Electrospray ion beam deposition of complex molecules on surfaces in the vacuum

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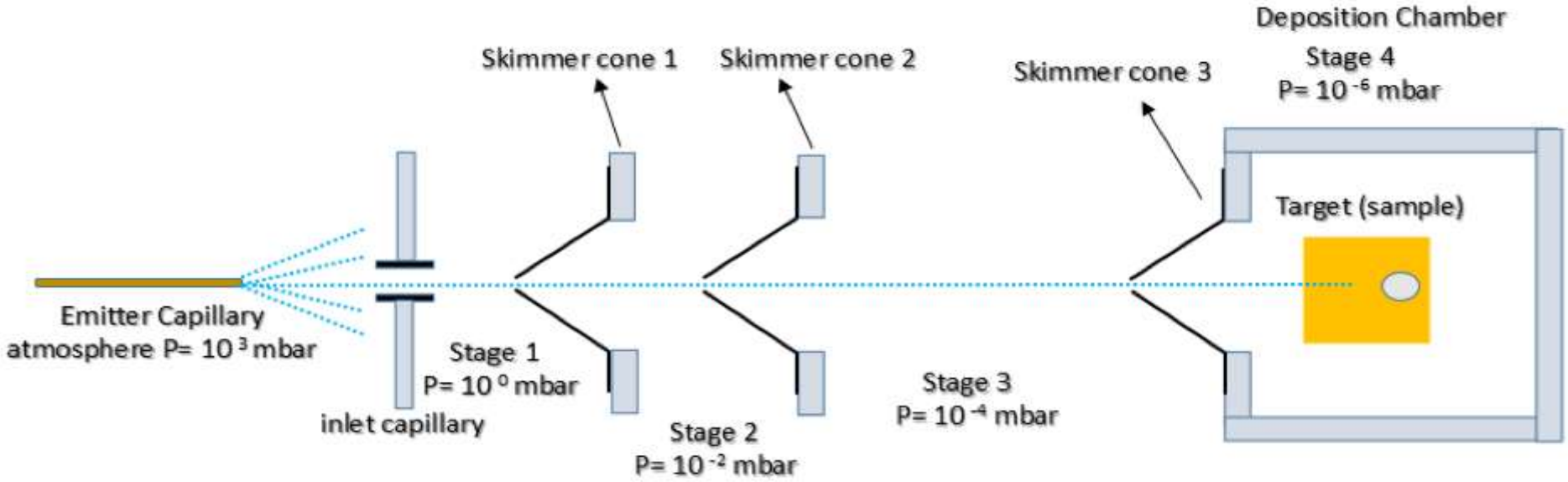
Introduction

Electrospray ion beam Deposition technique:

1- Study complex molecules on surfaces.
2- Use with non-volatile materials.
(large molecules, nanoparticles, dye-sensitizers of photovoltaics, water-splitting solar cells and biomolecules)

Traditional technique:

1- Used to transfer molecules from solid or liquid to gas phase depend on thermal evaporation or sublimation.
2- Small volatile and thermally stable molecules.



Electrospray deposition source with no mass-selection used. It shows that the liquid enters through a capillary and the apertures of a series of a differentially pumped allowing the pressure to be reduced at all stages to ultra-high vacuum range in the deposition chamber (UHV chamber).

★ Advantages:

1- Small.

2- Low-cost.

3-Portable and designed to be mounted on a wide range of UHV instruments.

