EQP energy and mass analyser

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iFAST

Overview

- Introduction
- Technical details of an EQP system
- Coating of Nb thin films using HiPIMS and bipolar HiPIMS
- Coating of alternative superconducting materials
- Summary

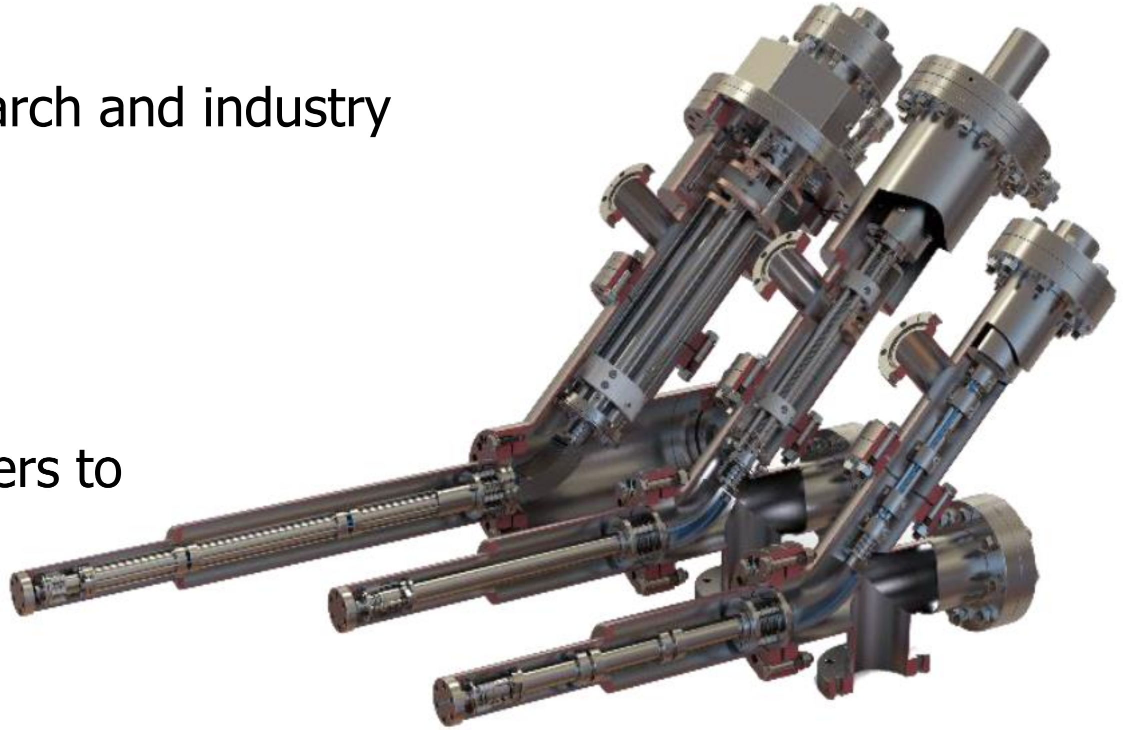
Introduction

- Development of thin films and their deposition methods significantly improved many industries over the past century

- Various techniques available, crucial role in research and industry
  - Magnetron sputtering
  - CVD
  - PECVD, etc.

- Each technique require specific process parameters to create the desired surface/film properties

→ EQP mass spectrometer



Introduction

- Electrostatic quadrupole plasma (EQP) mass spectrometer are designed for direct analysis of plasma ion mass and energy in both plasma characterisation and process diagnostic applications

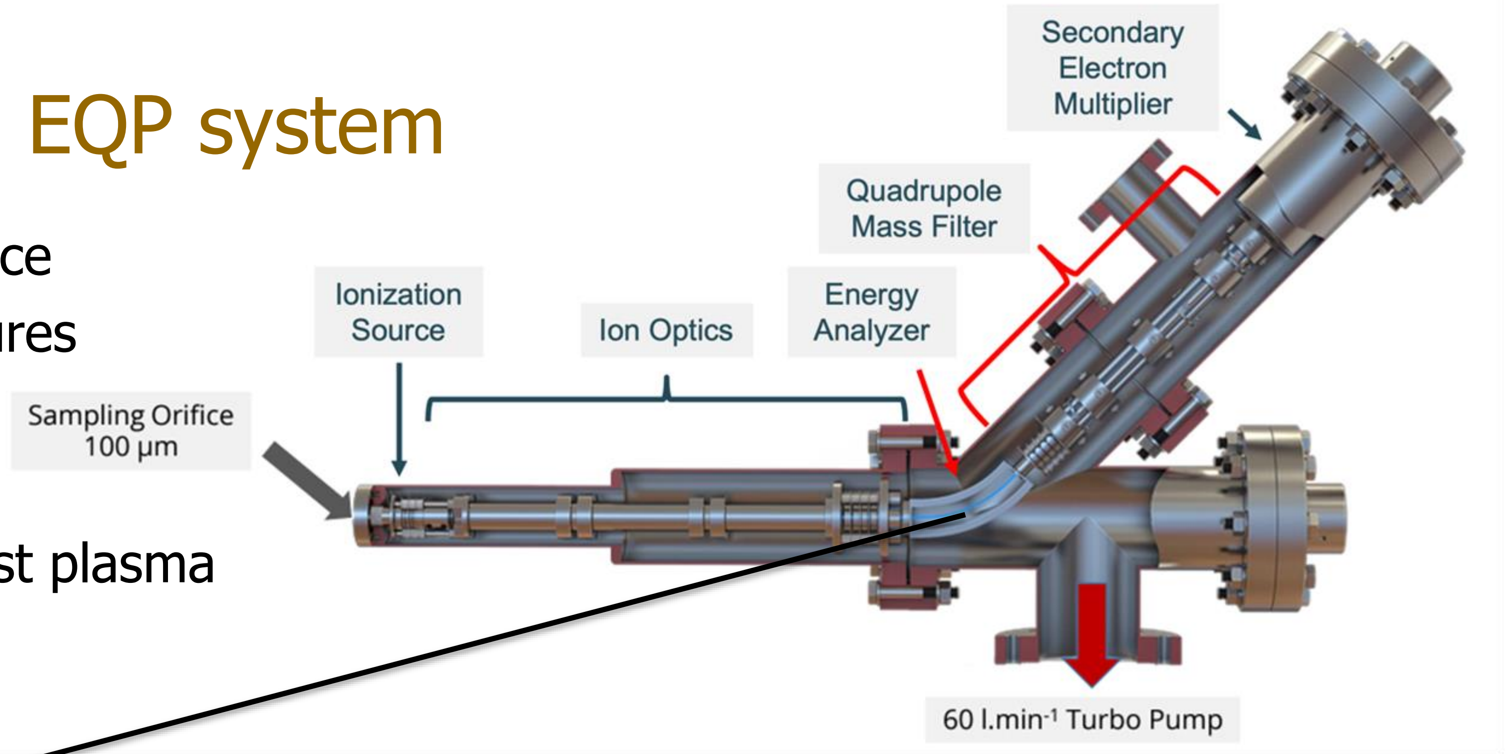
- EQP systems measure both positive and negative ions but can also perform neutrals analysis using an electron bombardment ion source

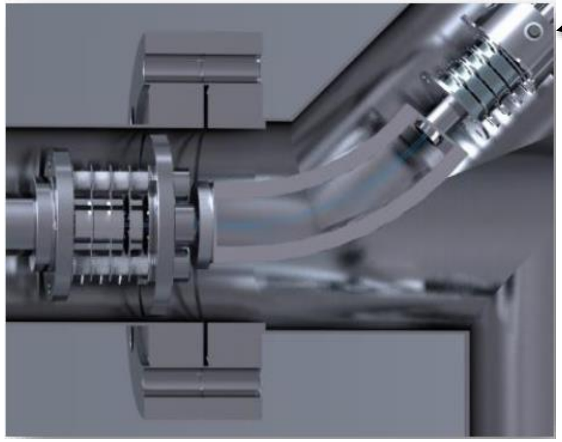
- Various field of applications
  - DC glow discharge
  - HiPIMS
  - Parallel Plate – RF plasma
  - ICP

Technical details of an EQP system

- Interchangeable sampling orifice
- Operational at different pressures
- Differential pumping

