Vacuum deposition chamber

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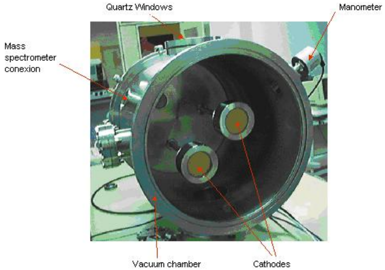
Outline

Overview of the problem

Problem statement

- In industry vacuum deposition is used for the generation of coating.
- Example: reflecting part of projectors for cars
- The deposition occurs in a chamber with two electrodes creating a gradient of potential.
- This modifies the repartition of the ions and electrons present in the chamber.
- The ions act as catalyser for the polymere reaction involved in the coating.

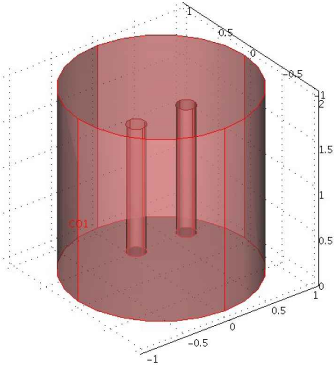
Main objective: Obtain in the chamber a large region with a high concentration of ions.



Our work : model and simulations

- Develop and study a model describing the process in the chamber
- 1D model (cartesian and cylindric)
- 2D model
- Influence of parameters (gas pressure, temperature, electrical voltage)

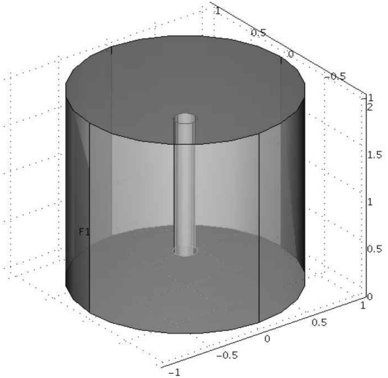
The simulations are all made with the software COMSOL.



Outline

The model: Hypothesis

- Electrostatic field
- Atmosphere of plasma (polymere) might contain all kind of positive and negative particules. We assume that the only positive particules are ions and the only negative particules are electrons.
- The chamber is cylindrical.
- The cathode is the small cylinder in the center of the chamber, which is used as the anode.



Outline

Equations

- 3 variables : potential V, density of ions n_i and of electrons n_e
- Poisson equation: $-\triangle V = \frac{e}{\varepsilon}(n_i - n_e)$,
  where $\triangle$ is the Laplacian, e is the elementary charge and ε is the dielectric constant of the atmosphere in the chamber.
- Continuity equations of the form: $\frac{\partial\rho}{\partial t} + divJ = source(x,t)$. In our stationary case:
  - $\nabla.J_i = \mu_i n_e S(V)$
  - $\nabla.J_e = \mu_e n_e S(V)$,
    where J_i and J_e represent the current densities of ions and electrons. μ_i and μ_e are the mobility of the ions and electrons. S(V) is the frequency of ionisation given by Townsend formula.
- The current densities are described by a model called "drift-diffusion" :
  $J_i = -\mu_i n_i \nabla V - D_i \nabla n_i$ and $J_e = -\mu_e n_e \nabla V - D_e \nabla n_e$

Dimensionless equations

We denote :

- $V = V_0$
- $n_i = n_0 n_i^{'}$
- $n_e = n_0 n_e^{'}$

and get the dimensionless equations:

- $-\triangle u = n_i - n_e,$
- $\nabla.(-n_i \nabla u - \nabla n_i) = \frac{\mu_e}{\mu_i} n_e S(u)$
- $\nabla.(n_e \nabla u - \nabla n_e) = n_e S(u)$

Boundary conditions

For the electrical potential, electron and ion densities:

- At the anode:
  - The potential is $u = u_0$
  - Electrons are attracted and effectively absorbed, $J_e.\underline{n} = -n_e \nabla V.\underline{n}$
  - No emission of ions, $J_i.\underline{n} = 0$
- At the cathode:
  - The potential is $u = -u_0$
  - Ions are attracted and effectively absorbed, $J_i.\underline{n} = -n_i \nabla V.\underline{n}$
  - No emission of electrons, $J_e.\underline{n} = 0$

Model test

In the cartesian coordinates the equations become:

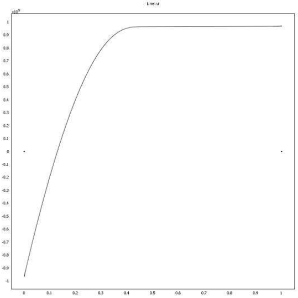
- $-u_{xx} = n_i - n_e$
- $(-n_i u_x - n_{ix})_x = \alpha n_e S(u)$,
- $(n_e u_x - n_{ex})_x$,

with the boundary conditions

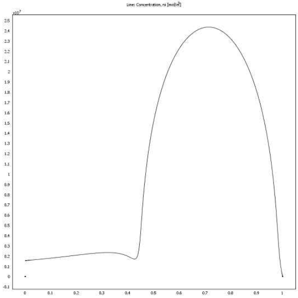
- at the anode (x=1)
  - $u = V_0 > 0$
  - $n_i u_x + n_{ix} = 0$
  - $n_{ex} = 0$,
- at the cathode (x=0)
  - $u = -V_0$
  - $n_{ix} = 0$
  - $n_e u_x - n_{ex} = 0$,

