Semion Commercial Applications

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Impedans PLASMA MEASUREMENT

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ICP
(300 mm AMAT AdvantEdge)

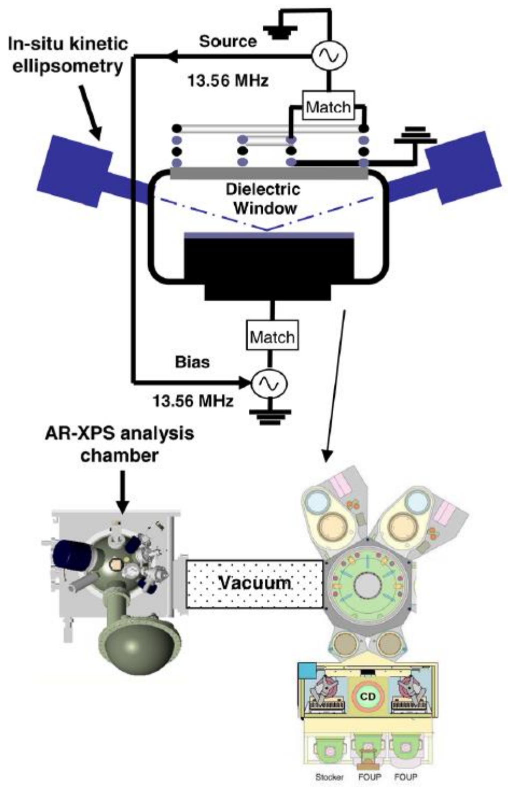
Measurement of the IEDF in an AMAT-ICP system

Etching mechanisms of thin SiO_2 exposed to Cl_2 plasma

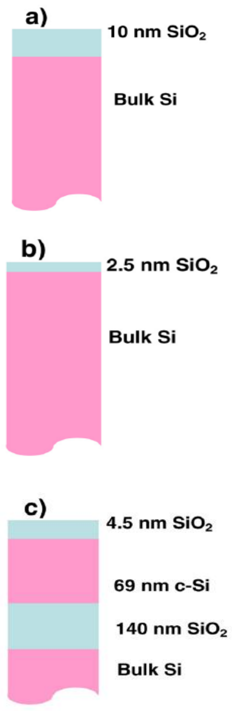
C. Petit-Etienne et al, CNRS-LTM, Grenoble Cedex, France
Applied Materials, Sunnyvale, California 95085, USA

DOI: https://doi.org/10.1116/1.3622311

The objective of this paper was to investigate how a thin silicon oxide layer on silicon behaves when it is exposed to a Chlorine (Cl_2) plasma, in order to be able to minimise the impact of etch processes on such layers.



Schematic of AMAT ICP reactor



SiO_2 samples used

The ion energy distribution function at the wafer surface, measured using multigrid retarding field energy analyser (SEMION from Impedans), ~ 105 eV

Measurement of Ion Flux and Ion Energy for changing pulsing frequency and bias power in a pulsed HBr/O_2 etch plasma

- **Development of etch processes based on pulsed reactive plasmas pulsed plasmas for etch applications**

Moritz Haass, LTM (CNRS/UJF-Grenoble1/CEA), Grenoble Cedex 9, France

DOI: https://tel.archives-ouvertes.fr/tel-00820065

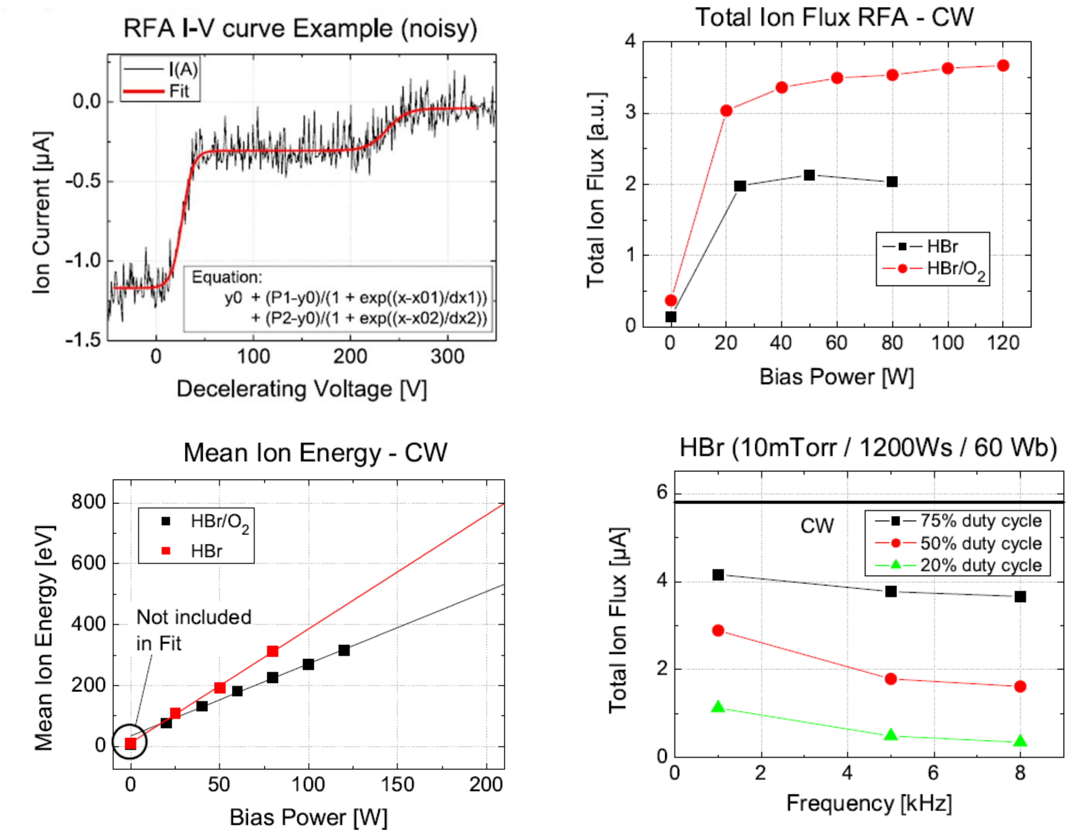
- **Silicon etching in a pulsed HBr/O_2 plasma.**
  I. Ion flux and energy analysis

Moritz Haass et al, LTM (CNRS/UJF-Grenoble1/CEA), Grenoble Cedex 9, France
Impedans Ltd Woodford Business Park, Santry, Dublin, Ireland

DOI: https://doi.org/10.1116/1.4917230

The objective of this work was to investigate the impact of synchronous pulsing on silicon etching in a HBr/O_2 plasma. The characterisation of plasma properties include measurement of ion flux, ion energy and ion energy distribution function.

Some example data is shown to the right



Examples of the Ion energy and ion flux with power and pulsing frequency variation

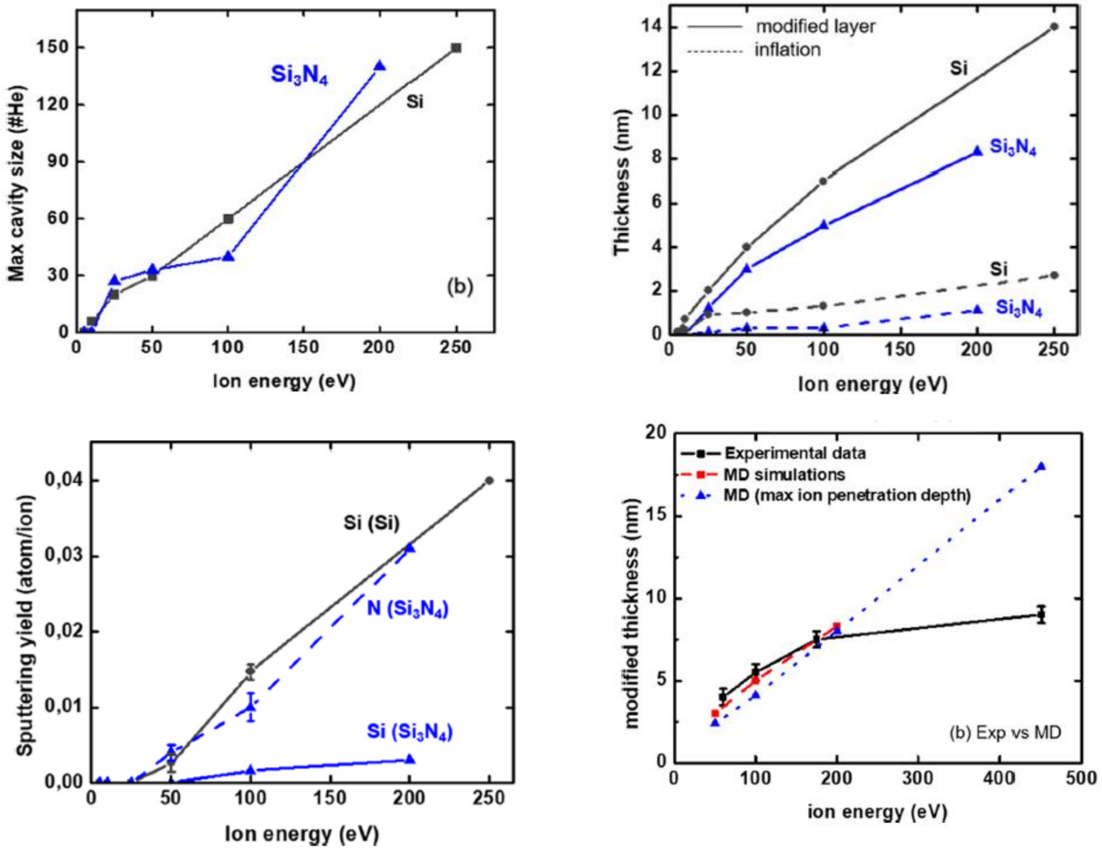
The impact of the ion energy on the modified thickness and sputtering

Helium plasma modification of Si and Si_3N_4 thin films for advanced etch processes

Vahagn Martirosyan et al, LTM, Univ. Grenoble Alpes, CNRS, Grenoble Cedex, France
DOI: https://doi.org/10.1116/1.5025152

The objective of this paper was to investigate the influence of He^+ ion bombardment on crystalline Si and amorphous Si_3N_4 substrates, for ion energies varying in the 5–250 eV range.