- Versatile and adaptable to most plasma chamber





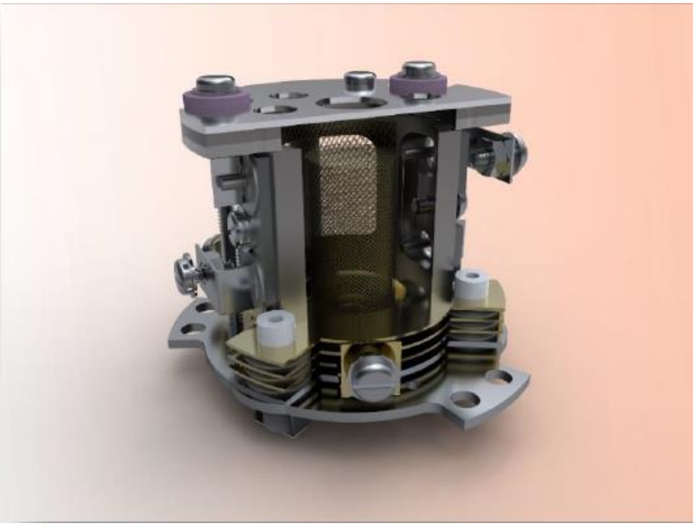
- 45˚ Electrostatic Sector Energy analyser
  - Constant transmission at all ion energies
  - Minimum perturbation of ion flight path
  - Energy resolution – 0.25 eV FWHM
  - Energy scan at increments from 0.05 eV
  - Possibility to float up to 10 KeV

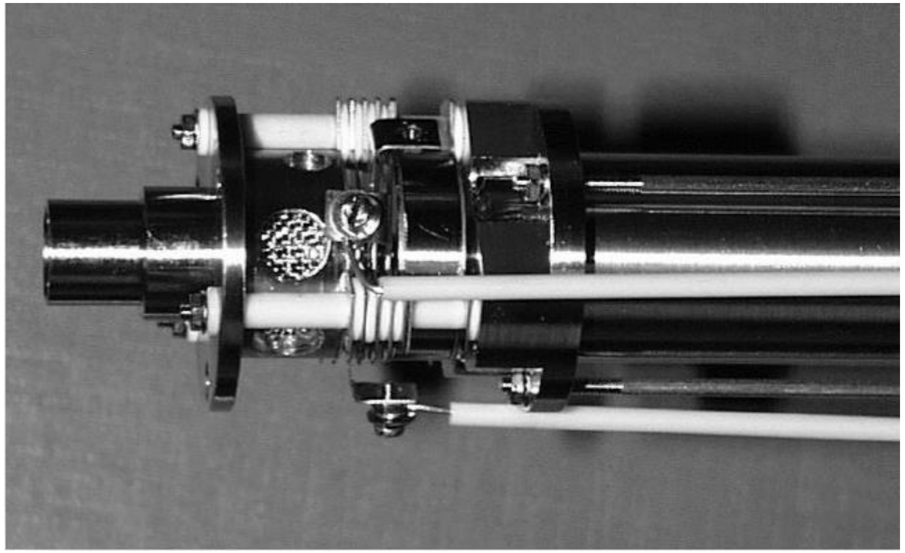
*Pictures courtesy of Hidden Analytical, Ltd

Technical details of an EQP system

- For the analysis of the neutrals
  - Electron energy (0-150 eV)
  - Thermionic emission (0.2 – 2000 uA)

- Extraction optics fully controllable by software discriminates +ve and –ve ions as well as e- and radicals





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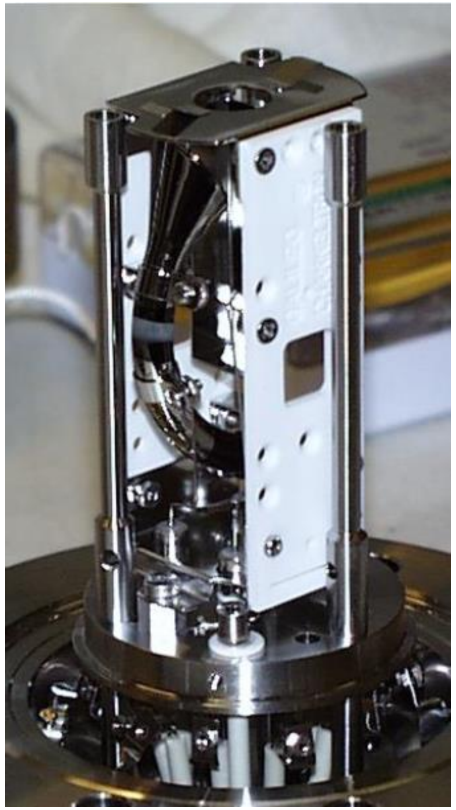
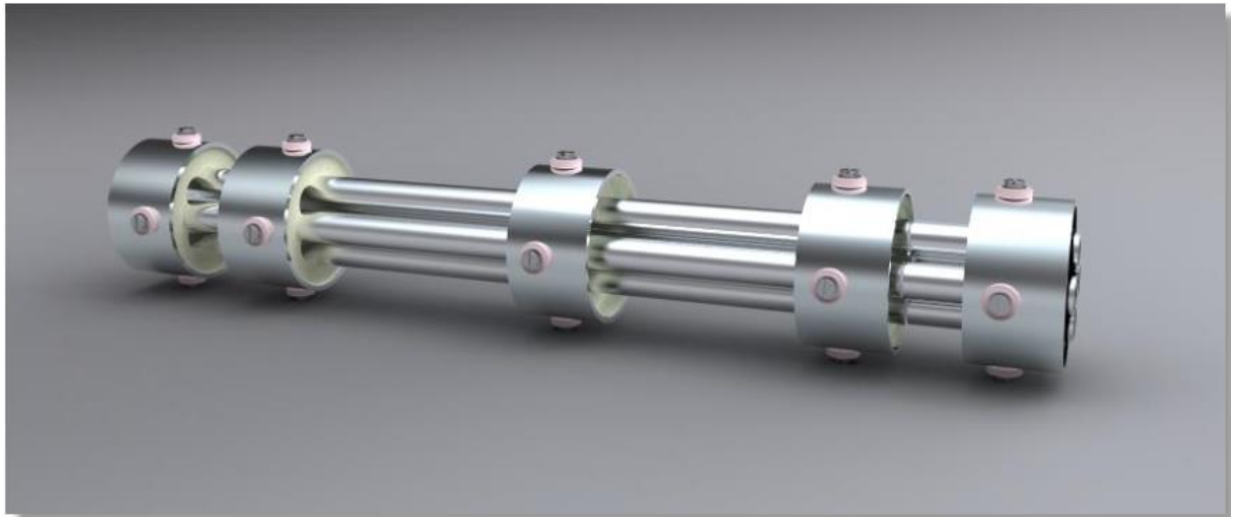
Technical details of an EQP system

- Control over the quadrupole entrance and exit fields provides enhanced sensitivity for high mass transmission and increased abundance sensitivity
  - Enhanced long-term stability



- High sensitivity secondary electron multiplier (SEM)
- Faraday cup option

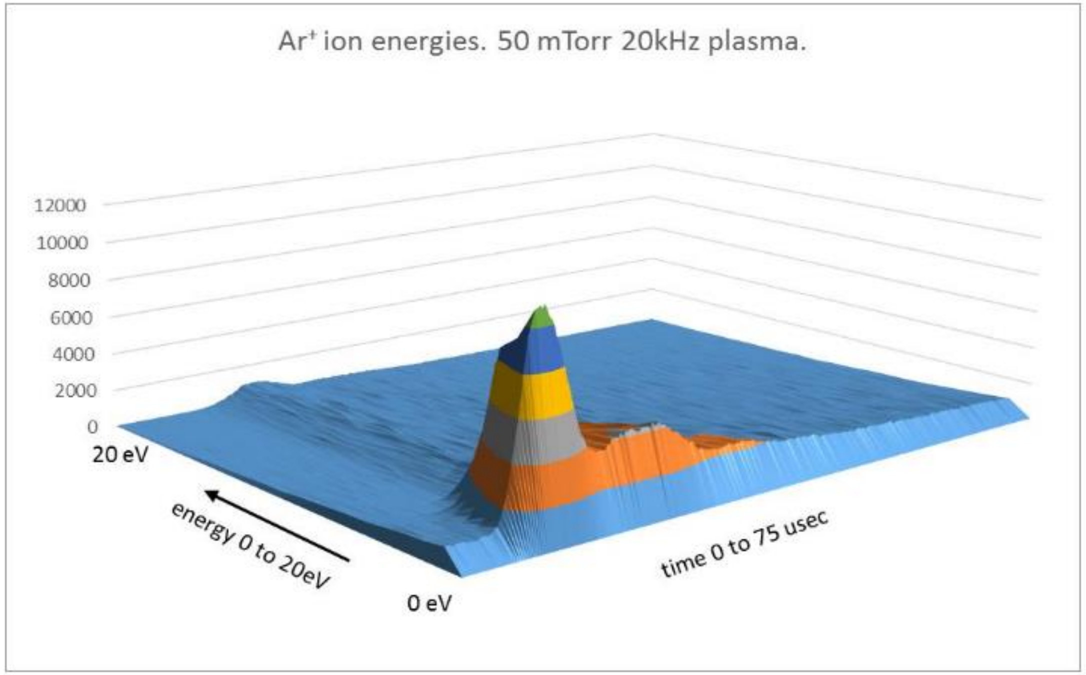


*Picture courtesy of Hidden Analytical, Ltd

Technical details of an EQP system

- Programmable Signal Gating
  - Signal gating input with 0.1 us resolution
  - Enhanced signal gating modes including programmable signal gating and MCS
  - Automatic background subtraction
  - Ion flight time measurements

