMETERS STUDY OF A SURFACE DOPING SIMULATION PROCESS

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ABSTRACT

This work presents algorithms and mathematical calculations implicated in the simulation of a surface doping process where a predetermined surface, with fixed dimensions, is randomly burst in similar radii circular holes. The simulation measures the number of intersections presented between holes as well as the intersection area for specific cases. Special interest is shown in measuring and testing the tendency towards a specific number of intersections among holes. This tendency depends on both, the hole's area and hole's density and is proven, in this work, by a large number of simulations. The simulation shown here has application on real processing, where the statistical information allows to determine appropriated doping density because the efficiency of surface doping depends on the total area occupied by the doping material.

Doping stadistical study, escencial for the electronics industry development.

1 Introduccion

This simulator was programed in language Pascal, using the compiler "Pascal of Borland version 7.0.". The program generates a certain number of circles of constant radius distributed semi-randomly in a certain area, then calculates the distances among them to determine the number of intersections and the total area occupy, finally statistical results are displayed graphic and quantitatively.

2 Brief description of the simulator

The program consists of the following main procedures:

2.1 Acquisition of data:

This procedure allows you to select the quantity of holes for the experiment, the radius of the circles and allows you to select the number of experiments that will be carried out, the area of the experiment is squared and it's given by pixels (480 x 480).

2.2 Semi-random numbers generator:

The functions *Random* and *Randomize* generate quasi-random or semi-random numbers that determine the coordinates of the centers of each circle.
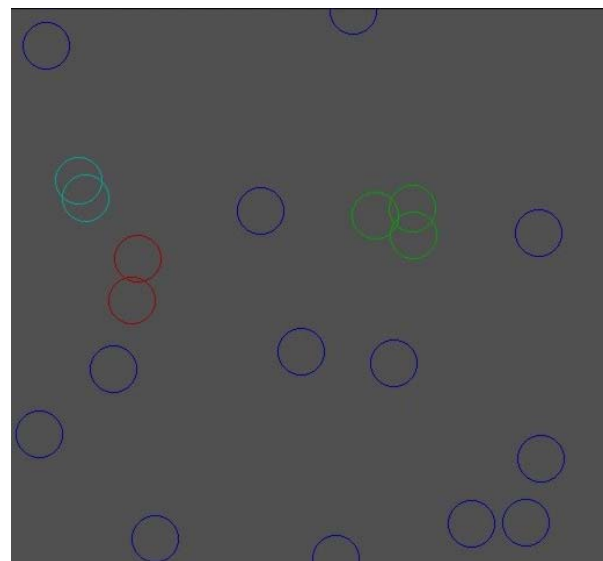

Fig 1. Typical doping experiment with 20 circles with 20 of radius.

2.3 Calculation of intercepted circles and the total number of intersections:

In this procedure the total number of intersections is determined, these are calculated comparing the distances among each of all the centers of the circles with the minimum distance of intersection without repeating none, the program takes charge of registering the circles where intersection exists as well.

2.4 Calculation of the area:

The area for the non intercepted circles (holes) is πr^2, to calculate the area of the rest, the program detects figures formed by circles that form closed areas when they are intercepted among them, to calculate each one of them an algorithm it's applied based on the theorem of *the interior polygon of the figure* which is described later.

2.5 Showing statistical numeric data:

When the program finishes generating and simulating a number "n" of experiments the computer registers the total of intersections and areas of each event, the program deploys information of the average, maximum value and minimum value of intersections, and shows the average area for a specific doping density.

2.6 Showing graphic statistic data:

The number of intersections by event is observed in a graph of bars, by a graph of frequencies we obtain graphic information of the intersections in all the events depending on the density of the experiment.

By increasing the number of times that is carried out this experiment we can observe in a clearer way a Gaussian function, which indicates the tendency of the experiment to a specific value for the conditions given initially.