Some example data is shown to the right



Examples of effect of ion energy variation on crystalline Si and amorphous Si_3N_4 substrates

ICP
(AMAT Centura 300 DPS)

Ion velocity distribution functions in an Ar/O_2 Inductively Coupled Plasma

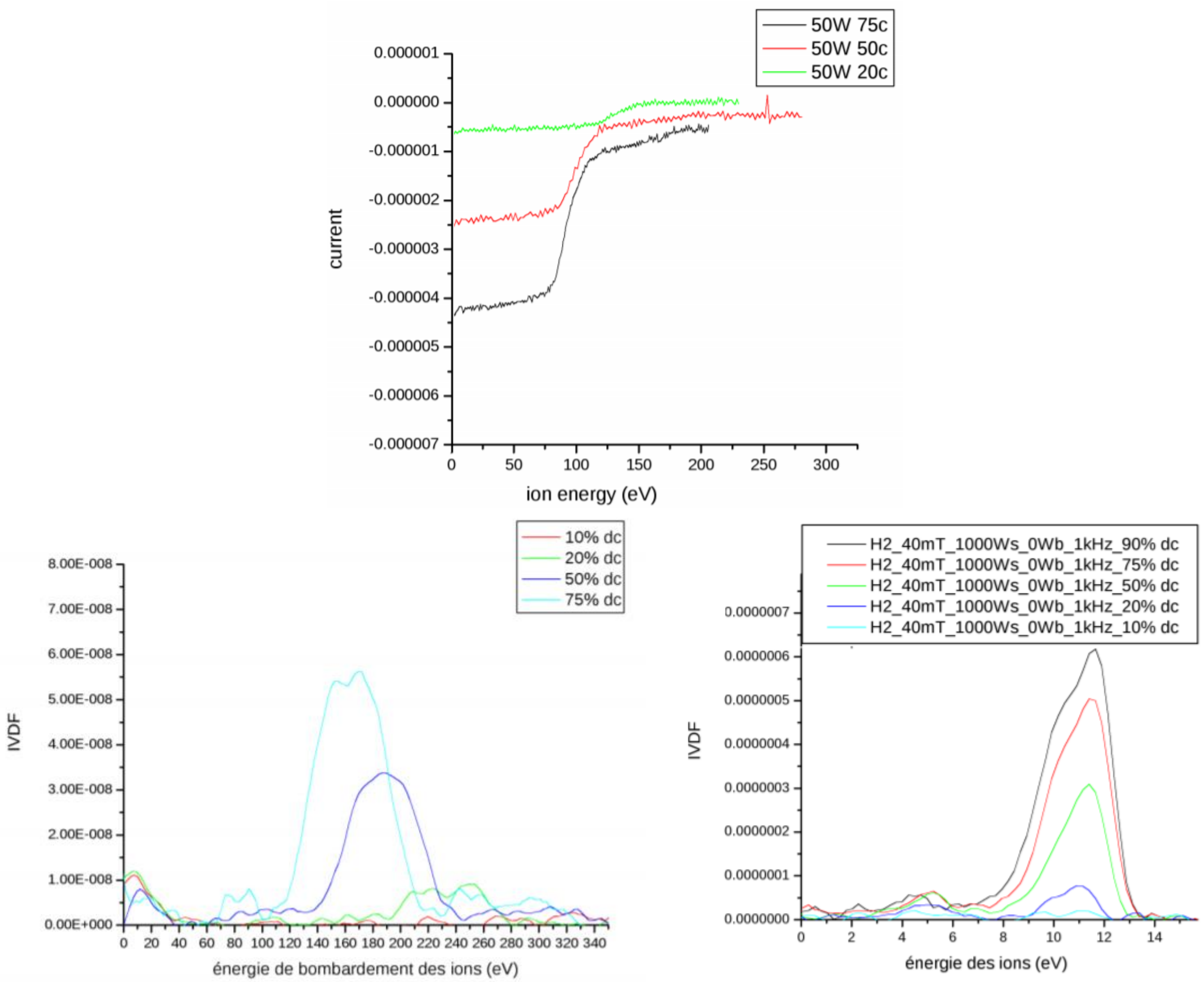
Development of innovative plasma etching processes for sub-14 nm technologies by coupling conventional lithography with the self-aligned approach by block copolymer

Philippe Bézard, LTM, Univ. Grenoble Alpes, CNRS, Grenoble Cedex, France

DOI: https://tel.archives-ouvertes.fr/tel-01285071

The objective of this thesis was to overcome some of the crucial etching challenges. In this work, it is shown that CD uniformity can be corrected by faceting the top of the patterns through plasma etching.

Some example data is shown to the right



Examples of RFEA measurements of collected current and associated IVDF in ICP

ICP for ALD
(Oxford Instruments FlexAL)

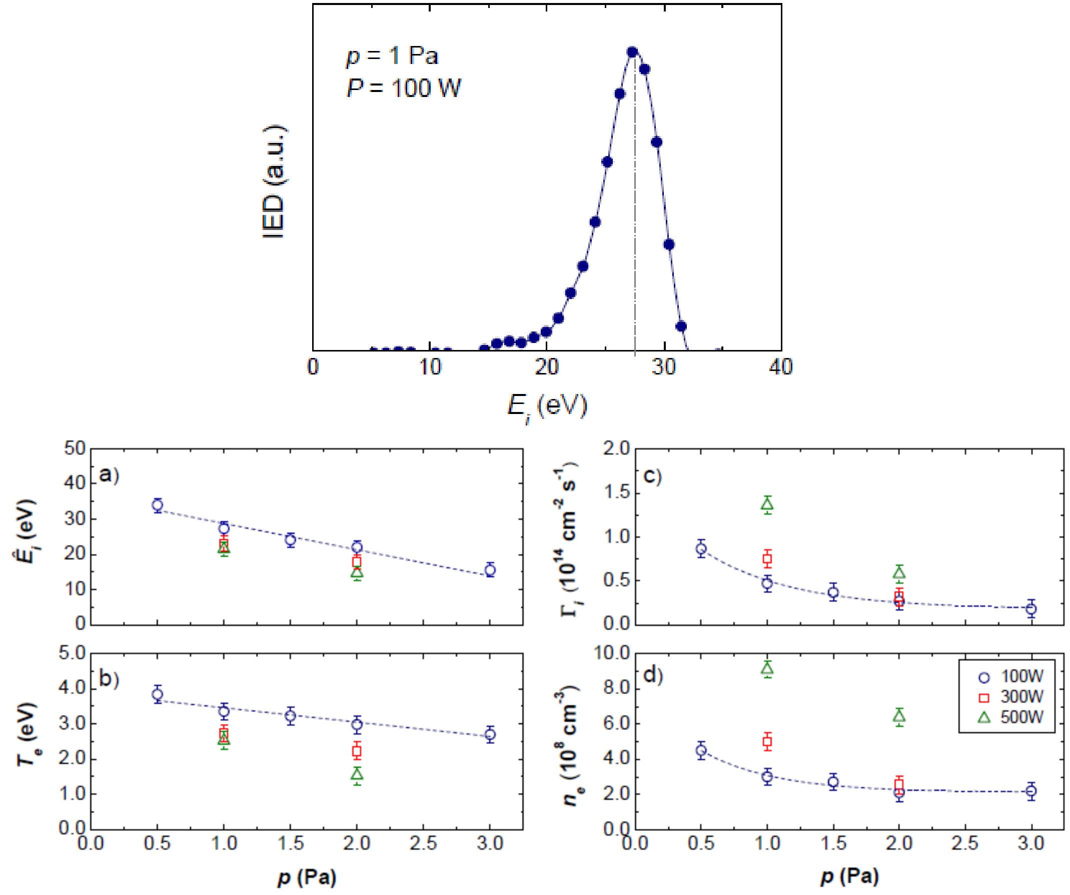
Influence of oxygen ions and photons during remote plasma atomic layer deposition of metal oxide thin films

The Influence of Ions and Photons during Plasma-Assisted ALD of Metal Oxides

Harald B. Profijt et al, Applied Physics, Eindhoven University of Technology, Eindhoven, Netherlands
DOI: https://doi.org/10.1149/1.3485242

In this work, it is demonstrated that the ions and photons present in plasmas during plasma-assisted Atomic Layer Deposition (ALD) can influence the deposition process and the material quality significantly. The ion energy and flux were studied for several oxygen gas pressures and ICP powers.

Some example data is shown to the right



Example of RFEA measurements as measured for an O_2 plasma. Also shown the peak ion energy E_i , electron temperature T_e , Ion flux Γ_i and electron density n_e.