- Multi-Channel Scalar (MCS) Device
  - Allow transient event analysis
  - Plasma ignition/modulation/extinction experiments
  - Ion flight time measurements



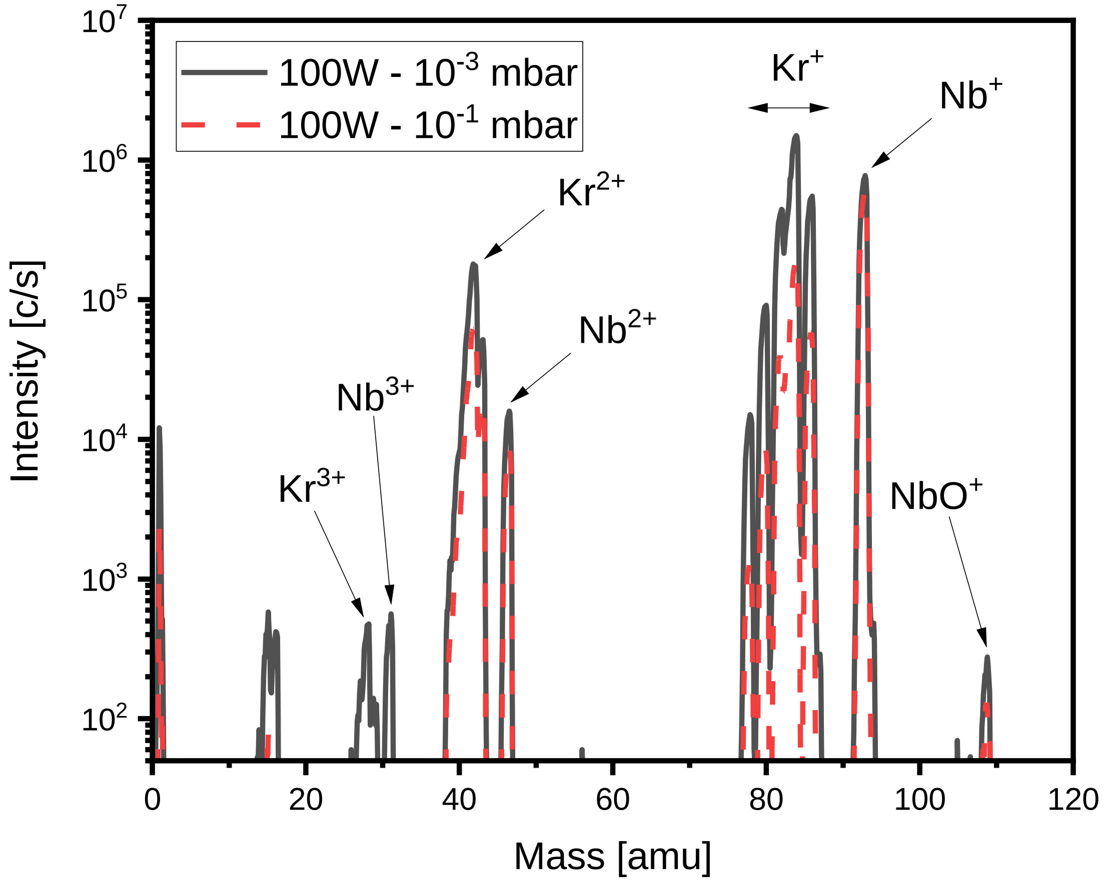
*Picture courtesy of Hidden Analytical, Ltd

Coating of Nb thin films: mass scan in HiPIMS

- Influence of pressure
  - Main ions: Nb^+ (93 amu), Kr^+ (84 amu), Nb^{2+} (46 amu), Kr^{2+} (42 amu) and NbO^+(109 amu)
  - Formation of NbO^+ due by recombination with residual H_2O

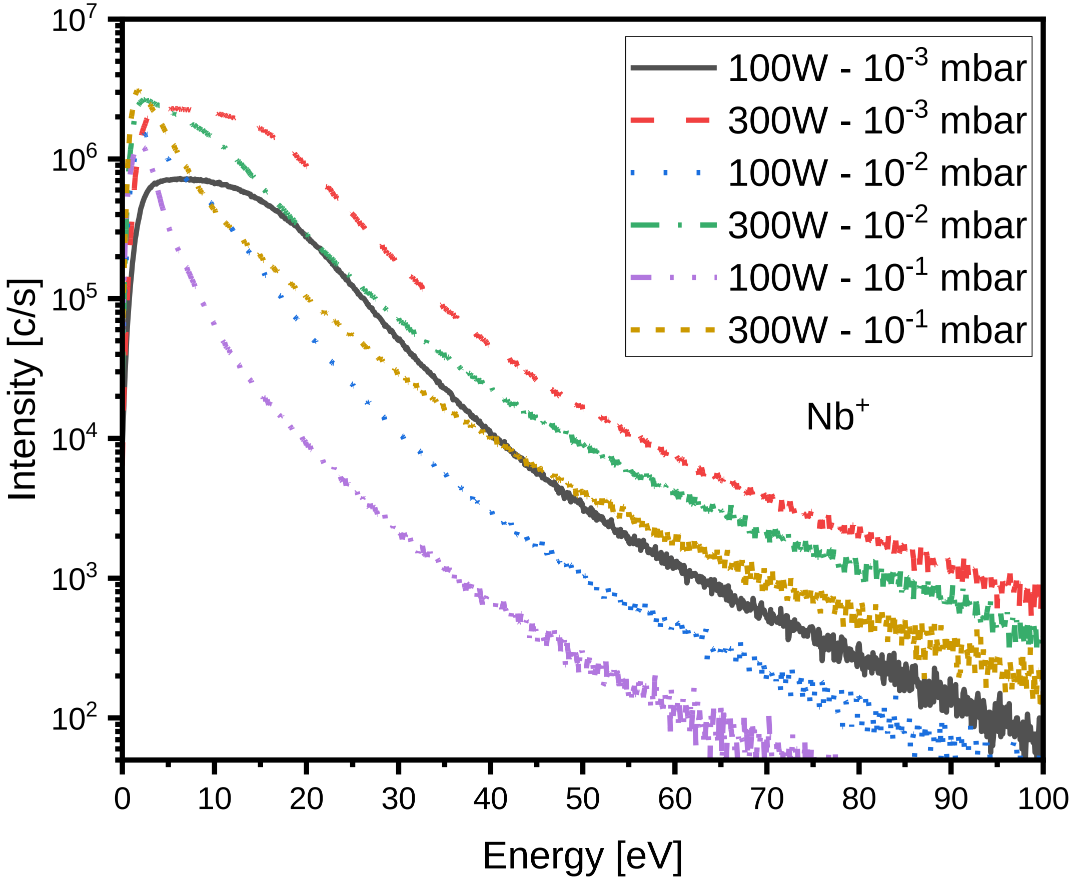
- At lower pressure, formation of Nb^{3+} (31 amu) and Kr^{3+} (28 amu)

- Presence of few residues (water)
  "rough" measurement (no baking)



Coating of Nb thin films: IEDF in HiPIMS

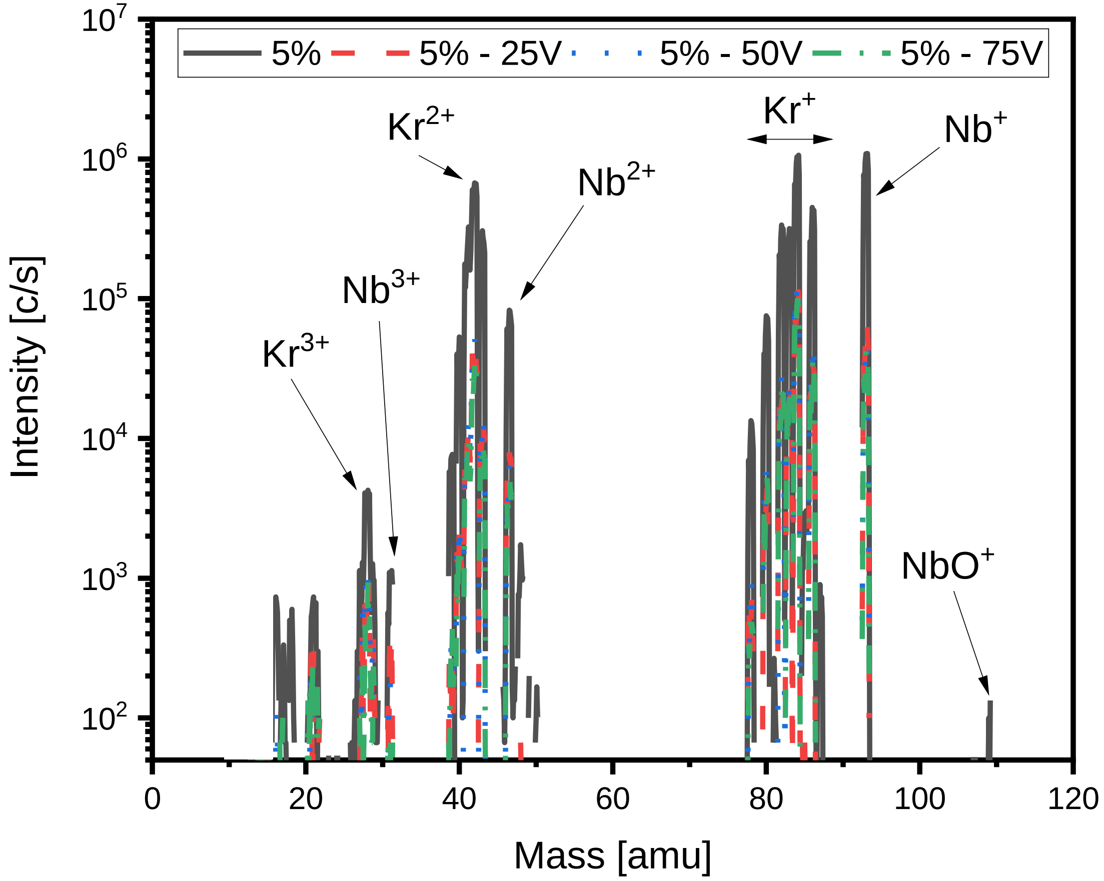
- Increase of pressure directly impact the ion energy
- At lower pressure, increase of input power benefit ion intensity. Whereas, at higher pressure the increase benefit both ion intensity and maximum energy
- Within a pressure range no significant variation