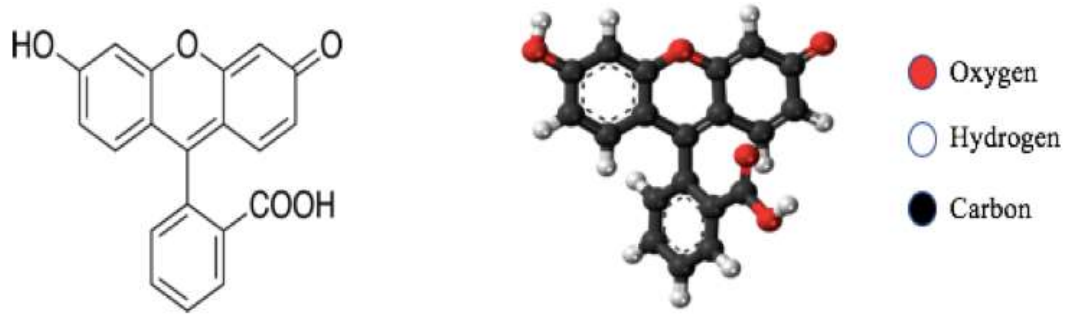
★ Downside:

1- No mass selection of the ion beam

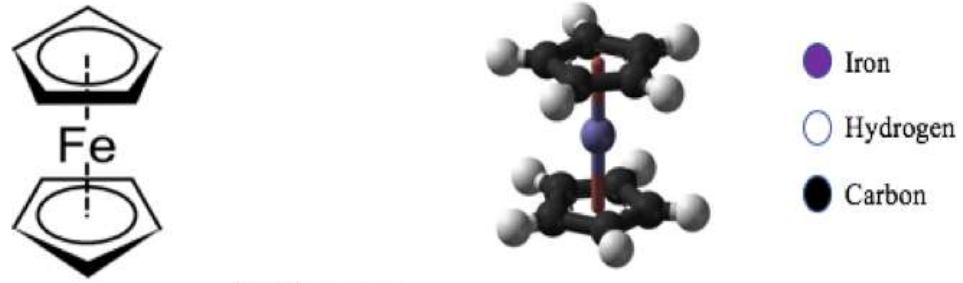
(Everything exists on the original solution has access to the surface).

The main goal of my current work

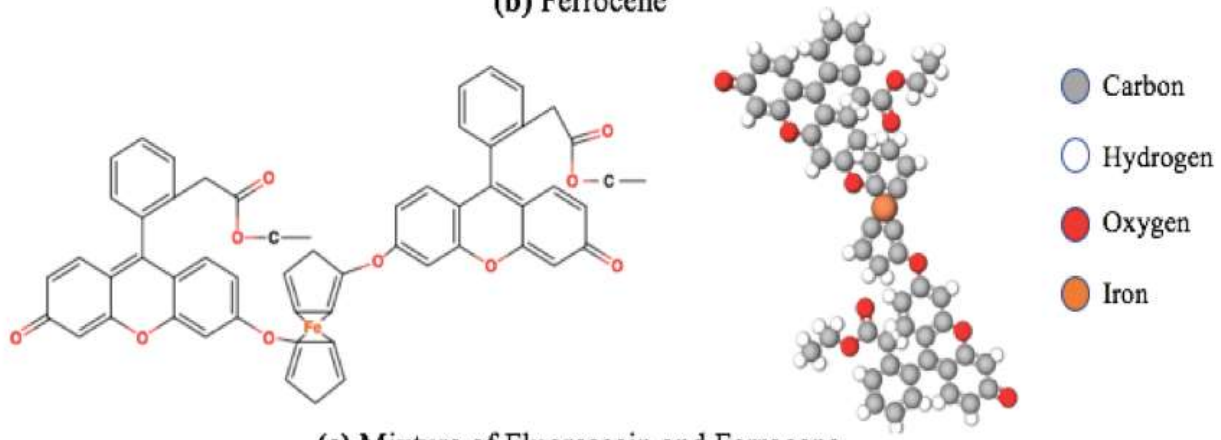
Present the solution for this issue by designing the mass-selected electrospray deposition instrument



