Bipolar HiPIMS:
Correlating plasma parameters to thin film properties

9th International Workshop on Thin Films and New Ideas for Pushing the Limits of RF Superconductivity

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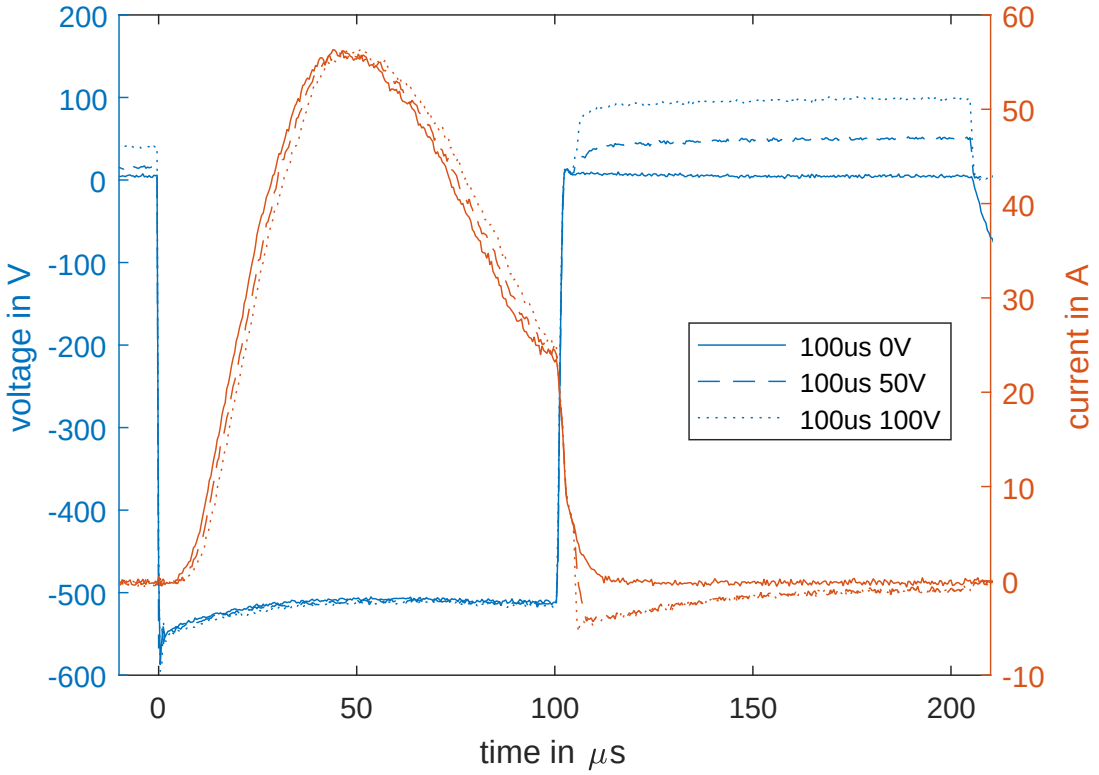
Overview

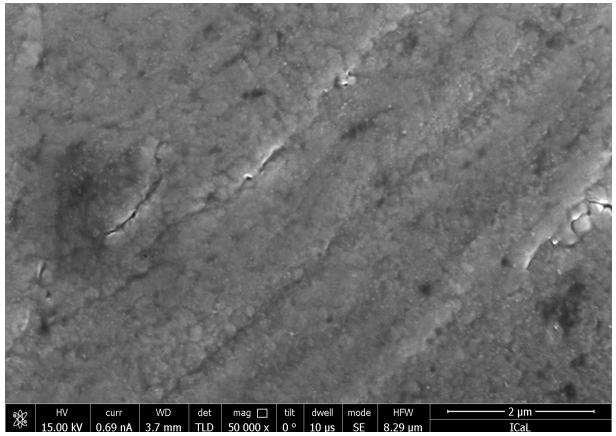
- Bipolar HiPIMS
- Thin film properties
- Plasma diagnostics
- Conclusion/Outlook