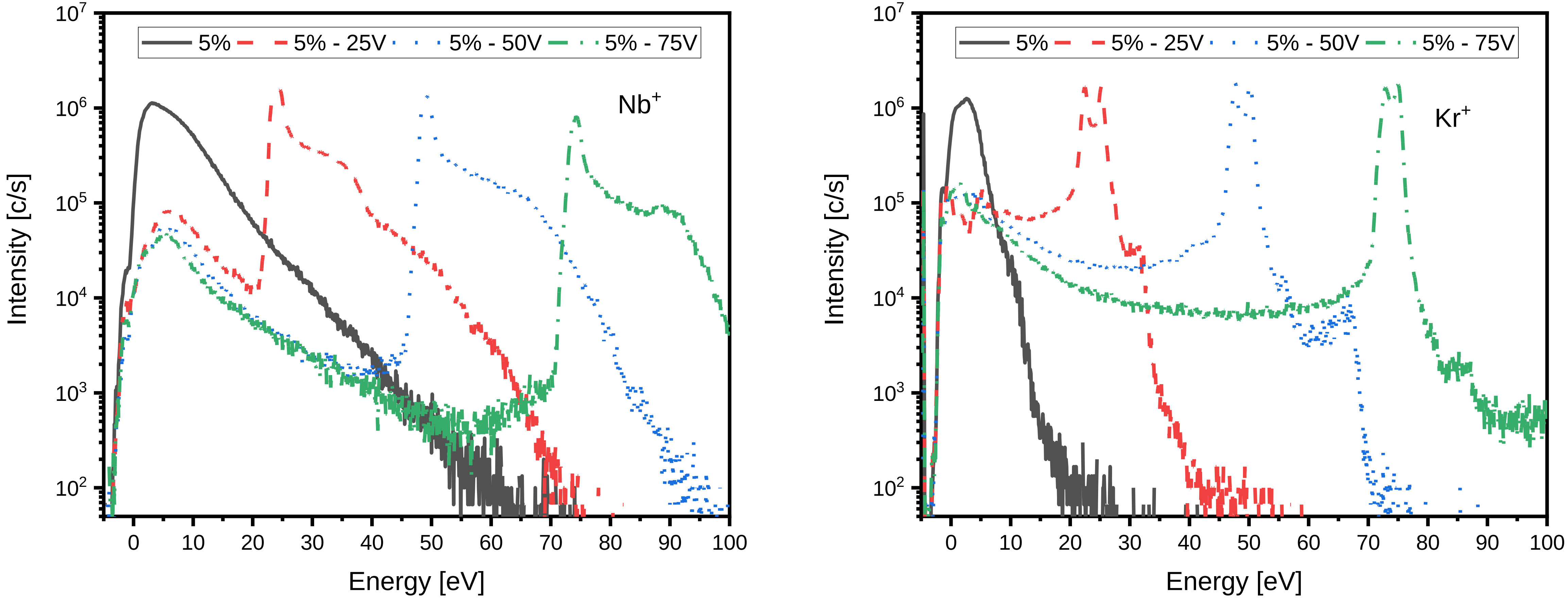
Coating of Nb thin films: mass scan in bipolar HiPIMS

- Main ions:
  - Nb^{+} (93 amu)
  - Kr^{+} (84 amu)
  - Nb^{2+} (46 amu)
  - Kr^{2+} (42 amu)
  - Nb^{3+} (31 amu)
  - Kr^{3+} (28 amu)
  - NbO^{+} (109 amu)

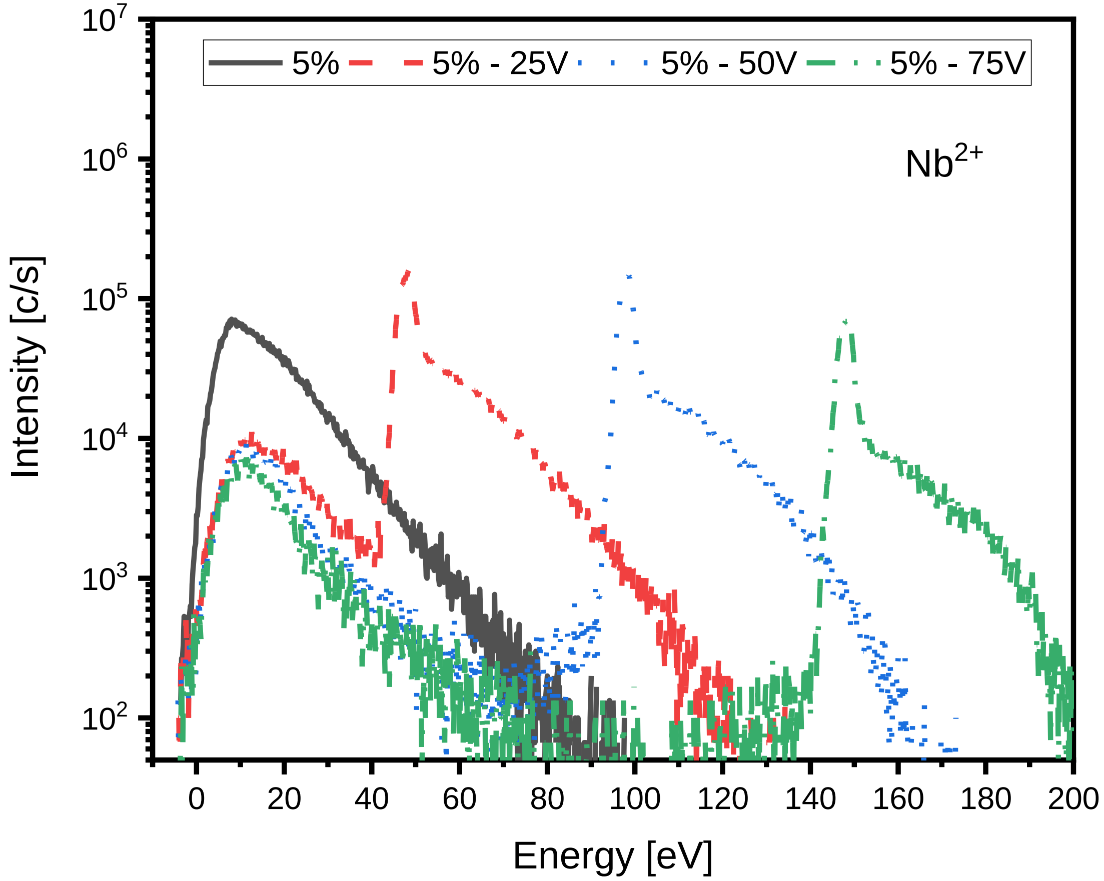
- Formation of NbO^{+} by recombination with residual O from water dissociation
- Decrease of intensity in bipolar mode