(a) Fluorescein



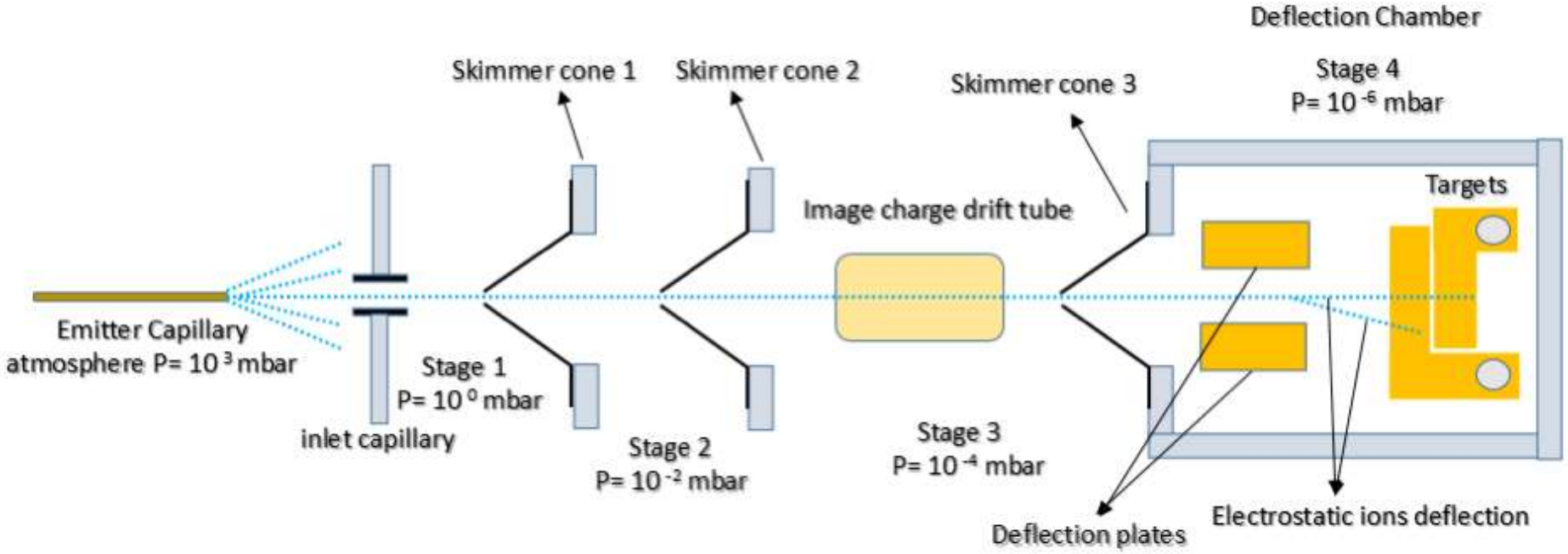
(b) Ferrocene



(c) Mixture of Fluorescein and Ferrocene

2D and 3D chemical structure of the a) fluorescein (consists of four benzene rings modified by the presence of a carboxylic (COOH), a carbonyl (C=O), a hydroxyl (-OH), and an ether type bonding (C-O-C), b) ferrocene (iron centered between two cyclopentadienyl ring) [13- 15], and C) mixture of fluorescein and ferrocene molecules that show that it is possible for the two molecules to combine in that way in the mixture, and we do not know if this is what happens. The molecules may still be present in their independent states as well.

Instruments



- 250 µm entrance capillary
- 0.4 mm, 0.6 mm and 0.6 mm skimmer cones aperture
- dry scroll pump
- turbomolecular pump
- manipulating the high-voltage power supplies
- 5mm
- picoammeter
- computer serial port using RS-232 cable

The reasons to use fluorescein and ferrocene solutions

★ The use of these two solutions is due to the great similarity in their properties

1- Low cost- effective.
2- Low toxicity.
3- Insoluble in water or it barely dissolved slightly.
4- Soluble in many organic solvents such as methanol and ethanol.
5- The major advantage of using them is their visibility on the surface due to powder color which appears orange-red in fluorescein and orange-yellow in ferrocene.