Bipolar HiPIMS

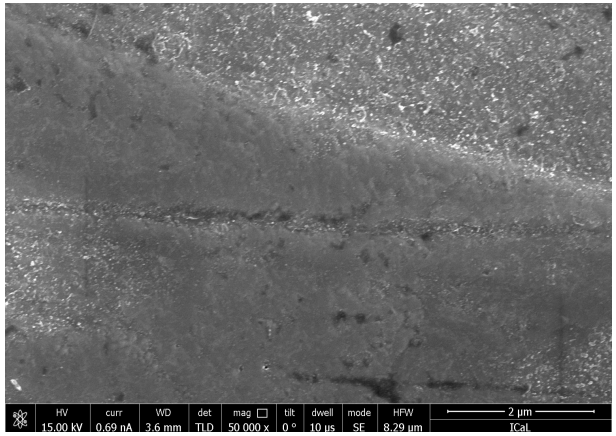


- 200 W avg Power, 100 μs HiPIMS pulse at 100 Hz, 5 $mTorr$
- positive polarity pulse of 50 V, 100 V, 150 V, 200 V

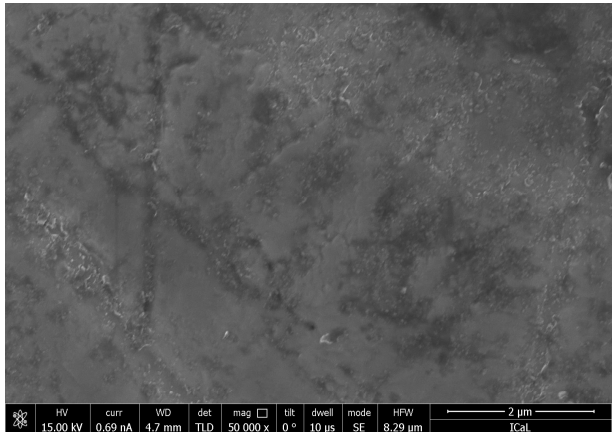
Thin film properties - SEM



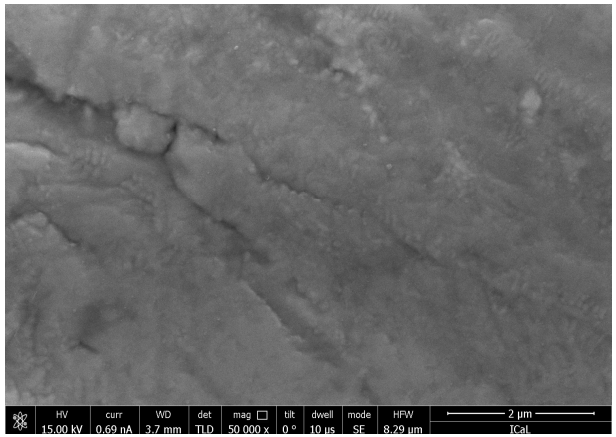
only HiPIMS



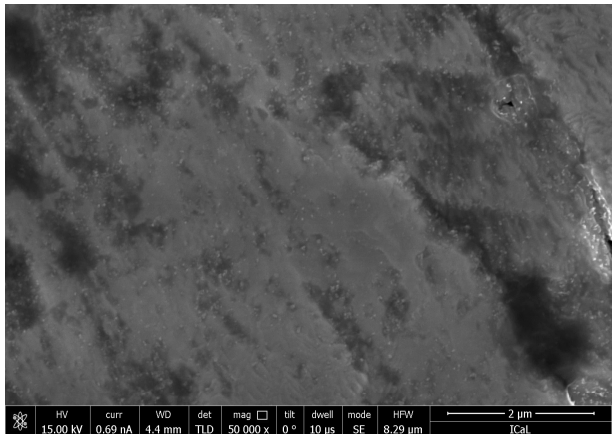
50V positive pulse



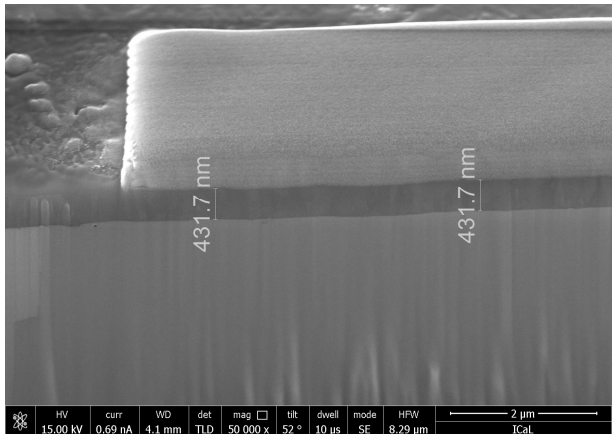
100V positive pulse



150V positive pulse



200V positive pulse



cross section

Thin film properties - XRD

Data set name	a(A)	b(A)	c(A)	Calc. density(g/cm^3)
400W DC	3.319	3.319	3.319	8.441
200W HiPIMS, NoKick	3.321	3.321	3.321	8.422
200W HiPIMS, 50V Kick	3.322	3.322	3.322	8.420
200W HiPIMS, 100V Kick	3.334	3.334	3.334	8.324
200W HiPIMS, 150V Kick	3.327	3.327	3.327	8.377
200W HiPIMS, 200V Kick	3.320	3.320	3.320	8.430