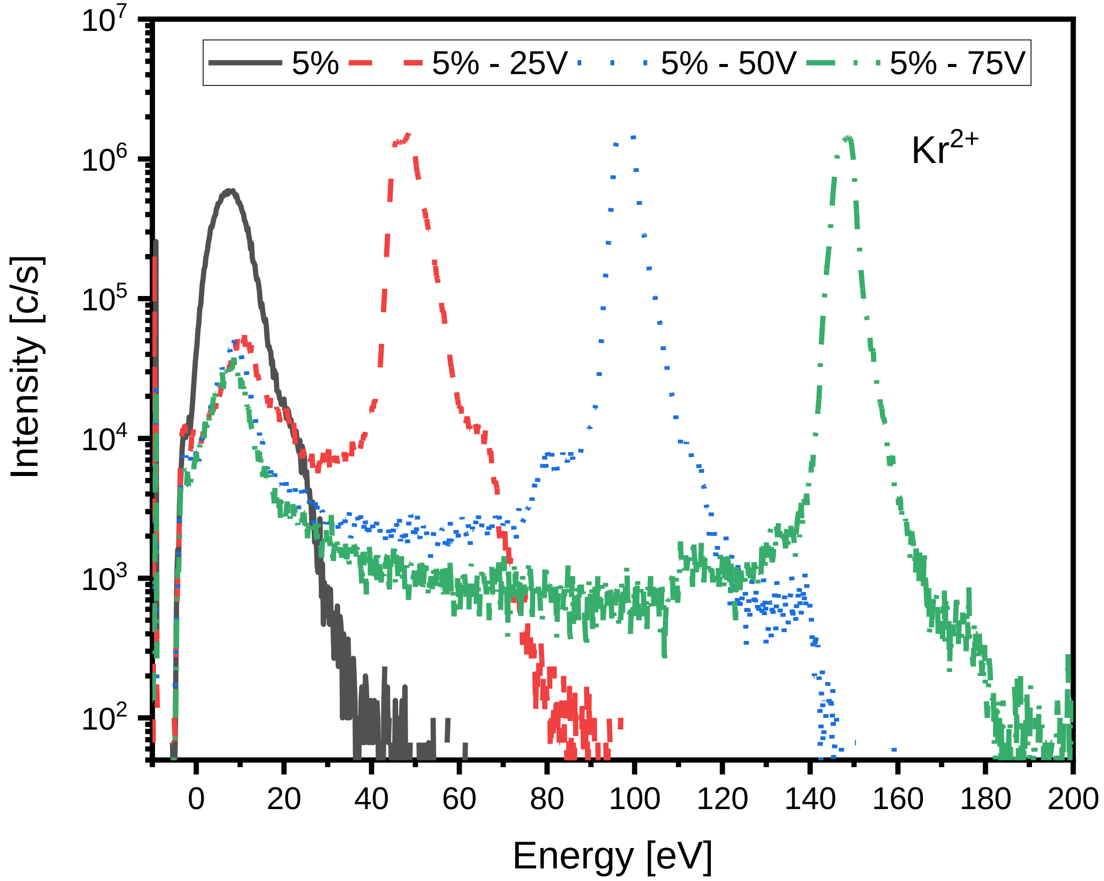


Coating of Nb thin films: IEDF in bipolar HiPIMS



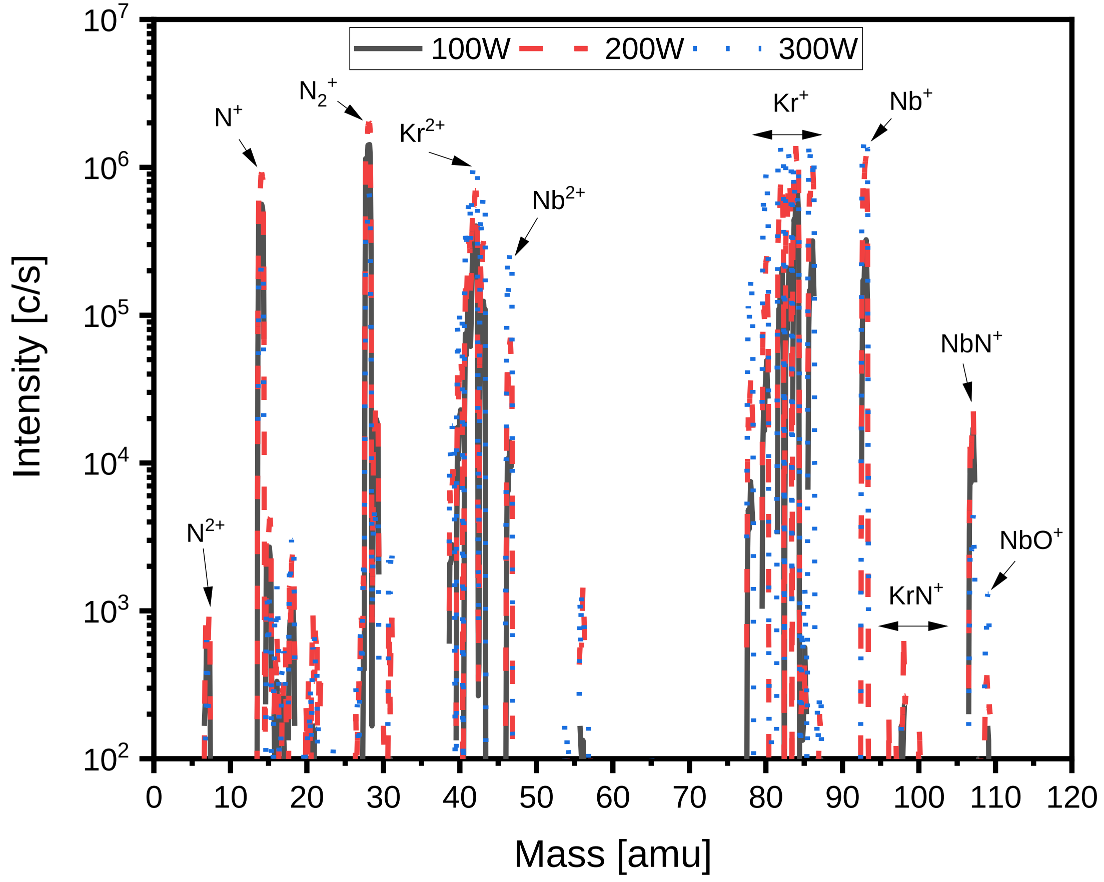
Coating of Nb thin films: IEDF in bipolar HiPIMS