3 Mathematical theory

3.1 Calculating intersections

An intersection occurs between two circles that belong to the same plane when at least they cut themselves in a point. To determine if intersection exists between two circles of same radii, the distance among centers "d" most be compared with the minimum distance of intersection that is twice the radius "r." If "d" it is smaller or equal to the mimimun distance the intersection occurs.
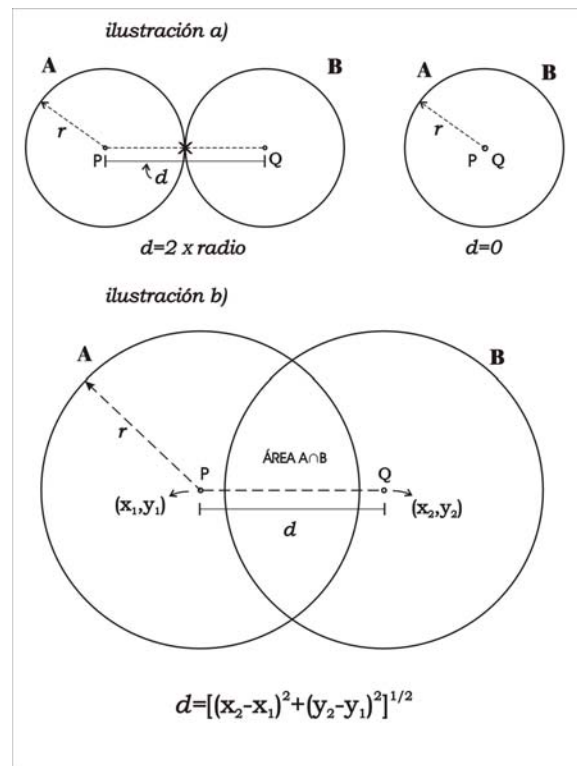
Fig 2. Intersection conditions.

3.2 Theorem of the internal polygon of the figure

This theorem was developed in this work to calculate areas of complex figures generated by circles of same radii in the same plane, however the theorem works also for circles of different radii by knowing the coordinates of the intersection points.

The theorem is not described detailedly in this article, but it consists fundamentally by forming

an internal polygon that divides the enclosed figure in sections of circles, this polygon, at the same time, can be divided in triangular sections that allow us to determinate exactly the area of the figure, as we see in the Fig 3.
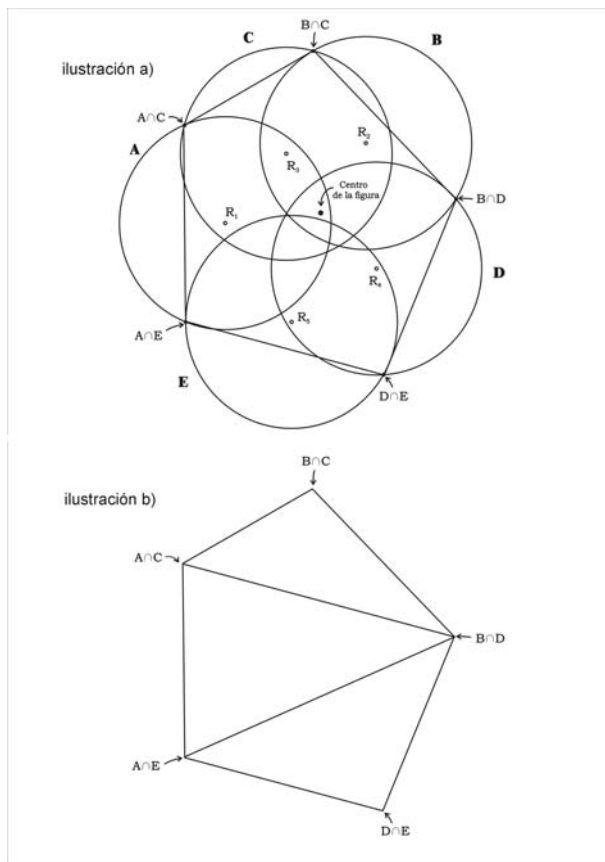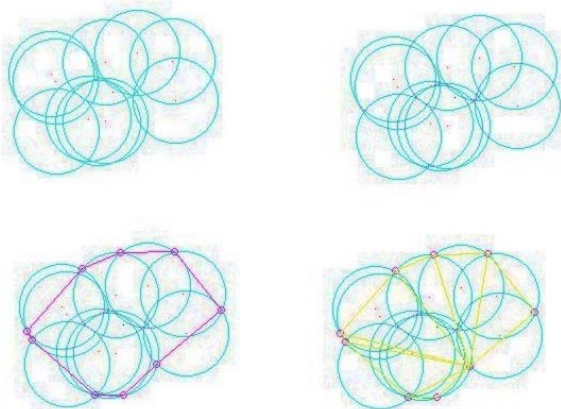

Fig 3. Theorem of the internal polygon. Below: The way the computer calculates the area.

