

Tailored Voltage Waveform Plasmas for Control of Surface Processing

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The use of non-sinusoidal, Tailored Voltage Waveforms (TVW's, as shown in figure 1) to excite capacitively coupled radio-frequency (RF) process plasmas has attracted much attention in recent years, both as a tool to reveal interesting physics and also to produce behavior that is not accessible when exciting a plasma in a symmetric way.

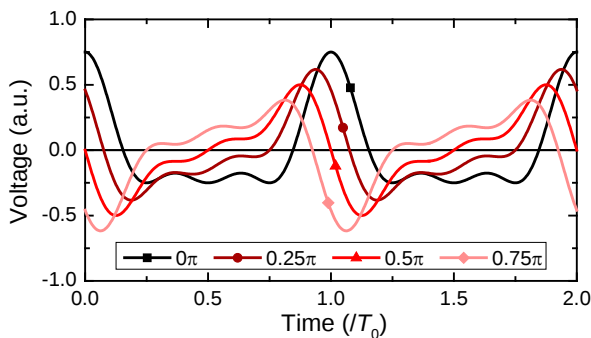


Figure 1: Examples of Tailored Voltage Waveforms

We show how the use of TVW's allow one to access regimes of operation (in terms of ion current and energy) unavailable through standard, single frequency excitation (figure 2), in particular for the case of an electronegative plasma used to texture-etch a silicon wafer. Doing so, we show how using such a plasma excitation technique allows one to isolate and separate the roles of ion energy and flux.

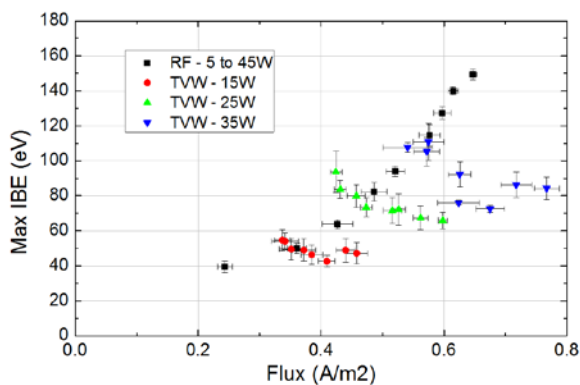


Figure 2: Ion flux and max IBE process conditions accessible using TVWs (RF for comparison)

Furthermore, we will also show that by using "sawtooth" shaped waveforms, one can generate an asymmetric ionization profile in the plasma that depends strongly on the electronegativity of the plasma (figure 3, from [1]). This will be demonstrated as a sensitive tool to detect plasma conditions such as the dominant heating mode [2], in addition to being used to produce "selective

deposition", that is the deposition of a thin film of silicon on one electrode, but not on the other [3].

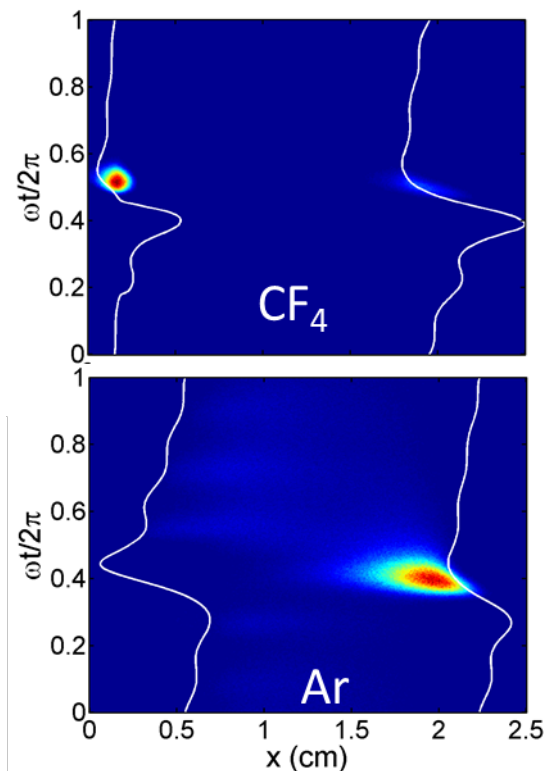


Figure 3: Modelled excitation profiles for "sawtooth" waveform, showing electropositive behavior for Ar and electronegative for CF₄.

Finally, a continuing challenge for the Tailored Voltage Waveform plasma excitation technique is making it completely and transparently adaptable to any system, as would be the case for a classical RF generator. We will present results documenting how a TVW system can be made truly "plug-and-play", making it a more accessible tool for academia and industry. In particular, we discuss recent modelling results on multifrequency impedance matching [4], which has also now been demonstrated in the laboratory.

References

- [1] B Bruneau *et al*, **Plasma Sources Sci. Technol.** **25** (2015) 01LT02.
- [2] G Fischer, K. Ouaras, E Drahi, B Bruneau and E V Johnson, **Plasma Sources Sci. Technol.** **27** (2018) 074003.
- [3] J. Wang and E.V. Johnson, **Plasma Sources Sci. Technol.** **26** (2017) 01LT01.
- [4] F. Schmidt *et al*, **Plasma Sources Sci. Technol.** (2018), in press, DOI: 10.1088/1361-6595/aad2cd