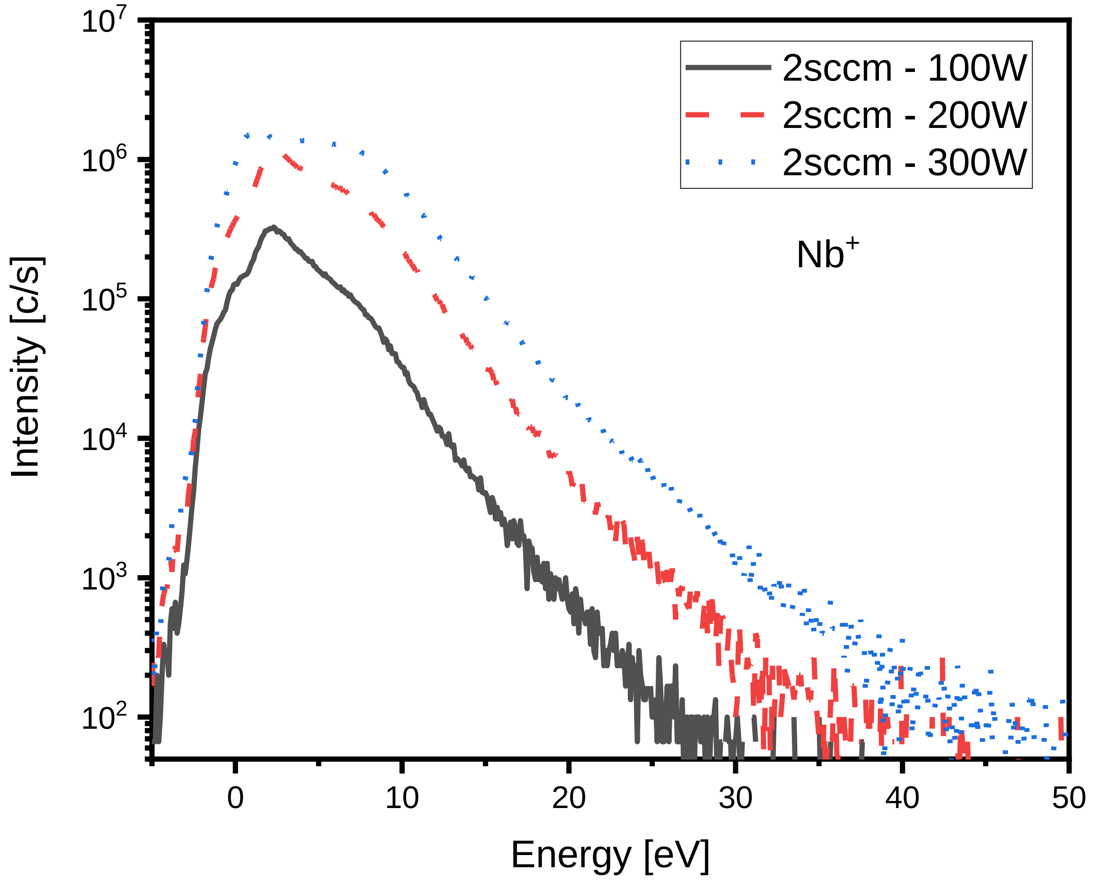


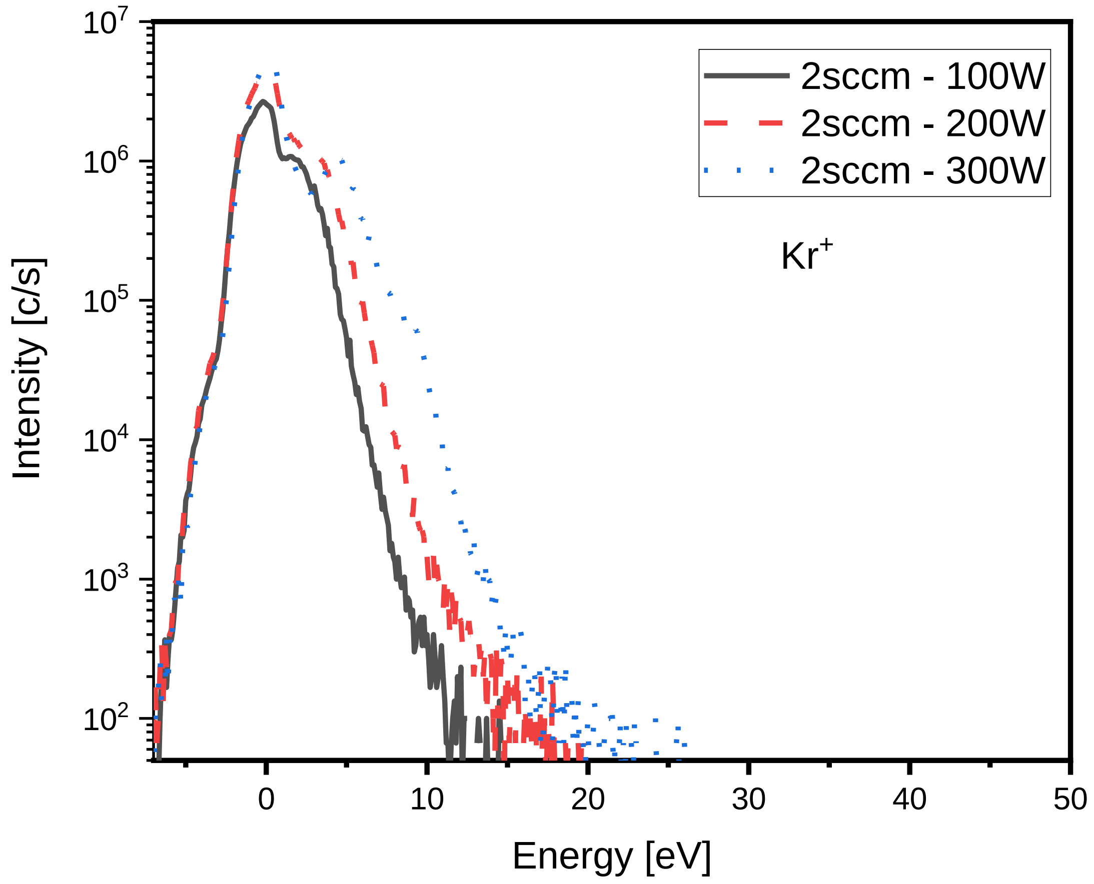
Coating of other superconducting materials

- Adapting results for the investigation of other superconducting materials such as NbN or NbTiN
- Presence of N_2 induces a reduction of the main ions (Nb^+, Kr^+, Nb^{2+} & Kr^{2+}). This can be compensated by increasing input power
- Recombination between nitrogen ions with niobium and krypton

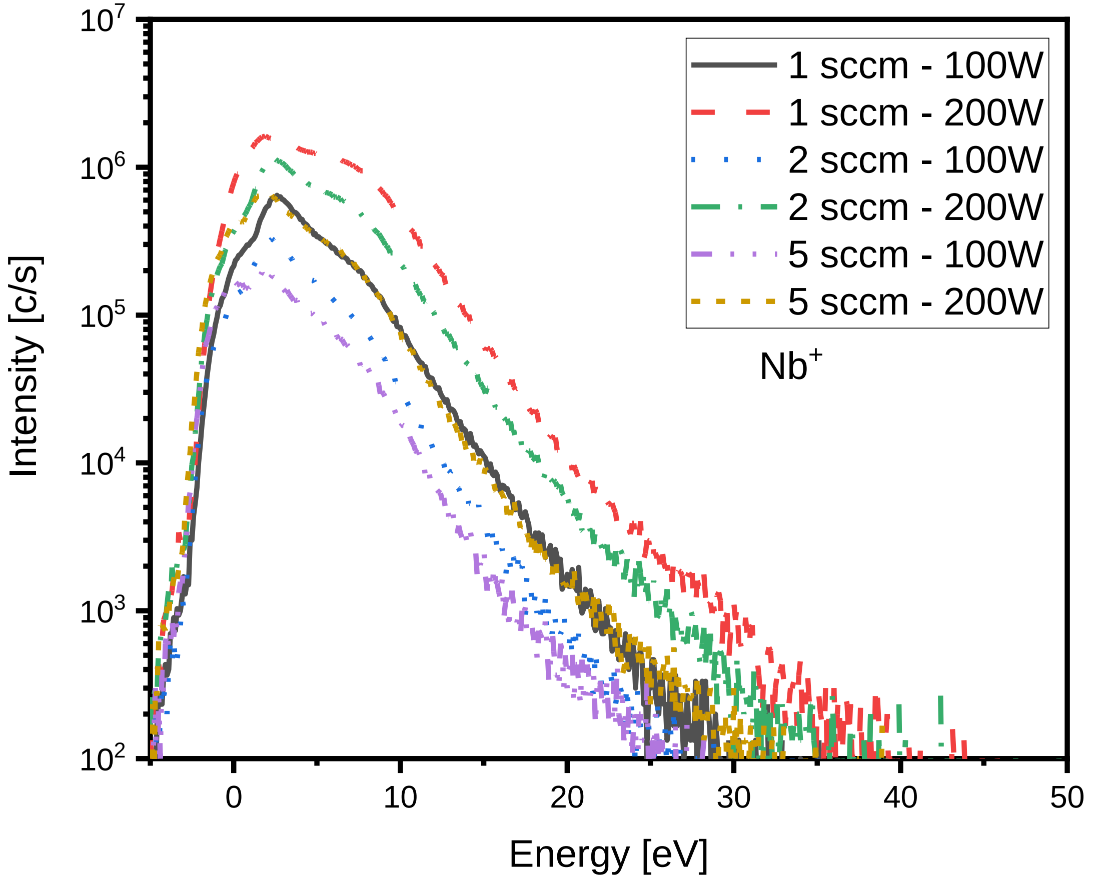


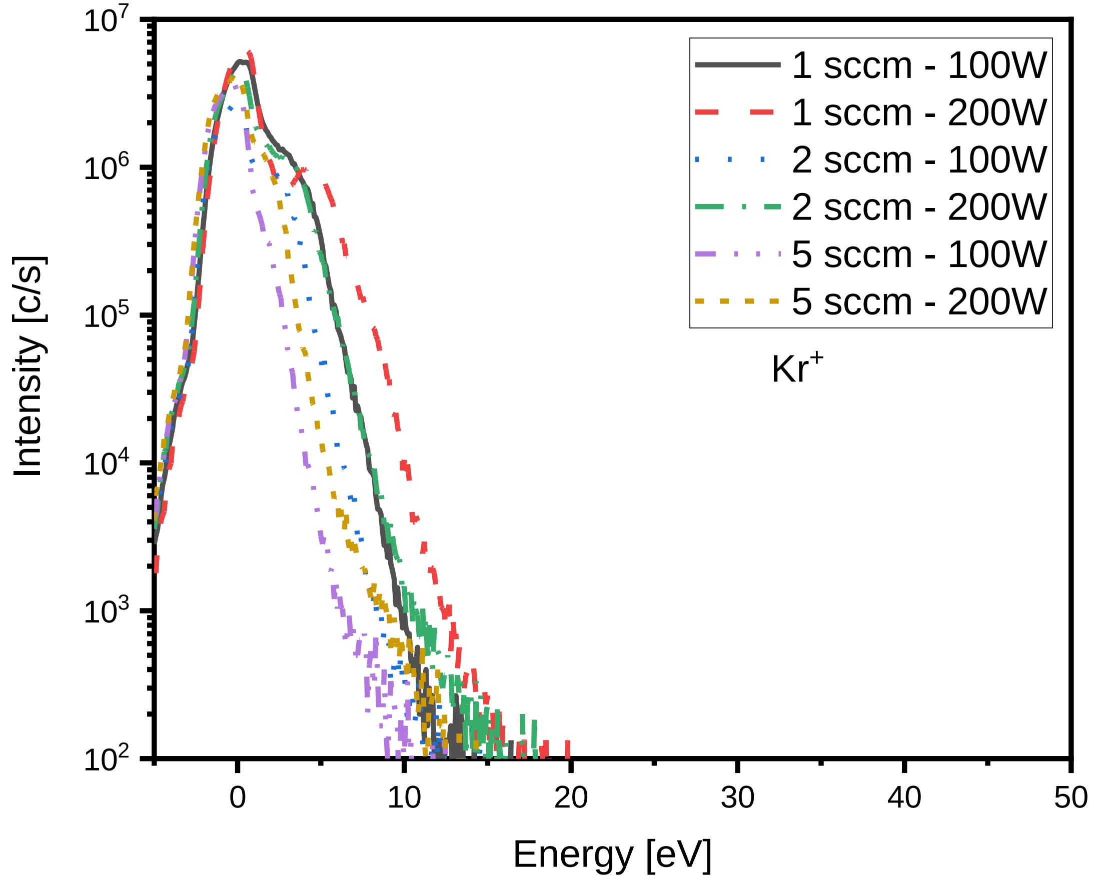
Coating of other superconducting materials: NbN