★ The difference between them is in the molecular weight

1- Fluorescein is 332.3 g/mol and ferrocene is 186.03 g/mol.

Electrostatic ion deflection data steps

1- Spraying solution through electrospray system.

2- During the electrospray process, the positive and negative voltages on the deflective plates were increased gradually from the voltage source so that the ion beam bent to hit the first target.

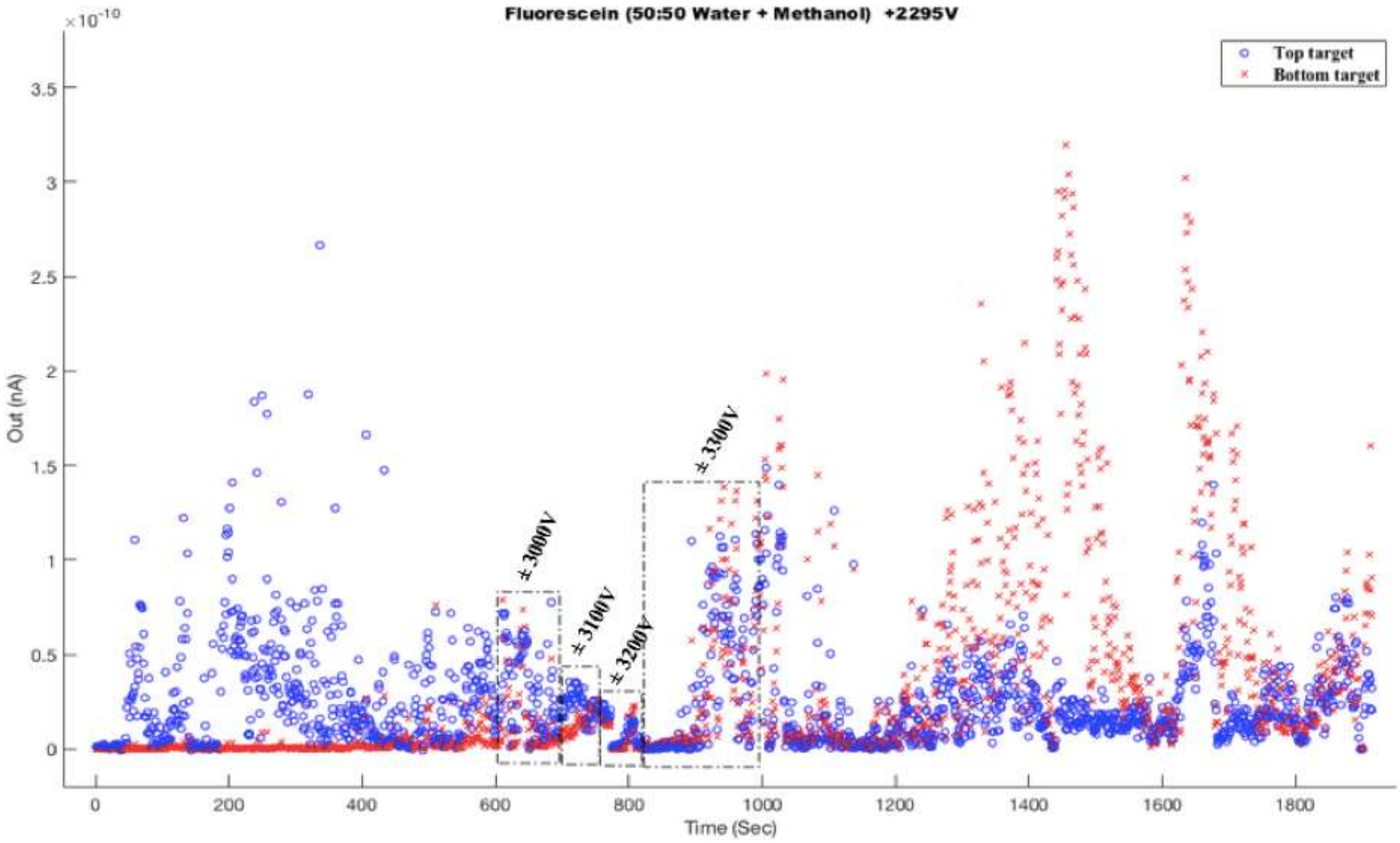
3- Continuous increase in positive and negative voltage leads also to the deviation of ions into the second target.