Data set name	Crystallinity(%)	Crystallite size(A)	Strain(%)
400W DC	59.6(3)	158	0.33
200W HiPIMS, NoKick	49.7(4)	158(28)	0.34(11)
200W HiPIMS, 50V Kick	45.5(4)	176	0.29
200W HiPIMS, 100V Kick	46.6(4)	115(12)	0.48(9)
200W HiPIMS, 150V Kick	43.4(15)	202(31)	0.37(6)
200W HiPIMS, 200V Kick	52.7(7)	204	0.40

Thin film properties - magentic

date	Data set name	parallel	Tc
13.9.2019	400W DC	170	9.5
11.9.2019	200W HiPIMS, 0V	220-370	9.55
6.9.2019	200W HiPIMS, 50V pos. pulse	160	9.55
4.9.2019	200W HiPIMS, 150V	120	9.6
30.8.2019	200W HiPIMS, 100V	140	9.55
29.8.2019	200W HiPIMS, 100V	190	9.5
27.8.2019	200W HiPIMS, 200V	140	9.55

thin films are identical!

Plasma diagnostics

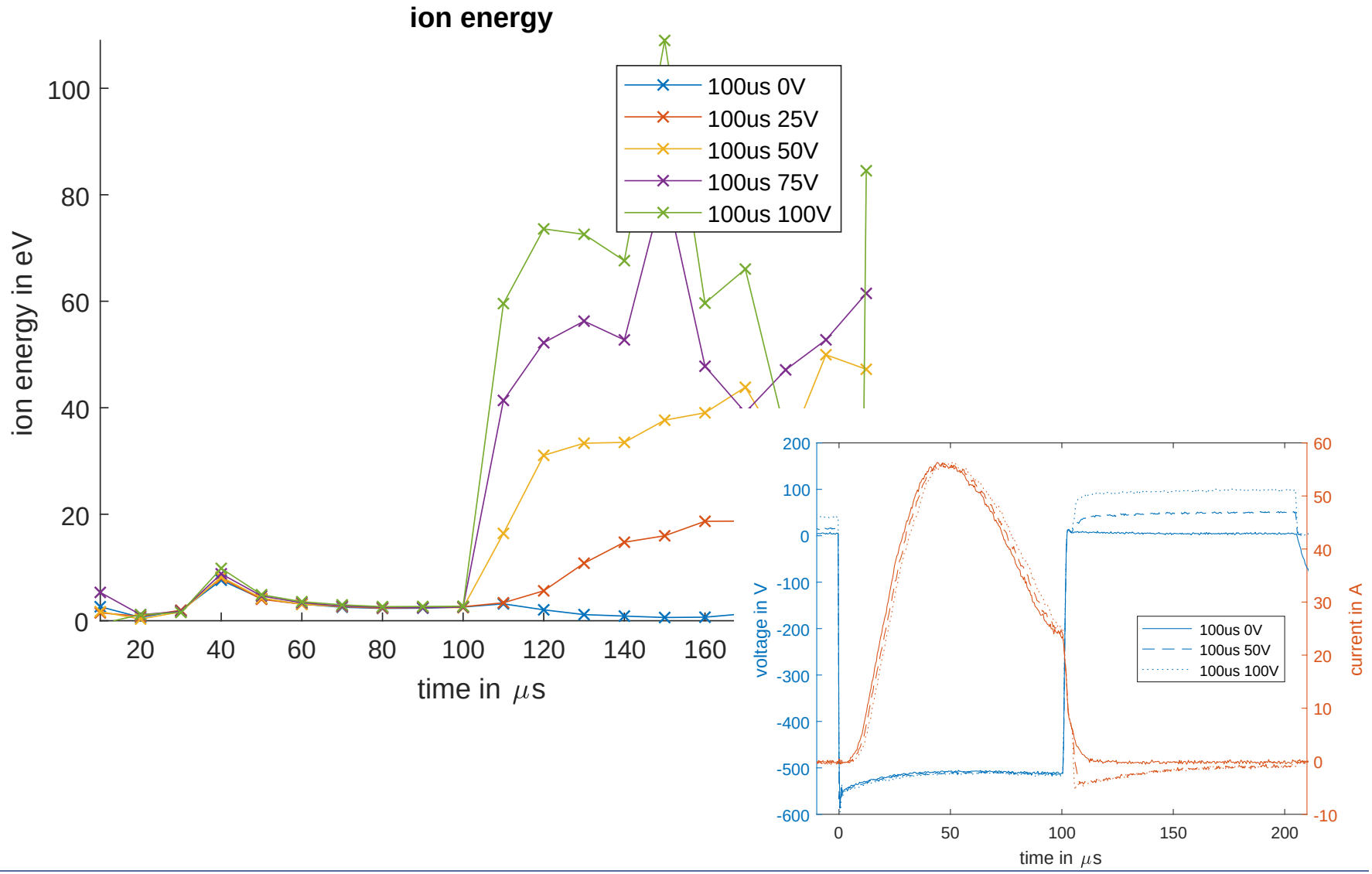
Plasma parameters in the bulk plasma

- electron Temperature
- electron and ion density

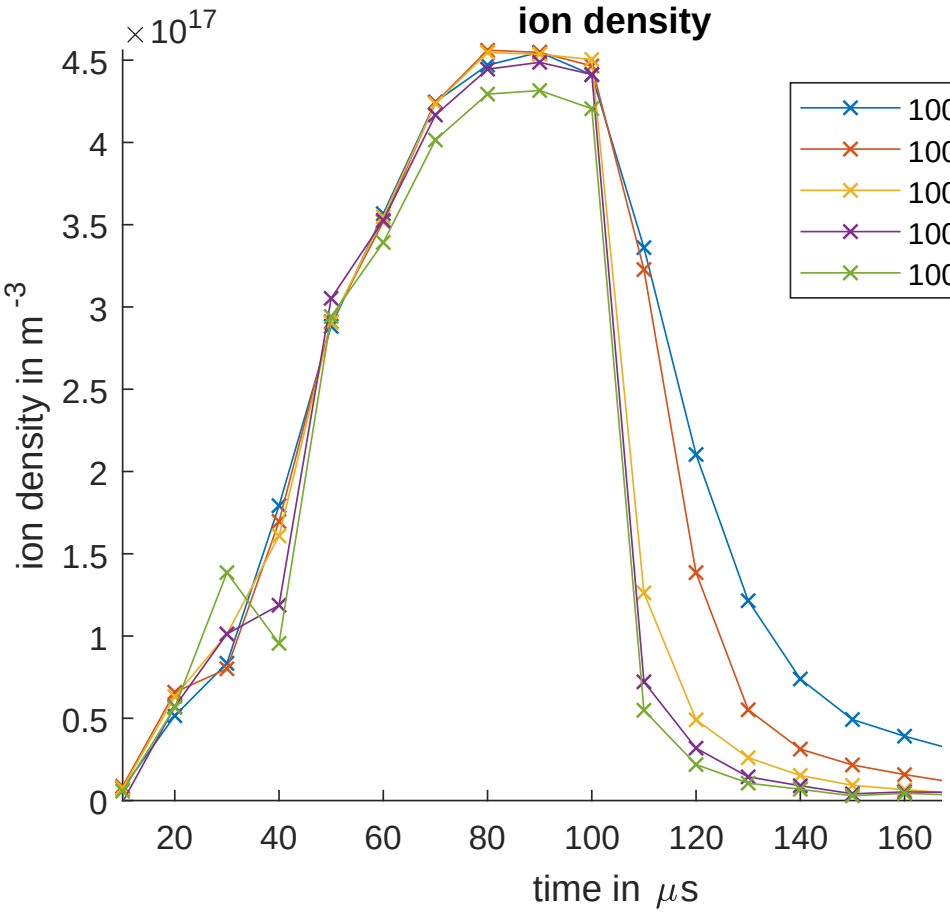
Plasma parameters on surface interaction