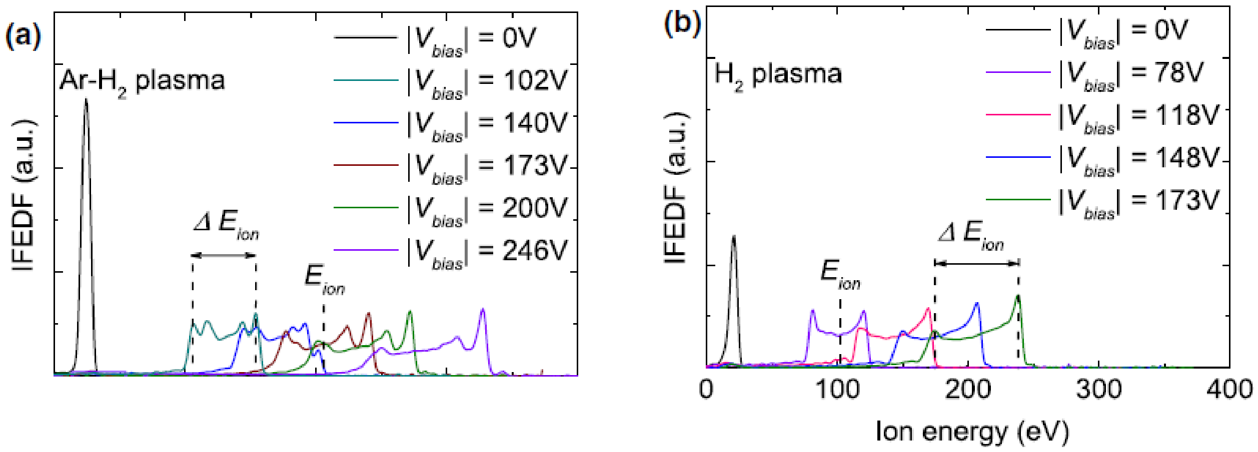
Impact of impingement of ions with larger mass and higher energy on the chemical and microstructural properties of HfN_x films

Plasma-Assisted ALD of Highly Conductive HfN_x: On the Effect of Energetic Ions on Film Microstructure

Saurabh Karwal et al, Department of Applied Physics, University of Technology Eindhoven, Eindhoven, Netherlands
Eurofns Material Science, High Tech, Campus 11, Eindhoven, The Netherlands

DOI:https://doi.org/10.1007/s11090-020-10079-x

In this work, the impact of impingement of ions with larger mass and higher energy on the chemical and microstructural properties of HfN_x films is addressed. The ion energy measurements carried out in the present work indicate that the growing HfN_x film is subjected to a higher average ion energy in the case of Ar–H_2 plasma with respect to the previously reported H_2 plasma process.



Example of RFEA measurements in (a) Ar–H_2 plasma operated at 6 mTorr and (b) H_2 Plasma operated at 30 mTorr for various values of $|V_{bias}|$

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Revisiting questions regarding the operation of the RFEA

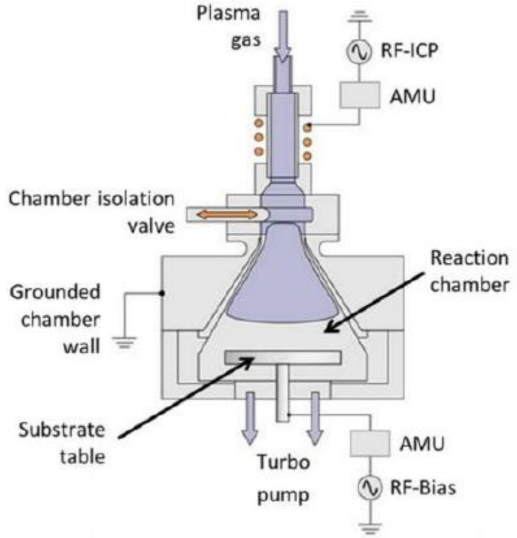
Functional analysis of retarding field energy analyzers for ion energy distribution measurements in plasma enhanced atomic layer deposition

Jan W. Buiter, Applied Physics, Eindhoven University of Technology, Eindhoven, Netherlands

DOI:
https://research.tue.nl/en/studentTheses/functional-analysis-of-retarding-field-energy-analyzers-for-ion-e

This work aims to obtain an improved understanding of the principles of RFEA measurements. Both simulations and experimental methods are used to gain insight into the various aspects that govern the operation of an RFEA and the cause of measurement artifacts.

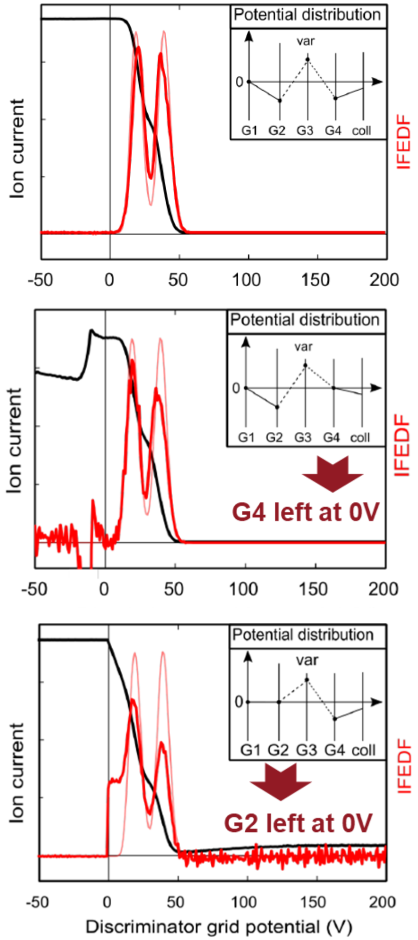
Some example data is shown to the right



FlexAL2 reactor used for RFEA measurements

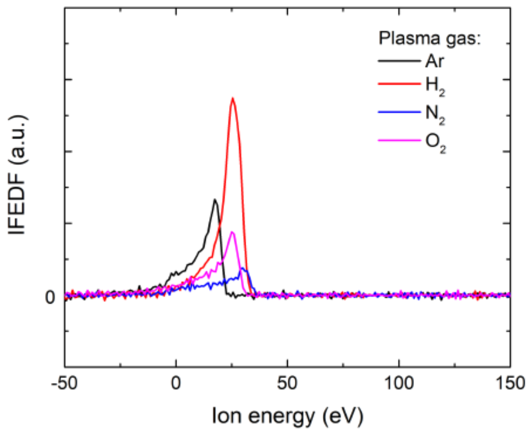
ICP for ALD (Oxford Instruments FlexAL)

Influence of grid potentials

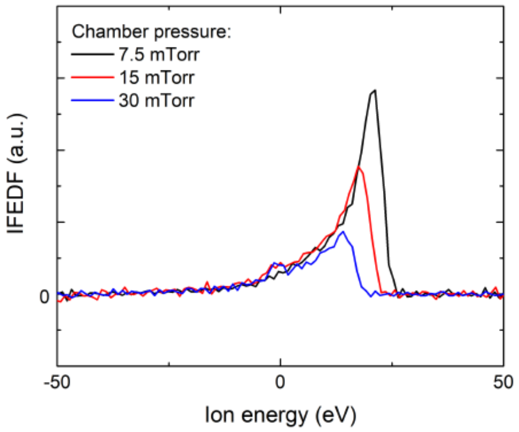


Simulated IV curve (black) and IED (dark red) of an RFEA measurement

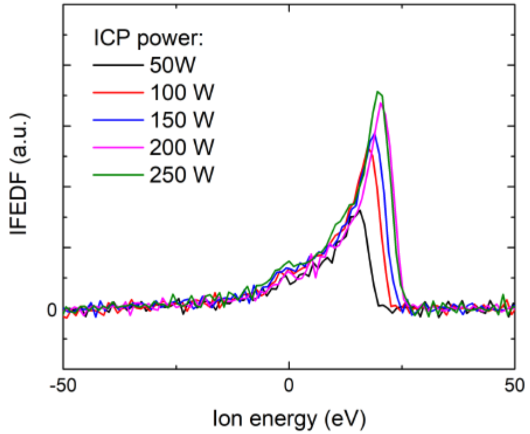
IFEDFs measured for various plasma conditions