4- Optimizing the deflection voltage is required to achieve equal current simultaneously on both targets.

5- All these steps are recorded as a graph by the MATLAB Program.

Results and discussion

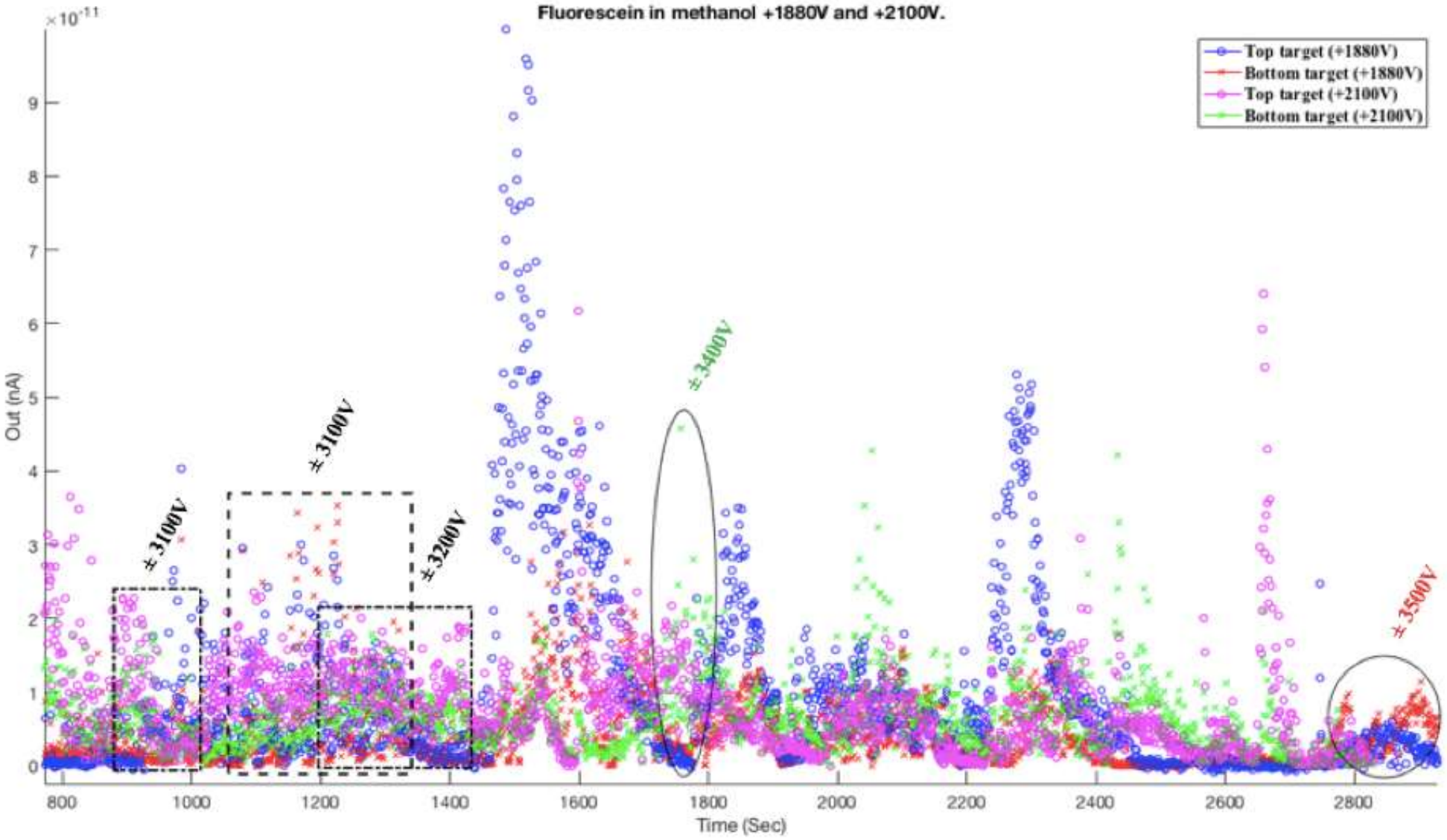
1- Electrostatic ion deflection data from spraying fluorescein (Methanol + Water 50:50)