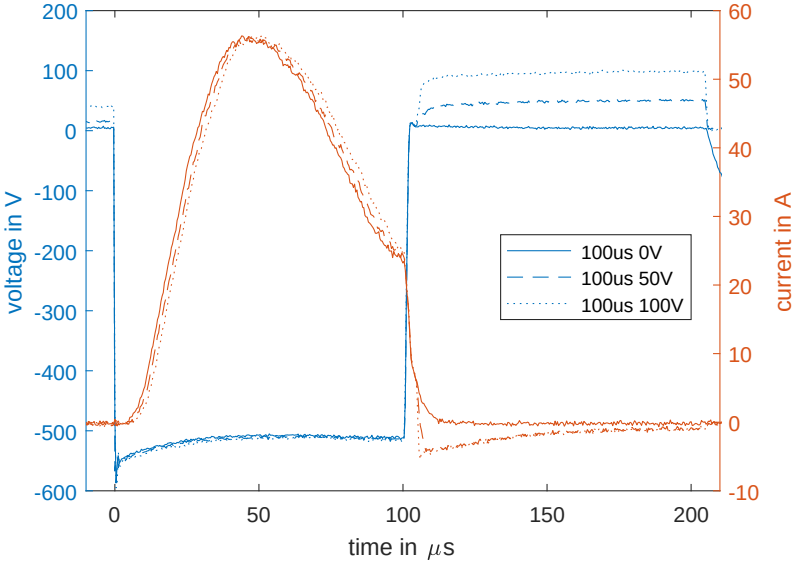
- ion velocity
- Ion Energy Distribution Function
- Ion Flux