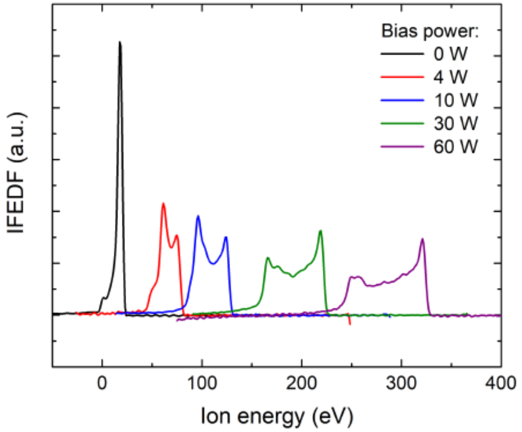
15 mTorr using 100W of ICP power



Argon plasma at three different pressures at 100W of ICP power



Argon plasma at 15 mTorr



Effects of bias power on a 600W argon plasma at 9 mTorr

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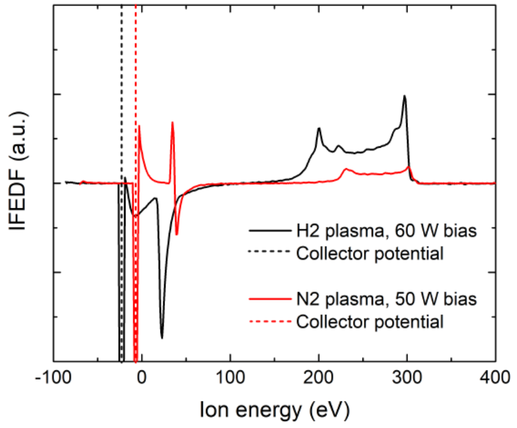
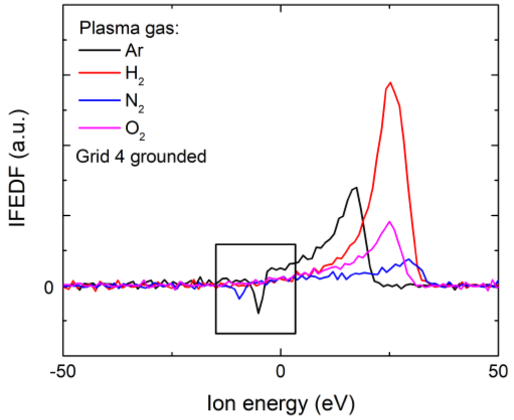
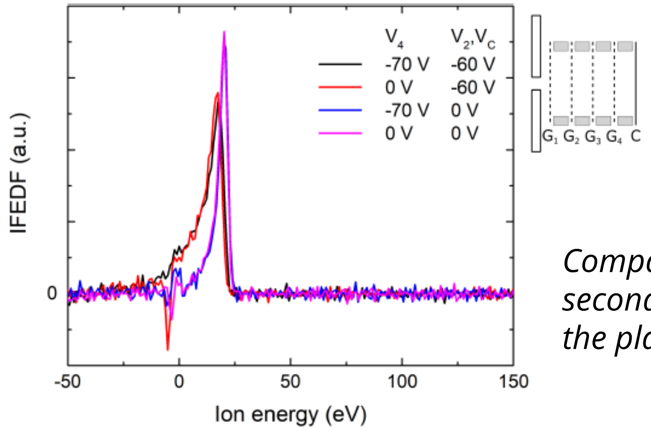
Investigating role of Secondary electrons



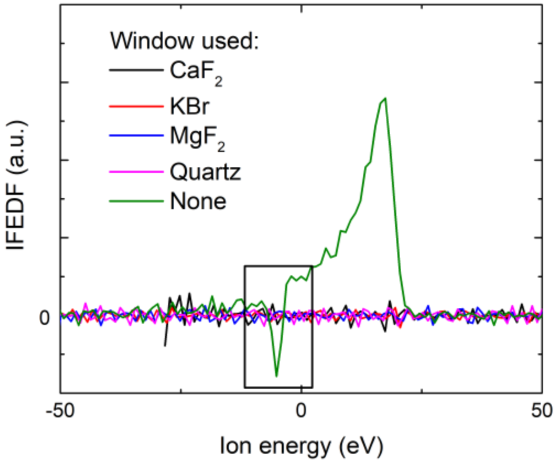
Examples of measurements performed in the FlexAL reactor that show a secondary electron peak.



Comparison of the effects of the disabled secondary electron suppression grid on the measured IFEDF between the four gases.



Comparison of the effect of grounding the secondary electron suppression grid and/or the plasma electron suppression grids.



Peaks in the IFEDF where no filter was used indicates that UV photons are not a source of secondary electrons.

Results of measurements of an argon plasma where a variety of filters were placed on the RFEA.*(100W argon plasma at 15 mTorr and a disabled secondary electron suppression grid).*

Control of the ion energy during plasma-assisted ALD using two substrate-biasing technique

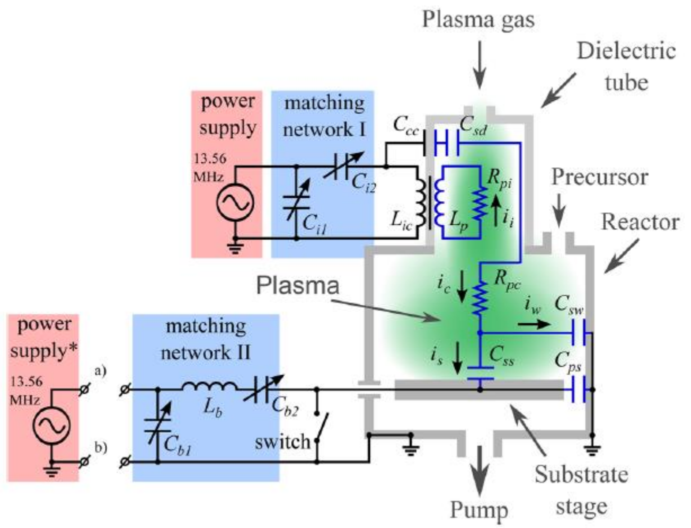
Substrate-biasing during plasma-assisted atomic layer deposition to tailor metal-oxide thin film growth

H. B. Profijt et al, Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

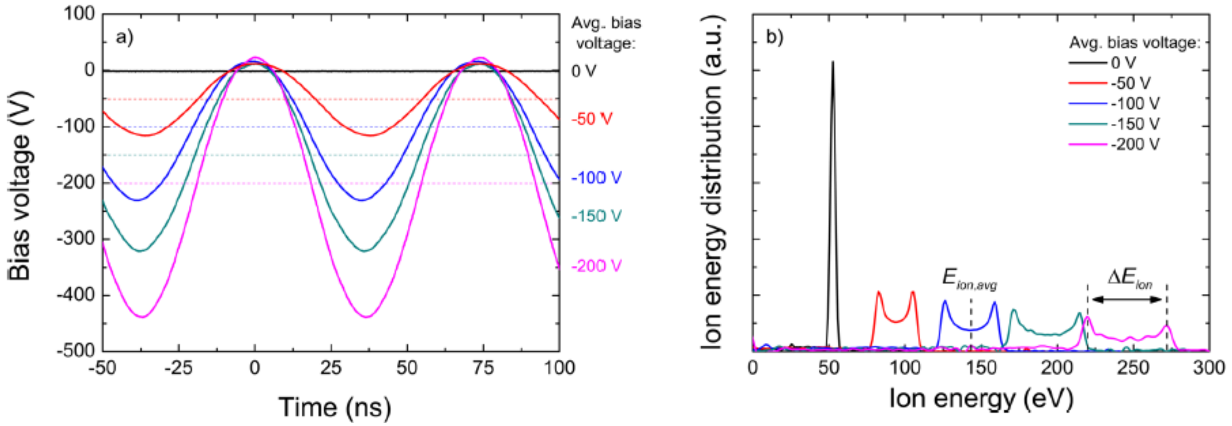
DOI: https://doi.org/10.1116/1.4756906

This article discusses the implementation of substrate-tuned biasing and radio frequency (RF) substrate biasing in a remote plasma ALD reactor. The impact of substrate biasing on the ion energy distribution (IED) is reported in detail.

Some example data is shown to the right



Remote plasma ALD reactor equipped with an inductively-coupled plasma source.



Substrate-tuned bias voltage, V_{subs} as a function of time, and the corresponding IEDs

ICP for ALD
(Oxford Instruments Atomfab)

Characterisation of a new low-damage remote plasma ALD system (Atomfab) for high-volume manufacturing of Al_2O_3 for GaN devices

Innovative remote plasma source for atomic layer deposition for GaN devices

Karsten Arts et al, Eindhoven University of Technology, Eindhoven, The Netherlands
Oxford Instruments Plasma Technology, Bristol BS49 4AP, United Kingdom;
Aalto University School of Chemical Engineering, Aalto, Finland

DOI: https://doi.org/10.1021/acs.chemmater.1c00781

This article outlines ion energy flux distribution functions and flux levels for a new remote plasma ALD system, Oxford Instruments Atomfab™, which includes an innovative, RF-driven, remote plasma source.
The source design is optimized for ALD for GaN high-electron-mobility transistors (HEMTs) for substrates up to 200 mm.