Results in 1-D

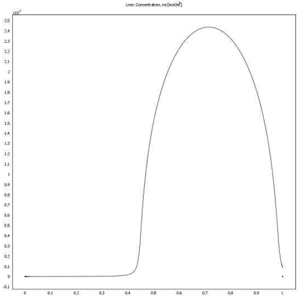
$V_0 = 2500$ V



Potential



Density of ions



Density of electrons

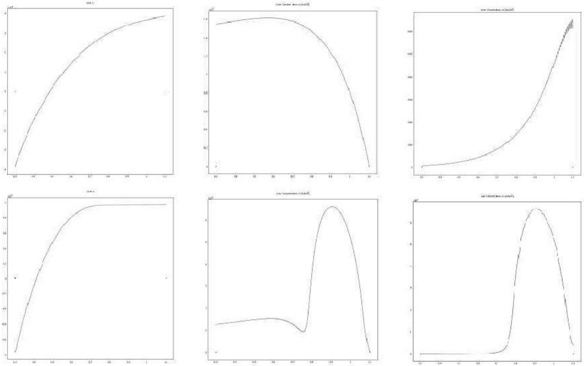
1D case

We consider a chamber with $L >> R$.
Then we have the cylindrical symmetry, i.e. 1D case.

- Gradient: $\nabla = \frac{\partial}{\partial r}$
- The divergence: $\nabla . = \frac{1}{r}\frac{\partial}{\partial r}(r\frac{\partial u}{\partial r})$

Results

Similar to the 1D cartesian case but much more sensitive to perturbations and need a higher external voltage to get to the same voltage profile.

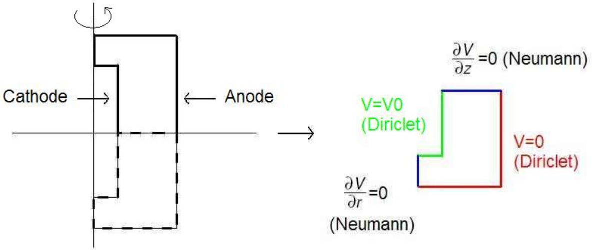


V0 = 1000V

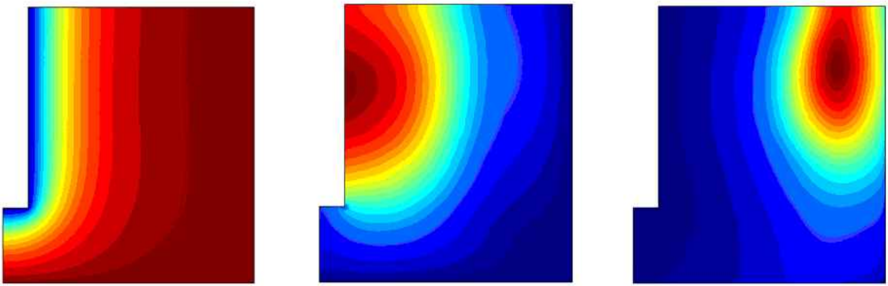
V0 = 2500V

2D model : Boundary domain and symmetries

The boundary shape is more complex than in the 1-D case.

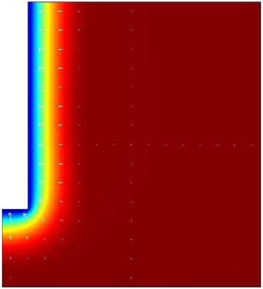


Results in 2D

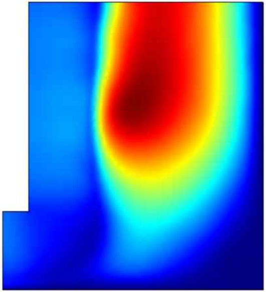


Potential Density of ions Density of electrons

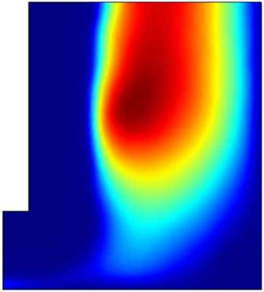
Results in 2D



Potential



Density of ions

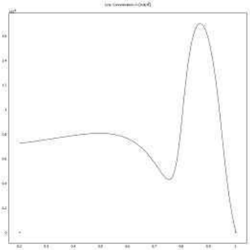


Density of electrons

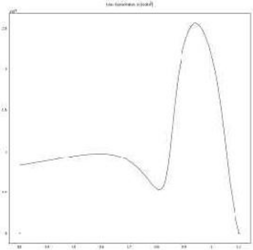
Outline

Modifications of the problem

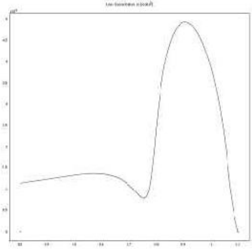
We varied temperature and pressure: for an increase of 100°C we observed only slight changes.



P = 9 bars



P = 10 bars



P = 10.6 bars

For a small increase of P the density of ions increase considerably but stay localized in the same region.

Outline

Conclusions

- The external voltage influences the distribution of ions
- With a potential large enough we obtain a localized distribution of ions
- A change in pressure changes the concentration and spread of ions
- Temperature doesn't have a notable influence

Next step: model with two electrodes.