Plasma diagnostics - Ion Energy

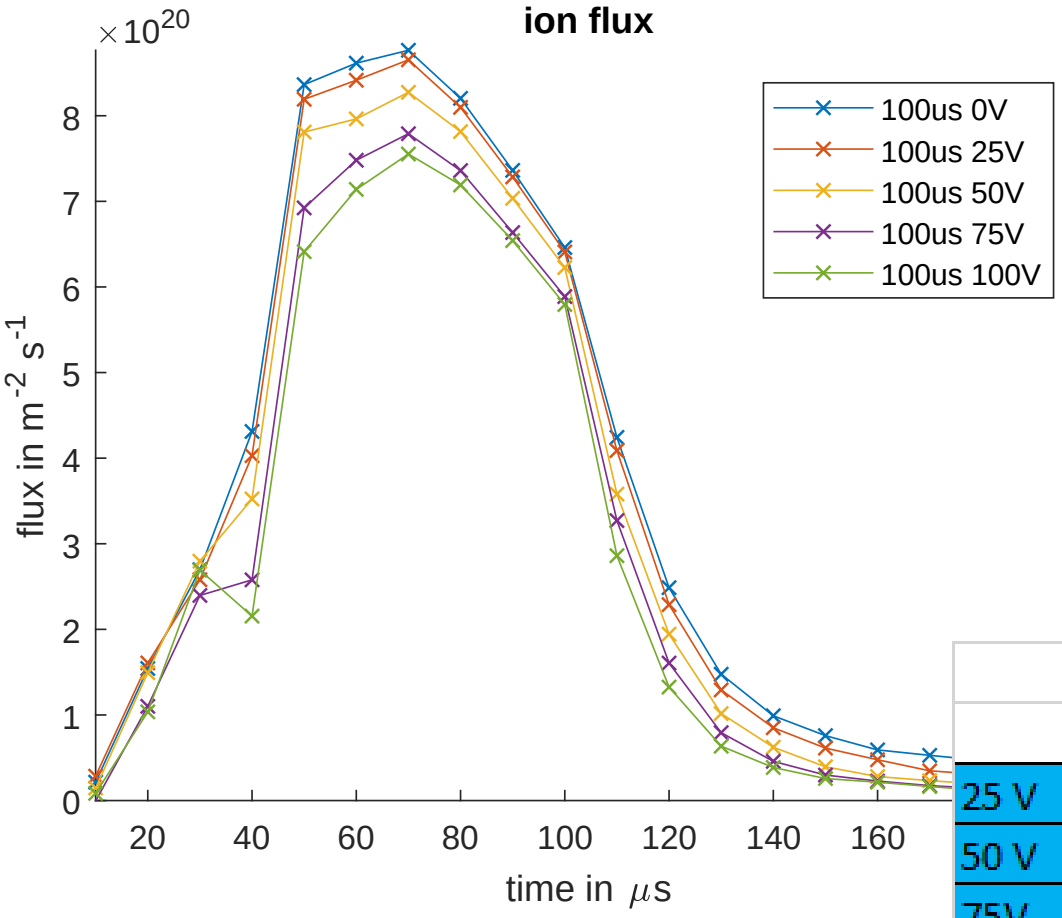


Plasma diagnostics - Ion Density



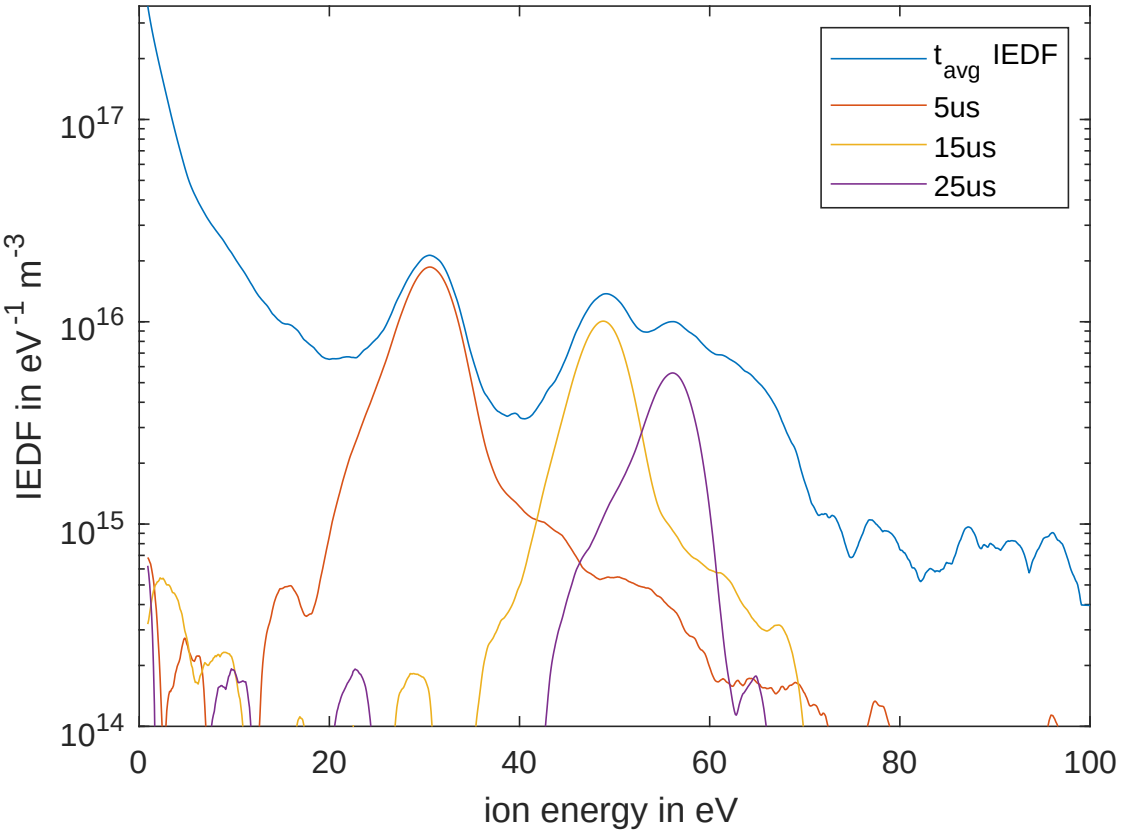