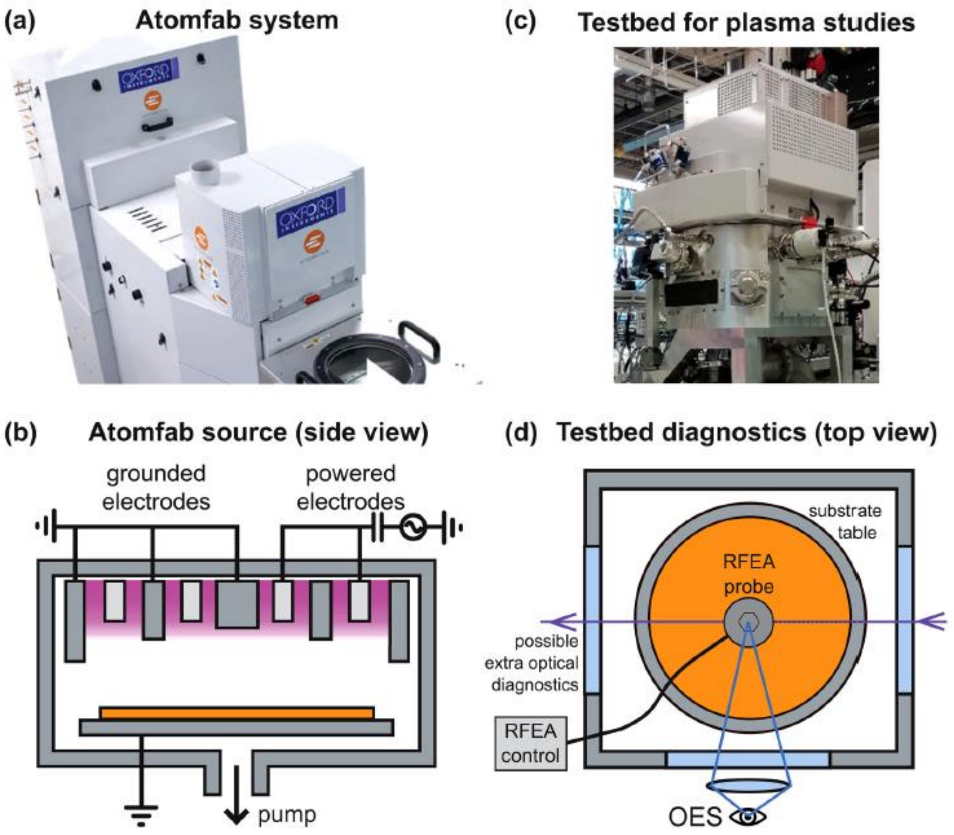
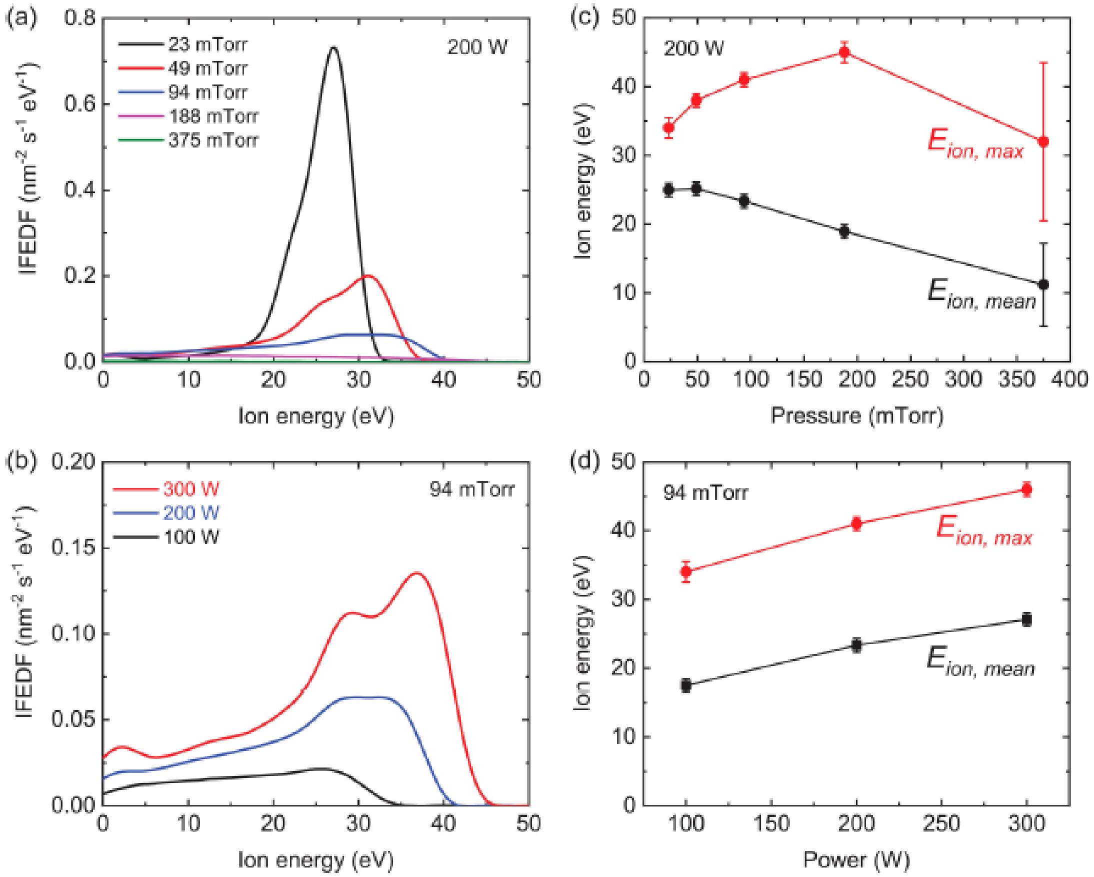
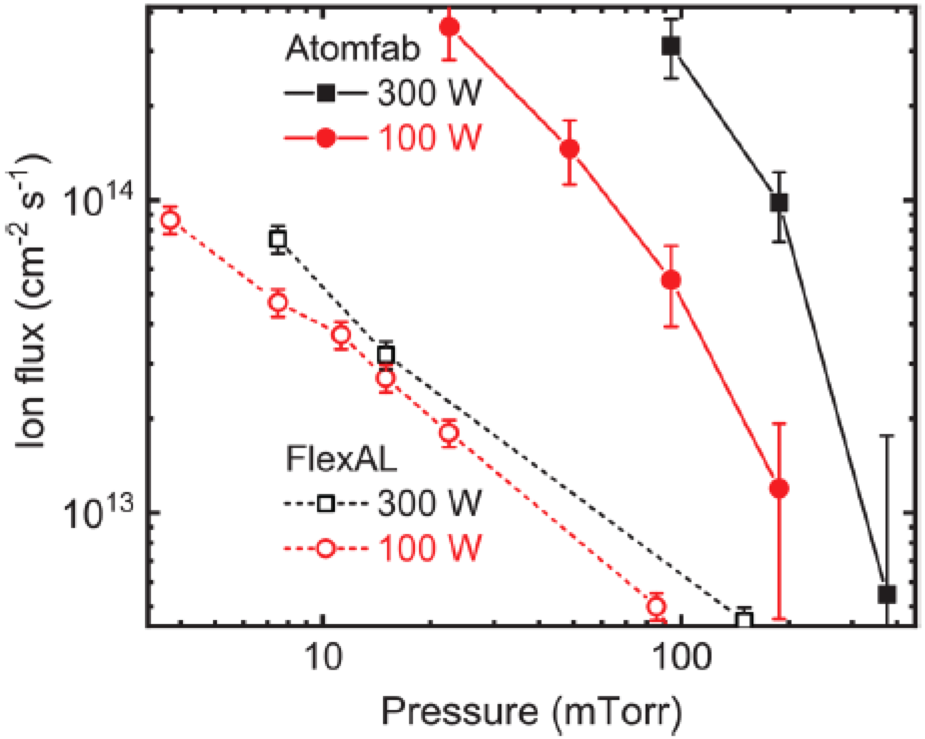


Image of the Oxford Instruments Atomfab system and RFEA installed in system.

Characterisation of a new low-damage remote plasma ALD system (Atomfab) for high-volume manufacturing of Al_2O_3 for GaN devices



IFEDFs for a range of chamber pressures at 200 W and plasma powers for O_2 plasma at 94 mTorr.



Ion flux as a function of pressure for FlexAL and Atomfab sources for O_2 plasmas of 100 and 300 W.

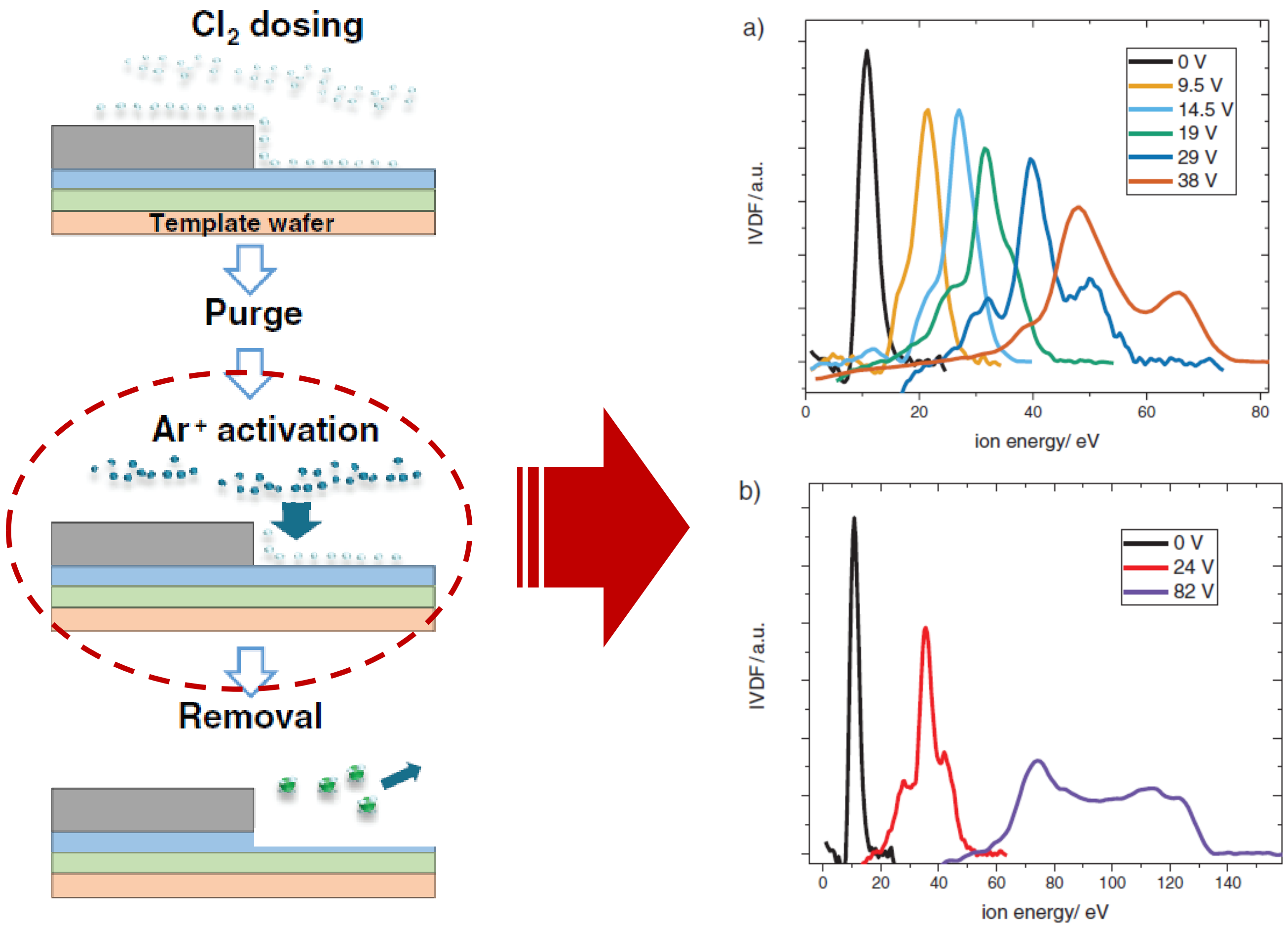
ICP for ALE (Oxford Instruments PlasmaPro 100 ALE)