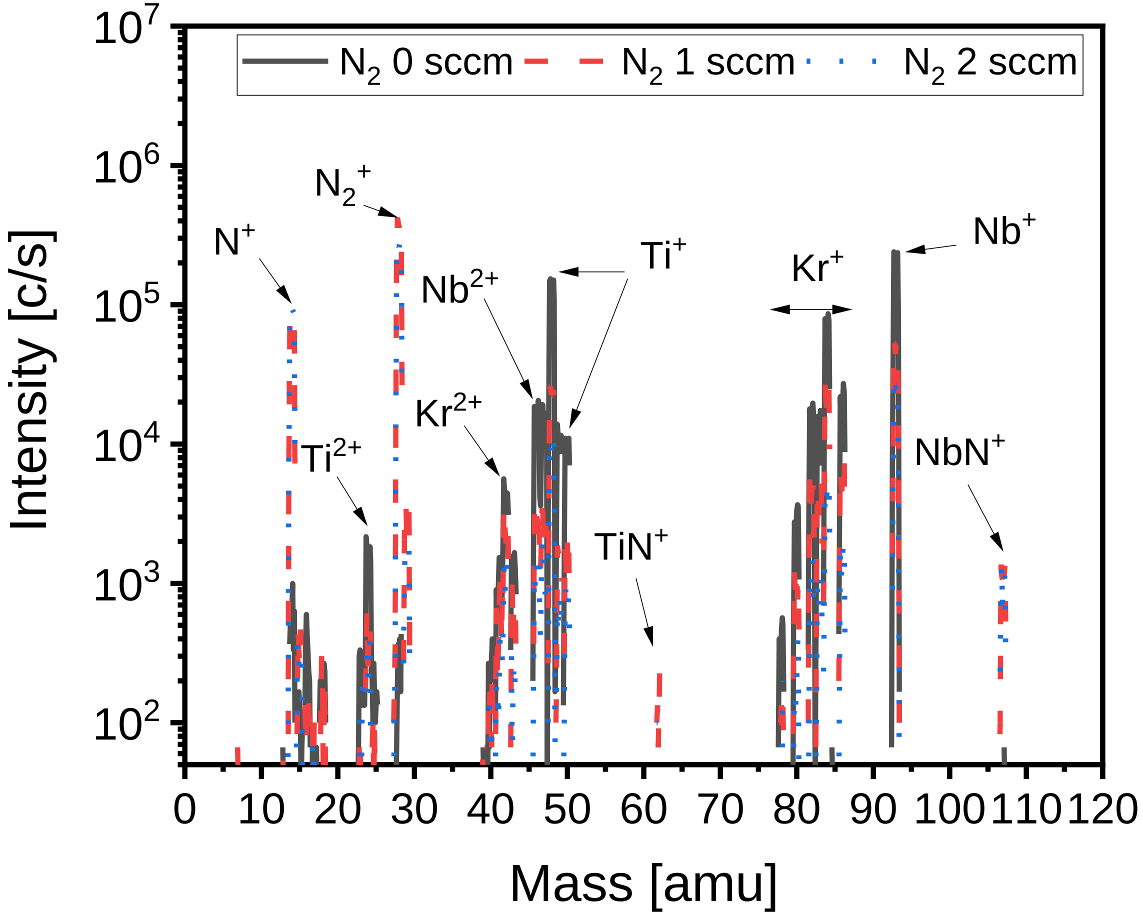
Coating of other superconducting materials: NbN