Plasma diagnostics - Ion Flux



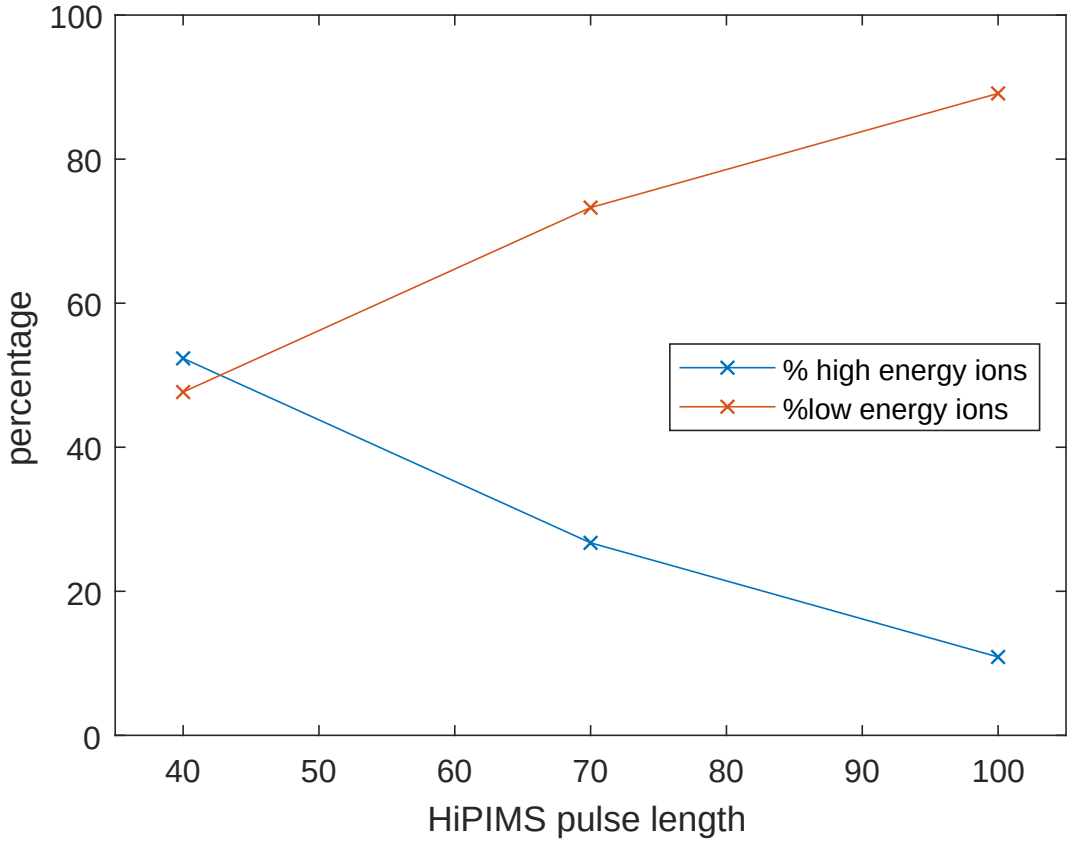
	Ion origin	
	positive pulse	HiPIMS pulse
25 V	14	86
50 V	12	88
75V	11	89
100V	10	90