A scalable, transfer free method to achieve horizontally individually patterned hetero-stacks

A route towards the fabrication of 2D hetero-structures using atomic layer etching combined with selective conversion

Markus H Heyne et al, Department of Chemistry, KU Leuven, Leuven, Belgium
Department Chemistry, University of Antwerp, Antwerp, Belgium
Imec, Kapeldreef 75,Leuven, Belgium
Faculty of Science, The Open University, Walton Hall, United Kingdom
Oxford Instruments Plasma Technology, North End, Bristol, United Kingdom
DOI: https://doi.org/10.1088/2053-1583/ab1ba7

In this work, atomic layer etching tool (ALEt) is used to pre-pattern a sacrificial Si layer on top of MoS_2 multilayers, which is afterwards converted into a stack of two transition-metal dichalcogenides (TMD), using an Si-to-WS_2 conversion process.
To estimate the bias power impact in the most critical Ar plasma activation step, the ion velocity distribution functions were determined by a retarding field analyzer (RFEA).



Schematic of the used ALEt process and Ion velocity distribution functions for different set points of bias voltage for (a) low bias range and (b) high bias range.

ICP for ALE
(Oxford Instruments PlasmaLab 80)

Extraction and acceleration of positive and negative ion beams from a pulsed inductively coupled plasma in SF_6

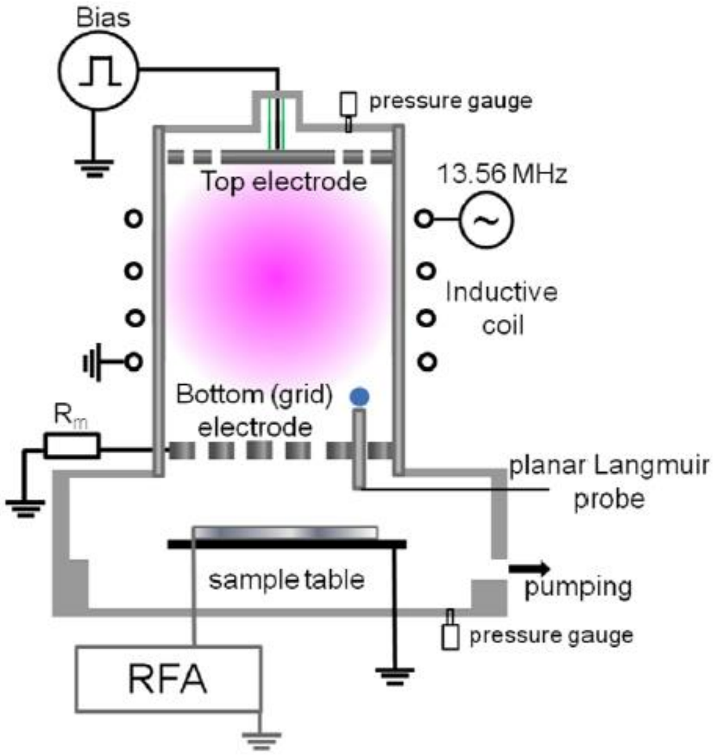
Extraction and neutralization of positive and negative ions from a pulsed electronegative inductively coupled plasma

D Marinov et al, Department of Physical Sciences, The Open University, Milton Keynes, UK
LPP, Ecole Polytechnique, CNRS, UPMC, Université Paris-Sud, Route de Saclay, Palaiseau, France
IMEC, Kapeldreef, Leuven, Belgium
Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, UK

DOI: https://doi.org/10.1088/0963-0252/24/6/065008

This work investigates the extraction of positive and negative ions from a pulsed inductively coupled plasma (ICP) in SF_6 bounded by two independently biased electrodes (with one of the electrodes fitted with an extraction grid). Time-resolved velocity distributions of extracted ions were measured synchronously with the variation of the plasma potential.

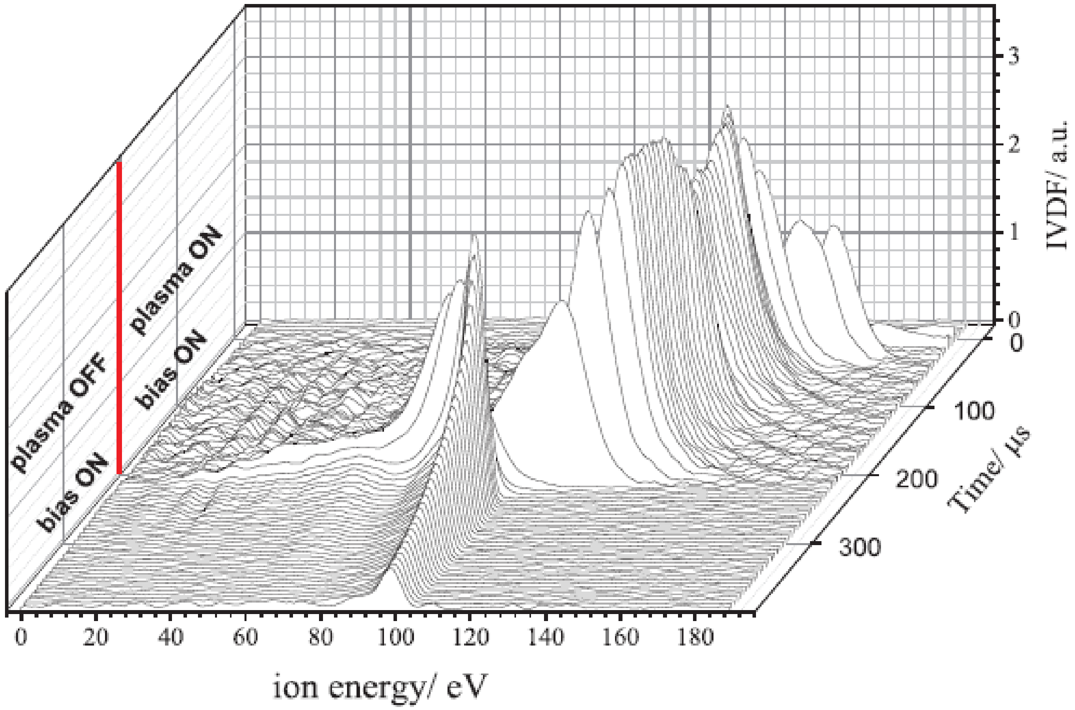
Some example data is shown to the right

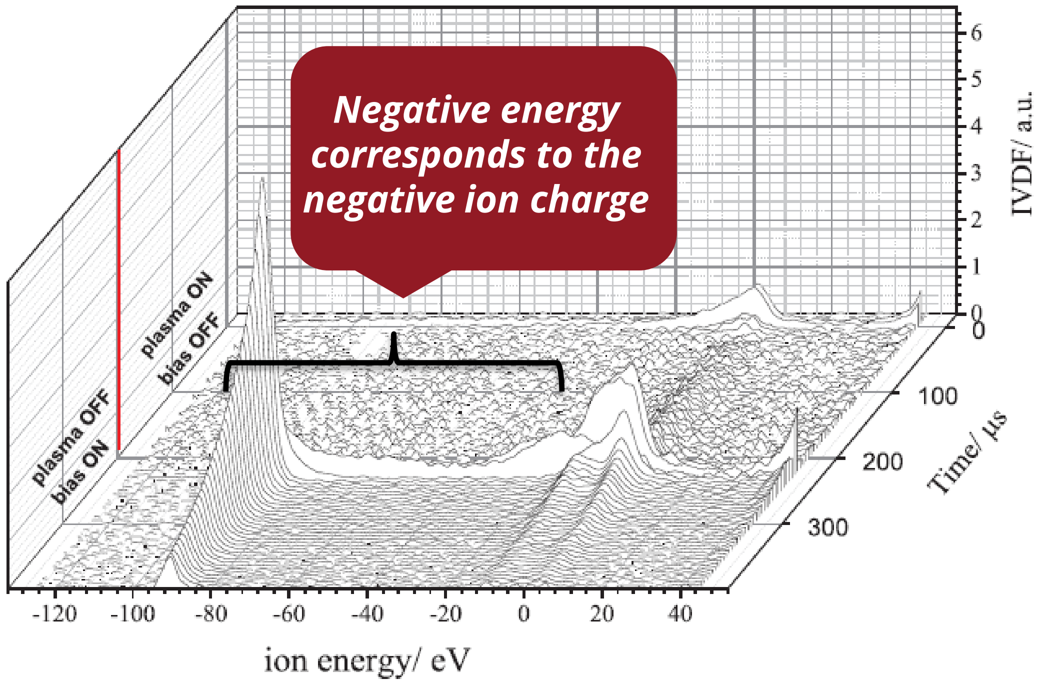


Oxford Instruments PlasmaLab80 (PL80) reactive ion etching system – ICP source.