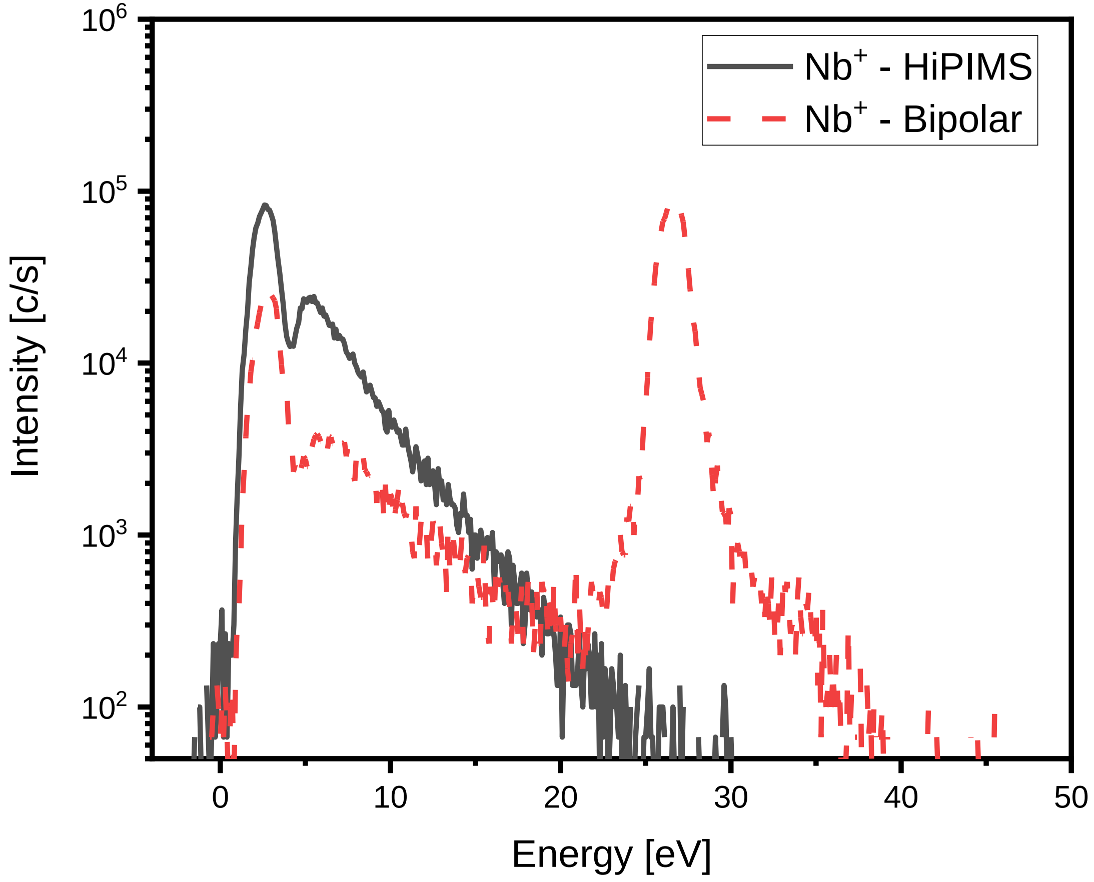


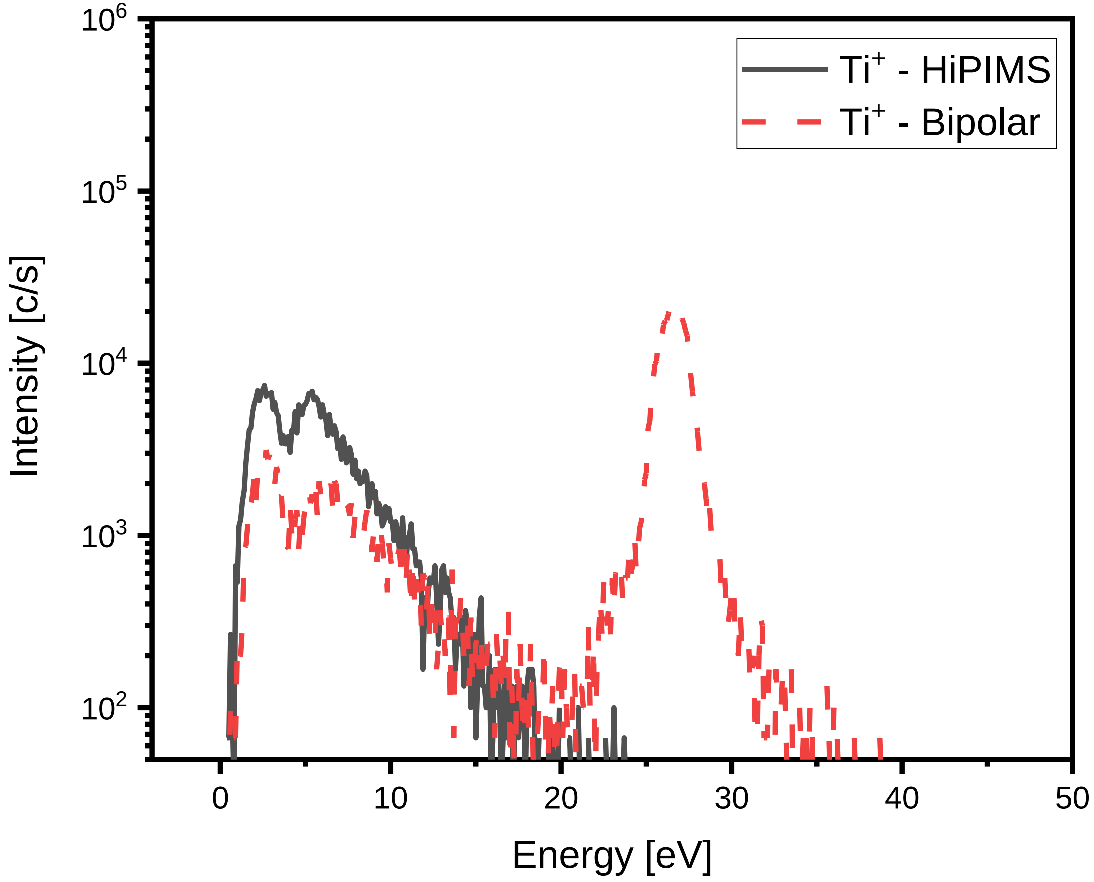
Coating of other superconducting materials: NbTiN

- Similarly to NbN, N_2 impacts other ions intensity
- Increase of N_2 flow rate favour its recombination with Ti
- Same fashion for Nb
- Unlike NbN study, Kr is not recombining with N_2

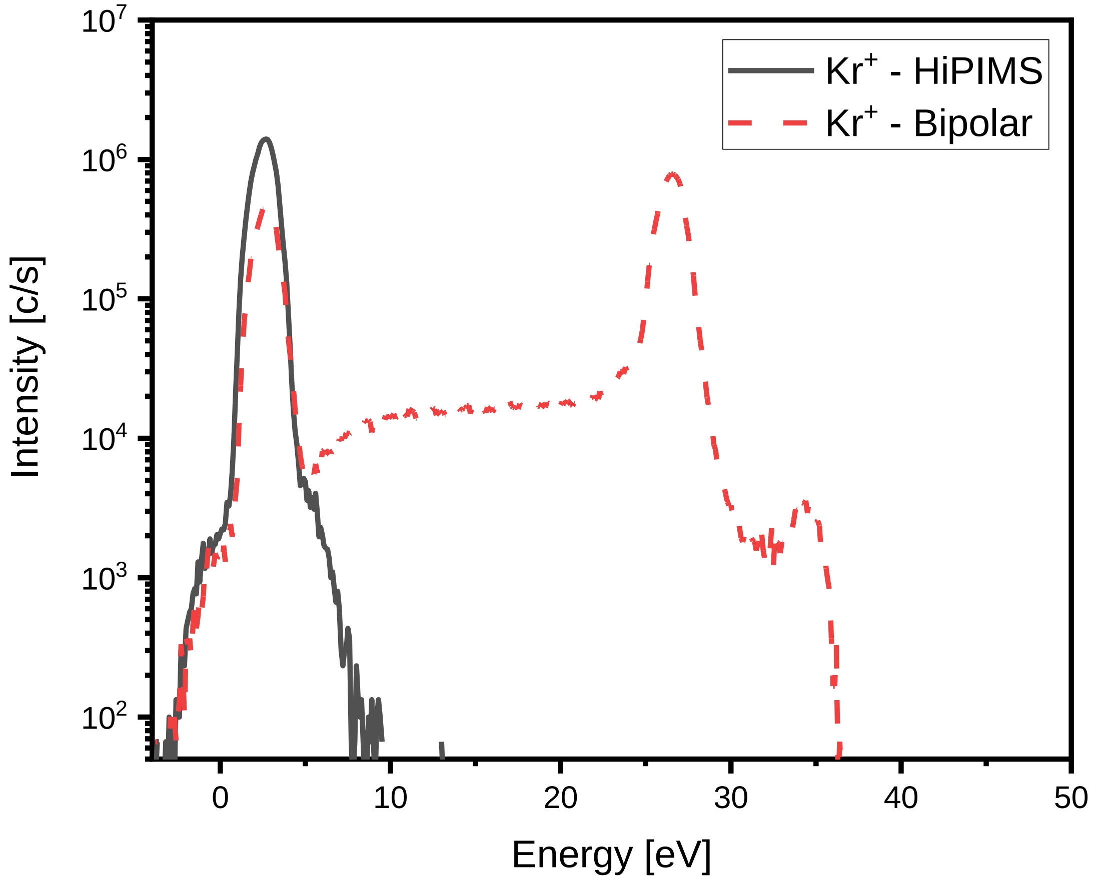


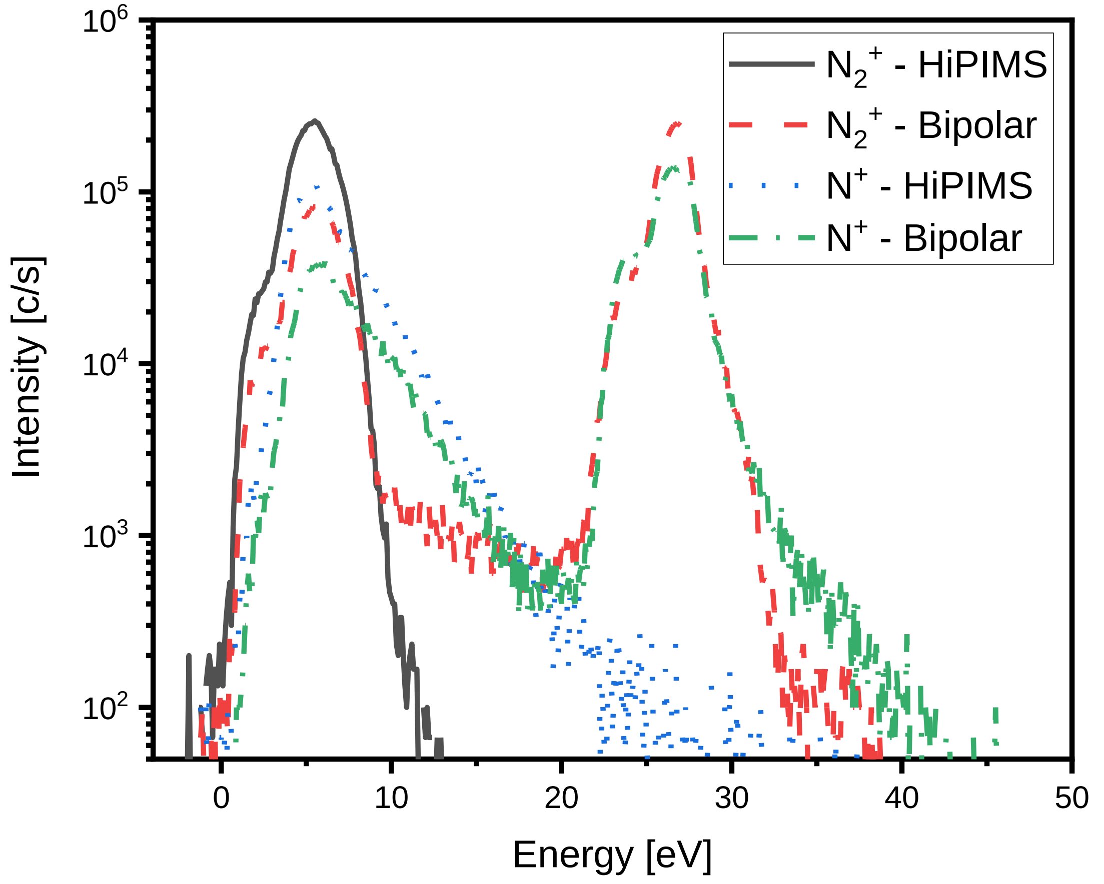
Coating of other superconducting materials: NbTiN





Coating of other superconducting materials: NbTiN





Summary

- EQP analyser can be customised for the mass/energy analysis of +ve/-ve ions and neutrals in plasma process used for thin film coating
- Both time –averaged / -resolved measurement available – capable to measure continuous or pulsed process
- Compatible (upon upgrade) with heated medium and reactive environment
- Ability to measure ion energies prior or during deposition could enhance thin film properties
- Addition of plasma diagnostic technique is key to improve thin film coating

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Coating Nb thin films: IEDF in HiPIMS