Plasma diagnostics - IEDF



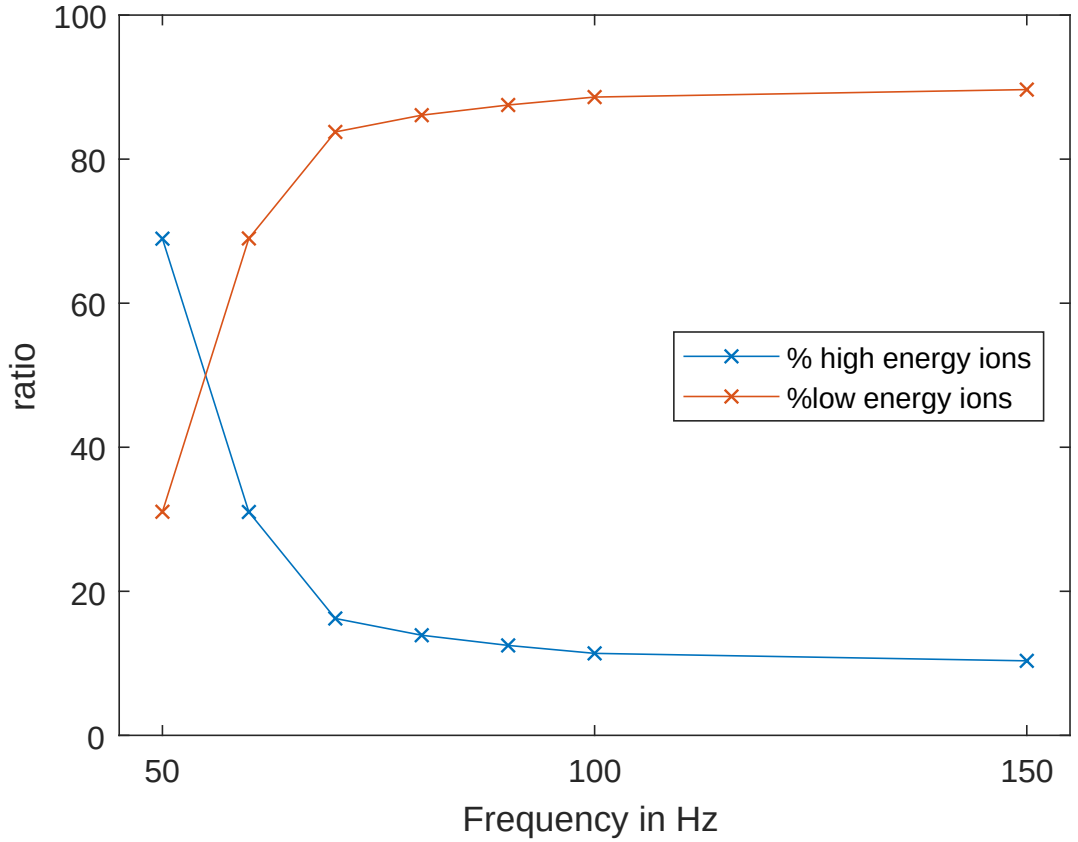
time averaged IEDF and time resolved IEDF 5 μs, 15 μs and 25 μs into positive pulse