- 0 V
- Top target at ±2000 V
- Both targets at ±3000 V, ±3100 V, ±3200 V and ±3300 V
- Bottom target at ±3400 V

Data collected using electrostatic ion deflection for 1 mM a standard fluorescein solution (50:50 water: methanol) sprayed at +2295 V. Blue spots refer to target 1 (Top target), and red markers refer to target 2 (Bottom target). The dash-dotted lines indicate to equal currents in both targets at different deflection voltages.

2- Electrostatic ion deflection data from spraying fluorescein dissolved in methanol



★ 1880 V

Top target at ±2000 V

Both targets at ±3100 V

Bottom target at ±3500 V

★ 2100 V

Top target at ±2000 V

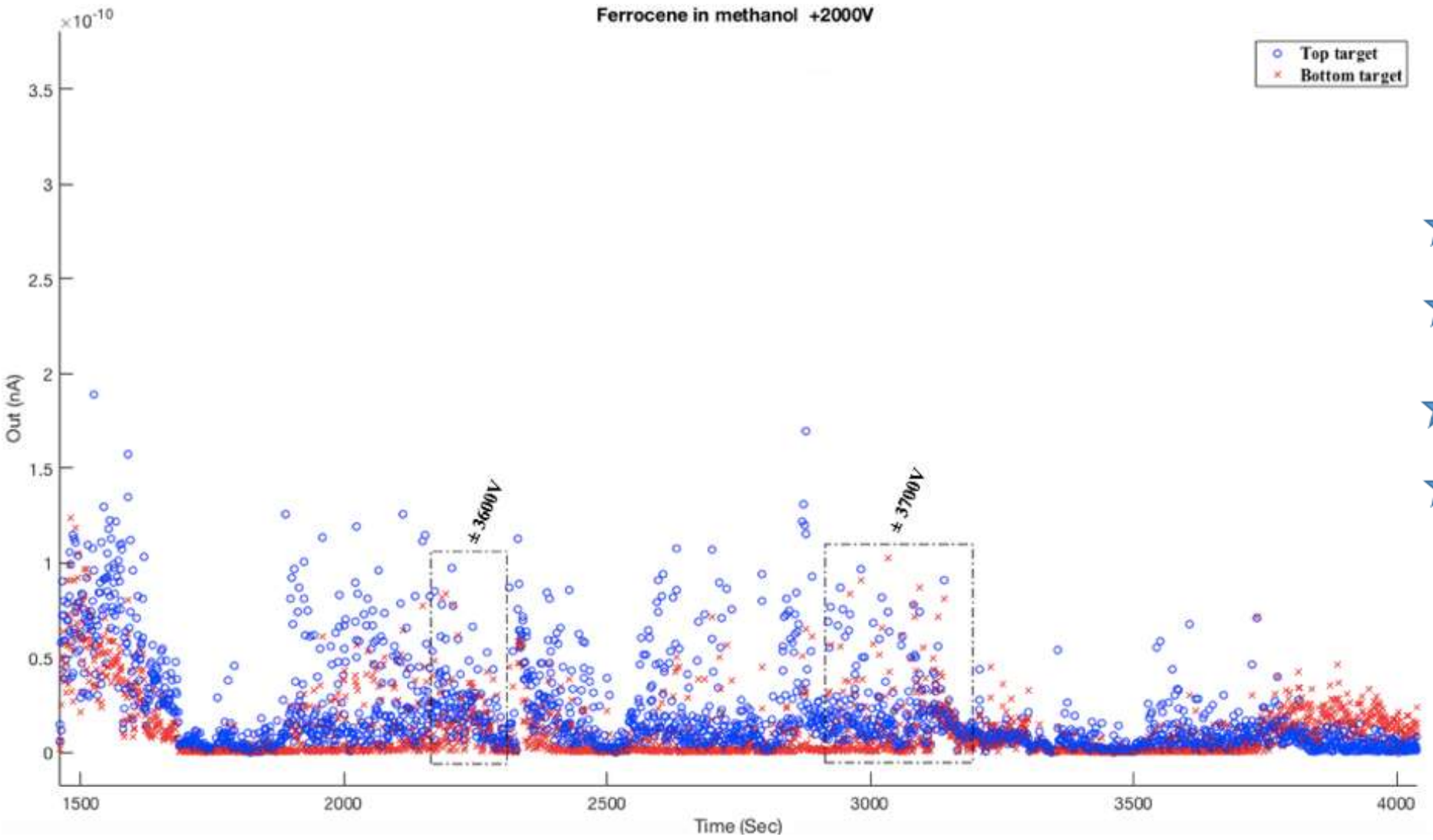
Both targets at ±3100 V and ±3200 V

Bottom target at ±3400 V

High magenta is because of using methanol

Plot zoom of combined data collected using electrostatic ion deflection for fluorescein solution in methanol sprayed at +1880 V and +2100 V. Blue and magenta data points indicate to out 1. Red and green cross markers symbolize to out 2. The dashed line applies to equalize current which sprayed at +1880 V. The dash-dotted lines indicate the same currents sprayed at +2100 V. Ellipses shape refers to the ions hitting the second target at ±3400 V and ±3500 V respectively.

3- Electrostatic ion deflection data from spraying ferrocene dissolved in methanol