4.1 Conclusions

Thanks to the simulator we have been able to prove experimentally that it always exists a tendency to a number of intersections depending on the radius of the holes and of the density in a doping material, likewise, we have been able to determine with a good degree of accuracy the relationship among area of each hole, doping density in a certain area of the material, and the number of intersections, as is shown in the Fig 4.

Number of circles In the experiment	Intersection average (5000 events per experiment)	Number of intersections (given by our formula)
1	0	0.0095205
2	0.0212	0.038082
3	0.0448	0.0856845
4	0.087	0.152328
5	0.2414	0.2380125
6	0.3484	0.342738
7	0.4242	0.4665045
8	0.5838	0.609312
9	0.7238	0.7711605
10	0.886	0.95205
11	1.083	1.1519805
12	1.3246	1.370952
13	1.5994	1.6089645
14	1.8566	1.866018
15	2.1288	2.1421125
16	2.438	2.437248
17	2.6786	2.7514245
18	2.9476	3.084642
19	3.4298	3.4369005
20	3.8082	3.8082
21	4.2476	4.1985405
22	4.6604	4.607922
23	5.0406	5.0363445
24	5.5366	5.483808
25	6.0354	5.9503125
26	6.5944	6.435858
27	7.1264	6.9404445
28	7.594	7.464072
29	8.1656	8.0067405
30	8.7032	8.56845

Table 1. Experiment made on december 2001 for radius equal to 20.

Graph of intersections for "n" circles of radius 20 for an area of 480 x 4
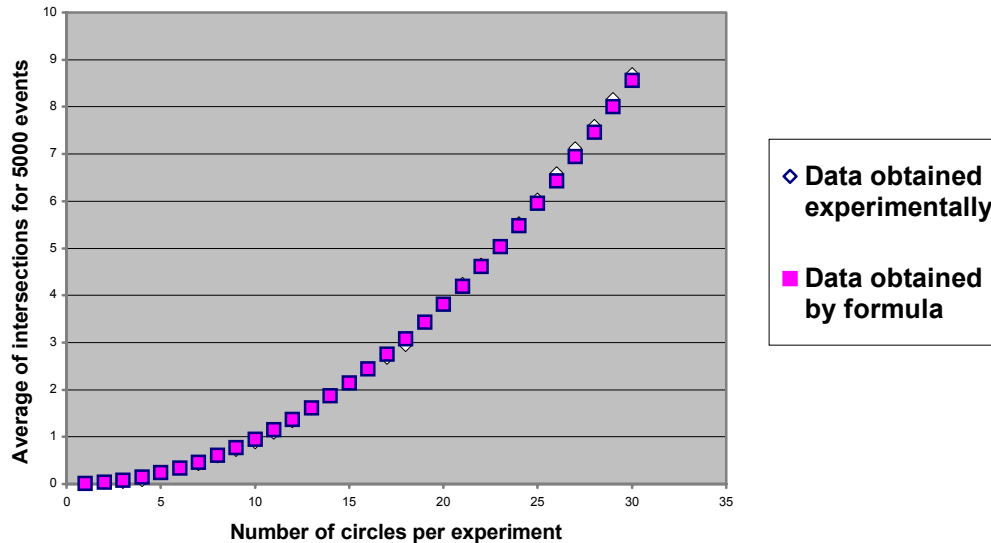

Fig 4. We proved the relation between density, area of a hole and the number of intersections.

This is an experiment of the calculation of intersections with to number of circles from 1 to 30, with 5000 events for each experiment and all with to radius of 20 pixels in an area of 480 x 480 pixels, the program siluated all these events and calculated the stadistics, from Table 1 we determinated the proporcion constant.

Now we are looking for the relationship among the number of intersections for a specific event and the average doping area, all this statistical information can help in questions of desing and development in the production of doping materials and as a consecuence in the electronics industry.

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