ICP (Oxford Instruments PlasmaLab 80)

SF_6 at 3.3 Pa, modulation frequency 2 kHz, pulse duration τ_{pulse} = 200 μs, peak RF power P_{RF} = 400 W





Time-resolved IVDF of the positive ion beam extracted from a pulsed discharge.
(a) A continuous bias voltage U_{bias} = 100 V.
(b) A pulsed bias voltage U_{bias} = −95 V.

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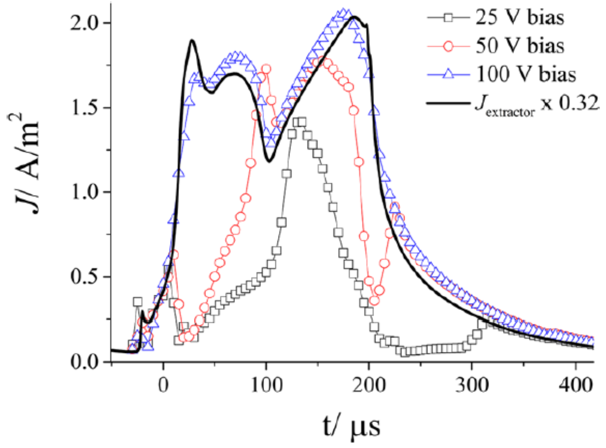
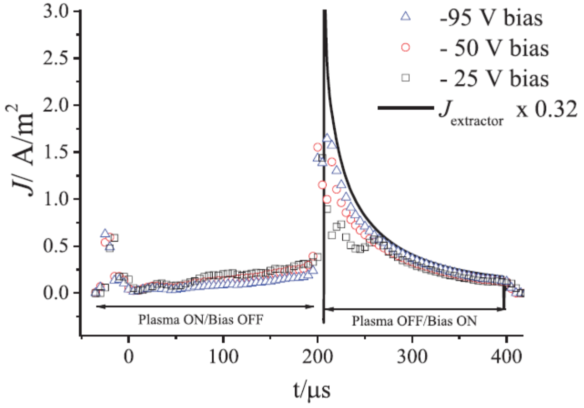
ICP (Oxford Instruments PlasmaLab 80)

Current density of the positive ion beam measured using the Semion RFA (open symbols) and the current density on the extractor multiplied by the transparency of the extraction grid (solid line).

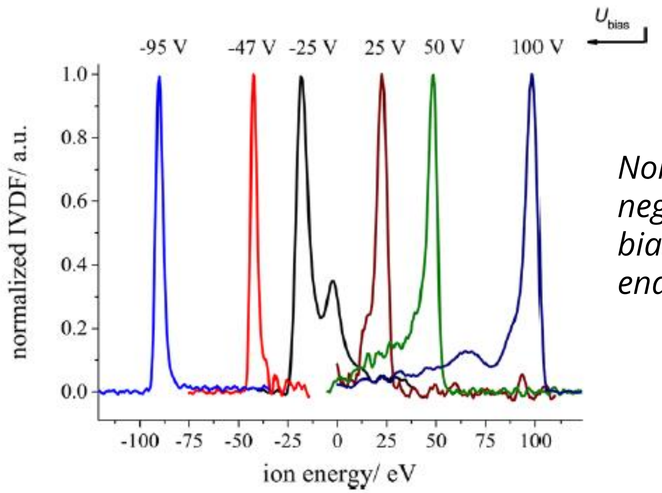


Continuous bias voltage was 25 V, 50 V and 100 V.

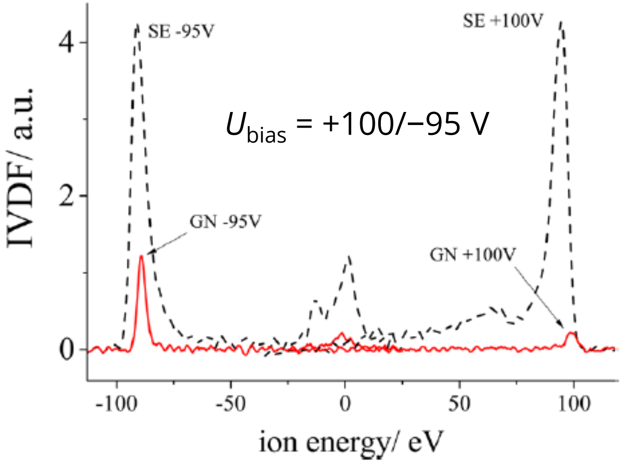


Pulsed bias voltage amplitude −25 V, −50 V and −95 V.

Pulsed ICP in SF_6 p = 3.3 Pa, P_{RF} = 400 W



Normalized IVDF of positive and negative ions extracted with different bias voltage measured 75 µs after the end of the discharge pulse.



IVDF of ions extracted with the graphite neutralizer (GN) and the stainless steel grid extractor (SE).

ICP
(Oxford Instruments Plasma Technology - PlasmaLab 100 Etcher)

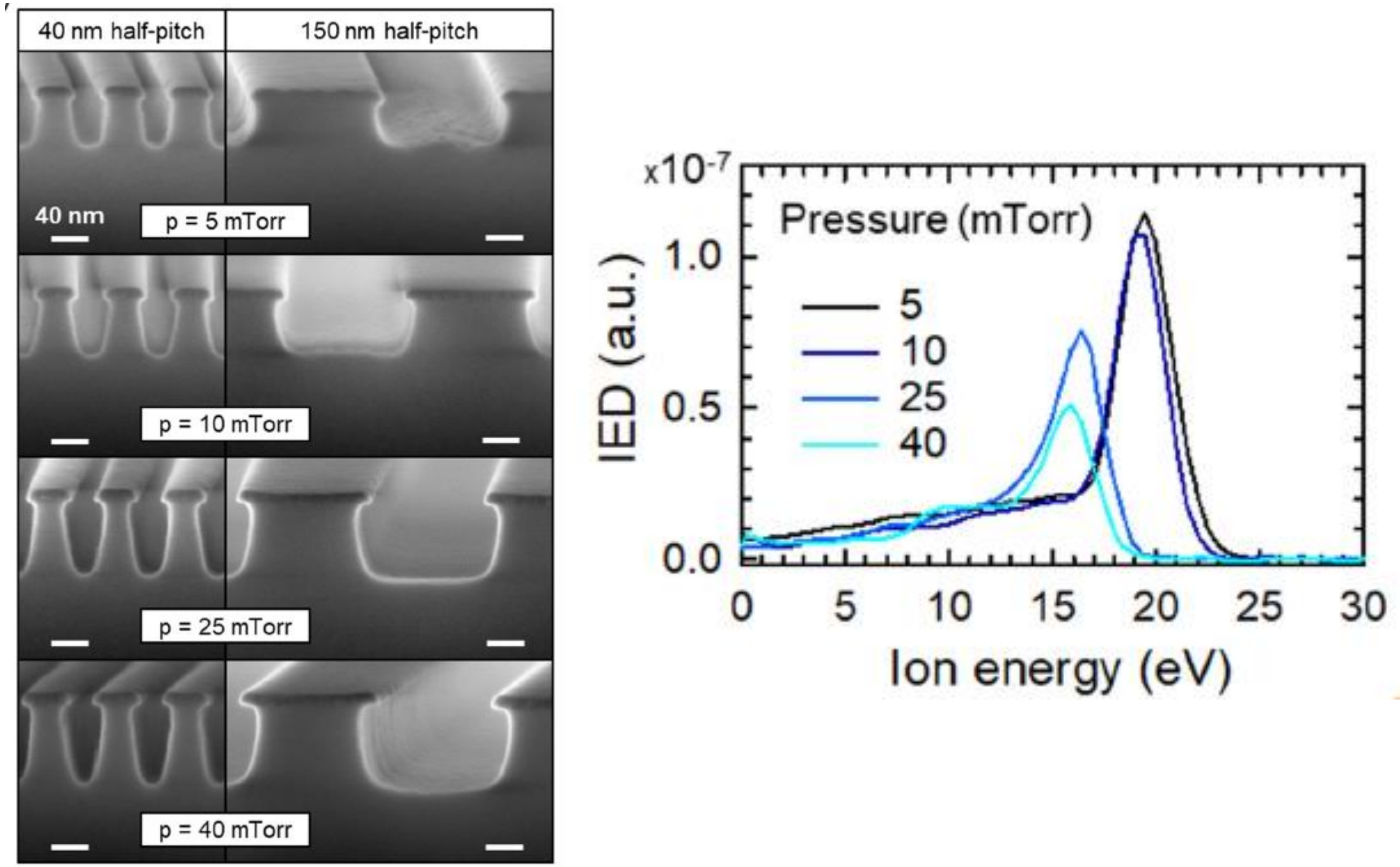
Effect of the pressure and ion energy distribution: Etch profile evolution of nano-patterned silicon oxide

Balancing ion parameters and fluorocarbon chemical reactants for SiO_2 pattern transfer control using fluorocarbon-based atomic layer etching

Stefano Dallorto et al, Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, California
Department of Micro- and Nanoelectronic Systems, Ilmenau University of Technology, Ilmenau, Germany
Oxford Instruments Plasma Technology, Bristol, UK

DOI: https://doi.org/10.1116/1.5120414

This work presents a study of the evolution of etch profiles of nano-patterned silicon oxide using a chromium hard mask and a CHF_3/Ar atomic layer etching in a conventional inductively coupled plasma tool.