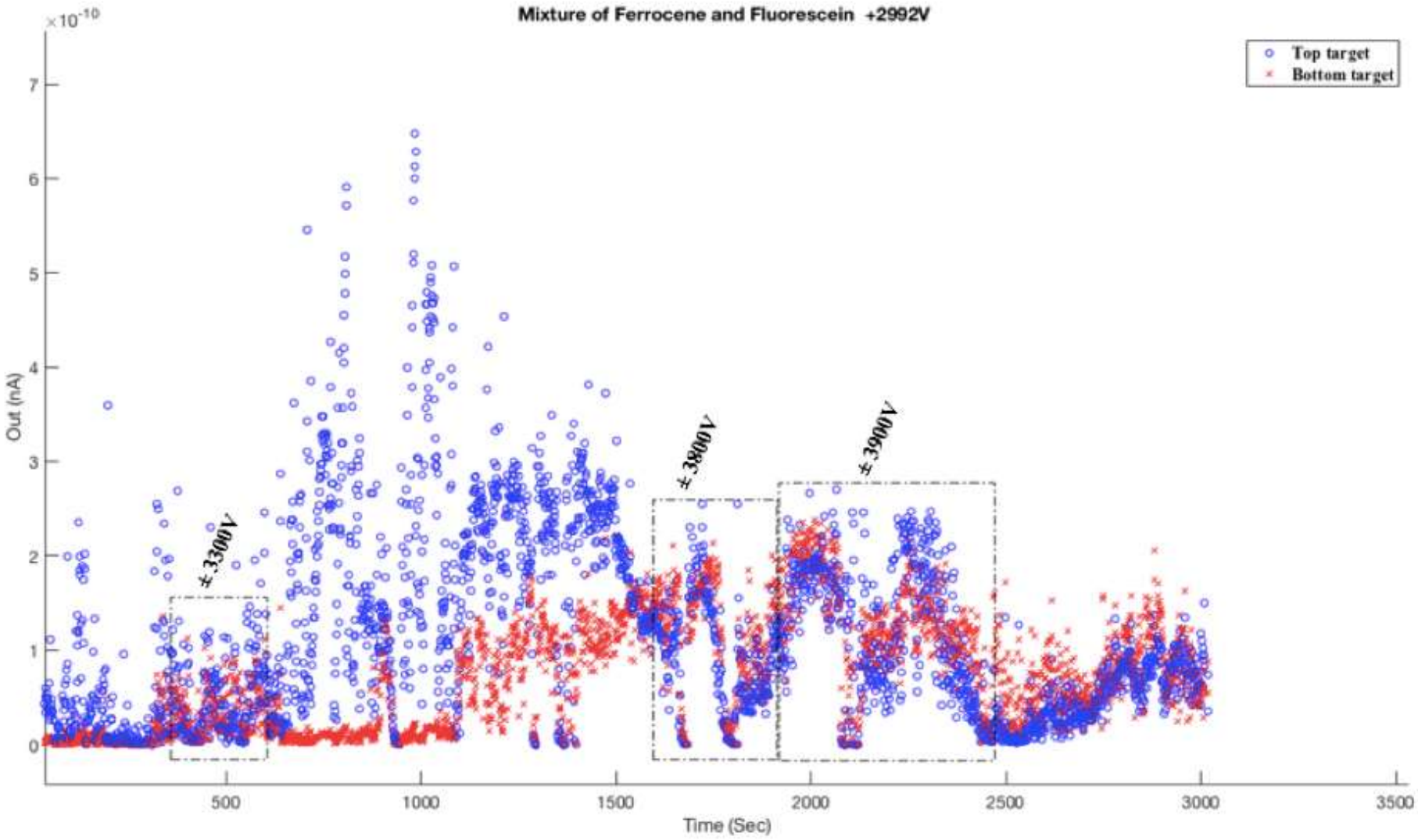


- Top target at ±2000 V
- Both targets at ±3600 V and ±3700 V
- Bottom target at ±3800 V
- Ferrocene is 186.04 g/mol whereas fluorescein is 332.31 g/mol

Plot zoom of data collected using electrostatic ion deflection for ferrocene dissolved in methanol sprayed at +2000 V. Blue data points indicate to ions hitting the top target. Red cross markers refer to ions hitting the bottom target. The dash-dotted lines indicate to the equalize currents for targets together.

4- Electrostatic ion deflection data from spraying mixture of ferrocene and fluorescein dissolved in methanol

The mixture solution is used to separate two components of the beam which are the light and heavy molecule.



- Fluorescein (the heavier molecule)
  - Both targets at ±3300 V
- Ferrocene (the lighter molecule)
  - Both targets at ±3800 V and ±3900 V
- Bottom target at ±4000 V

Collected data using electrostatic ion deflection for a mixture of fluorescein and ferrocene dissolved in methanol sprayed at +2992 V. Blue data points indicate to out 1. Red cross markers symbolize to out 2. The dash-dotted lines point out to the equalize currents for both targets.

Conclusions

- Deflection voltages data for the equivalent currents of fluorescein dissolved in 50: 50 methanol + water and methanol only using the biases of +2295 V, +1880 V, and +2100 V were extremely similar.

- The results of the sprayed ferrocene solution at +2 kV demonstrated clearly the difference in the deviation voltages data for equal currents compared to the fluorescein solution.

- A mixture of fluorescein and ferrocene solutions sprayed at +2992 V, it has proven the success of the above-mentioned experiments where stated that the lighter molecules as ferrocene deflected more than the heavier molecules as fluorescein.

Future Plans

I have planned to conduct SIMION simulate in the upcoming year. This software work to model the system in an ion workbench scenario to simulate the energies and masses of the molecular ions through the system so that I can refine the mass-selection process.