Plasma diagnostics - Ion ratio



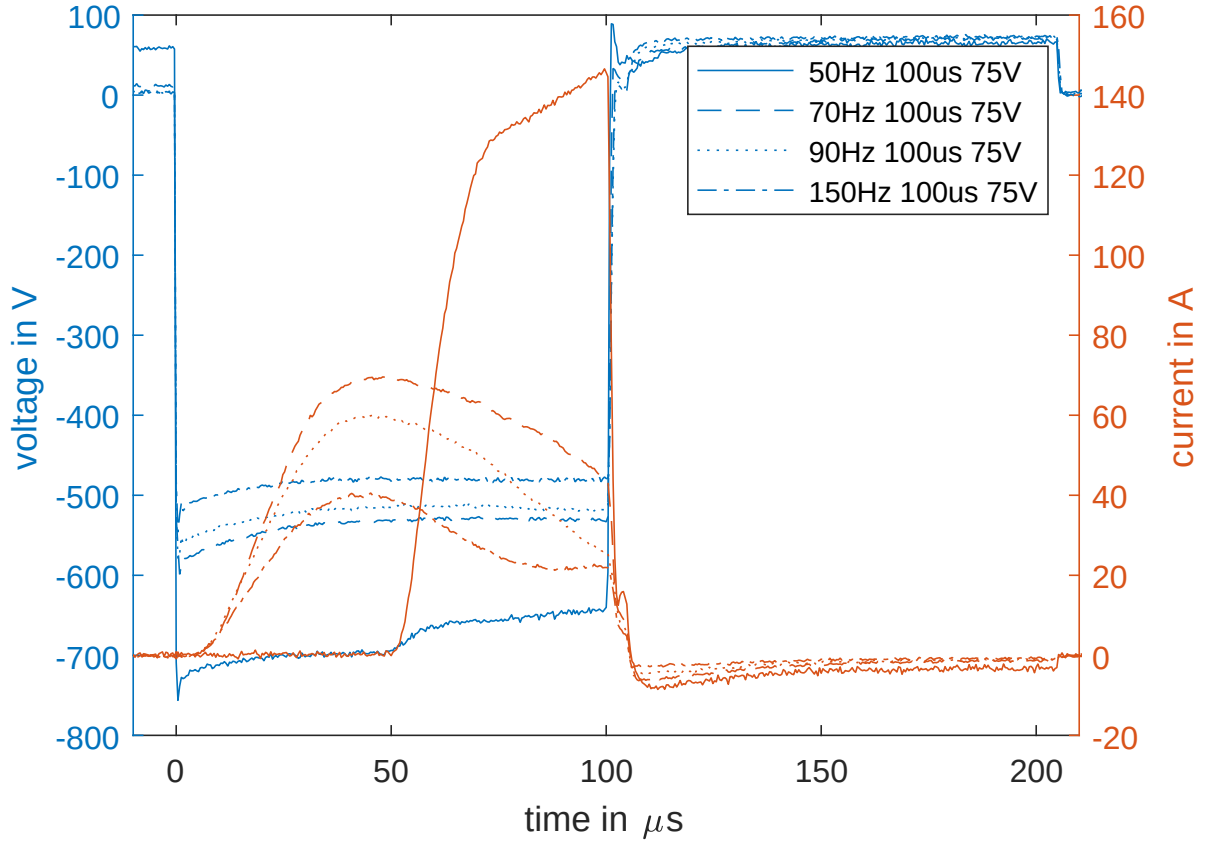
$200\,W$ avg Power, variable HiPIMS pulse length at $100\,Hz$ with a $75\,V$ positive pulse, $5\,mTorr$

Plasma diagnostics - Ion ratio



200 W avg Power, 100 μs HiPIMS pulse with a 75 V positive pulse, 5 $mTorr$

Plasma diagnostics - Ion ratio



200 W avg Power, 100 μs HiPIMS pulse with a 75 V positive pulse, 5 $mTorr$

Conclusion/Outlook

- Understanding the plasma process is vital for thin film development
  - Tailored ion energies
- Plasma generator is a key element
  - waveform
  - ability to control process
- process transfer from planar sample to cavity
  - Planar to Cylindrical Magnetron