Cross-sectional SEM images of silicon oxide features patterned using FC-Ar ALE reported for four different pressure values, along with the IED for −9 V DC bias, 300W ICP power, and 100 sccm Ar flow.

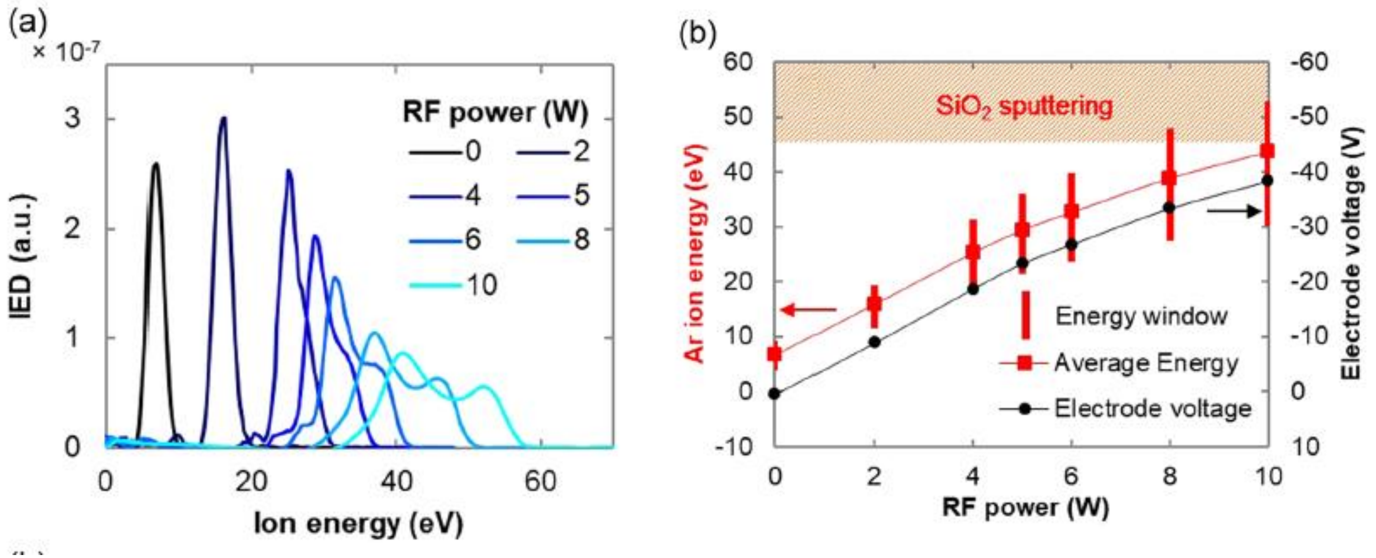
Atomic Layer Etching (ALE) in a conventional inductively coupled plasma tool

Atomic layer etching of SiO_2 with Ar and CHF_3 plasmas: A self-limiting process for aspect ratio independent etching

Stefano Dallorto et al, Department of Micro and Nanoelectronic Systems, Ilmenau University of Technology, Ilmenau, Thuringia, Germany
Oxford Instruments Plasma Technology, Bristol, United Kingdom
Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, California

DOI: https://doi.org/10.1002/ppap.201900051

This work demonstrated that by using Ar plasma, periodic injections of CHF_3, and Ar ion bombardment in a conventional plasma tool, atomic layer etching (ALE) of SiO_2 is possible. Low energy ion bombardment is crucial for minimising the physical sputtering of SiO_2. This has been studied using an RFEA, and we demonstrated that the Ar ion energies are within the ALE window.



(a) Measured IED at 10 mTorr chamber pressure, 300W ICP power, and 100 sccm Ar flow.
(b) Measured electrode voltage (DC bias) and the average energy of the measured IED function as a function of the discharge power.

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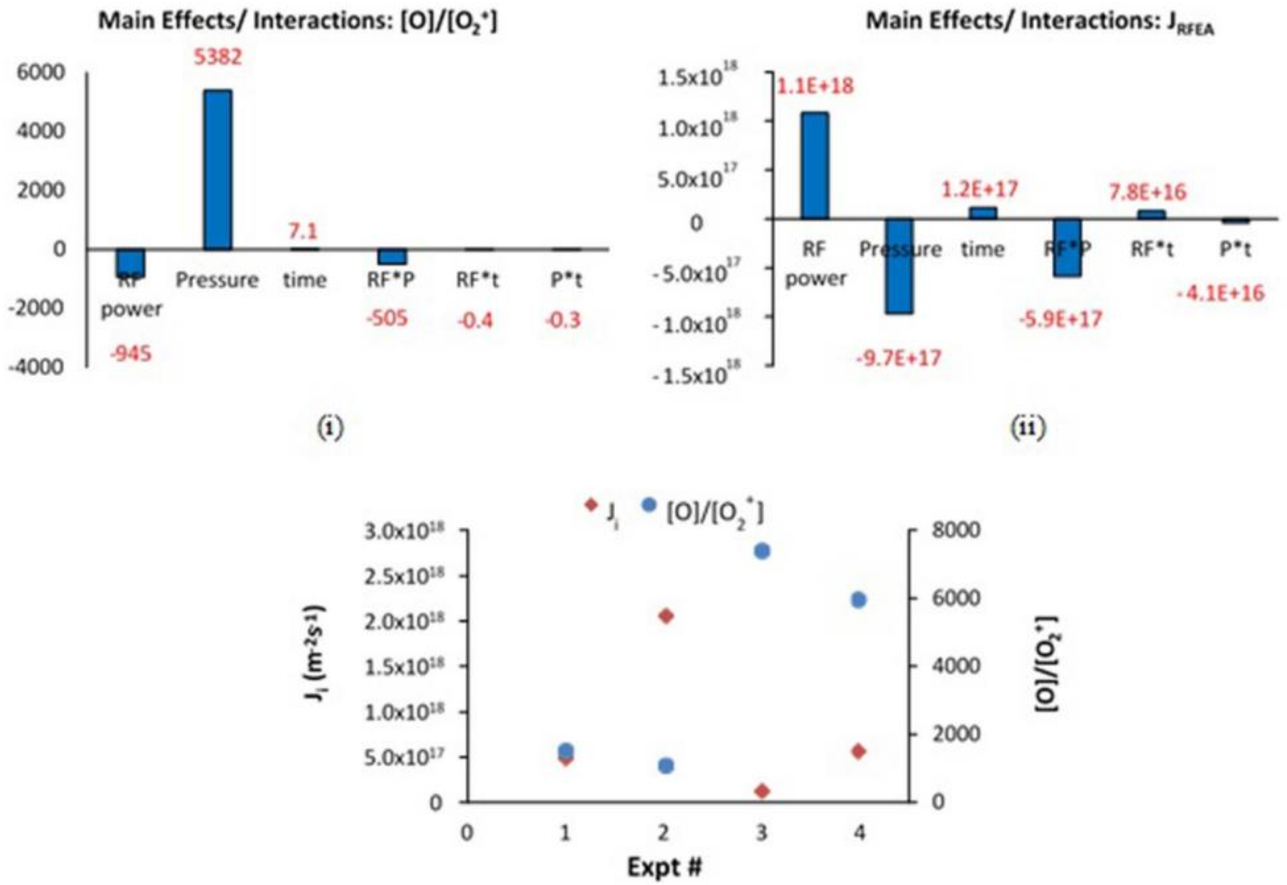
An asymmetric capacitive RIE system to treat metal samples

Use of plasma oxidation for conversion of metal salt infiltrated thin polymer films to metal oxide

J Conway et al, National Centre for Plasma Science and Technology, Dublin City University, Dublin, Ireland
School of Physical Sciences, Dublin City University, Glasnevin, Dublin, Ireland
AMBER Research Centre and School of Chemistry, Trinity College Dublin, Dublin, Ireland

DOI: https://doi.org/10.1088/1361-6463/ac8e12

Oxygen plasma treatments for conversion of metal salt infiltrated polymer films to metal oxide films using an asymmetrical capacitively coupled plasma system were investigated. The impact of radio frequency (RF) power, gas pressure and process time on plasma composition and the resulting metal oxide films were studied.



Main effects and 2-factor interactions for (i) $[O]/[O_2^+]$ (ii) ion flux JRFEA: gas pressure and RF power have the largest effect. RF and pressure also exhibit the strongest 2-factor interaction. (iii) Plots of $[O]/[O_2^+]$ and ion flux J_i for the experimental plasma conditions.

ICP (300 mm SEMES RIE)

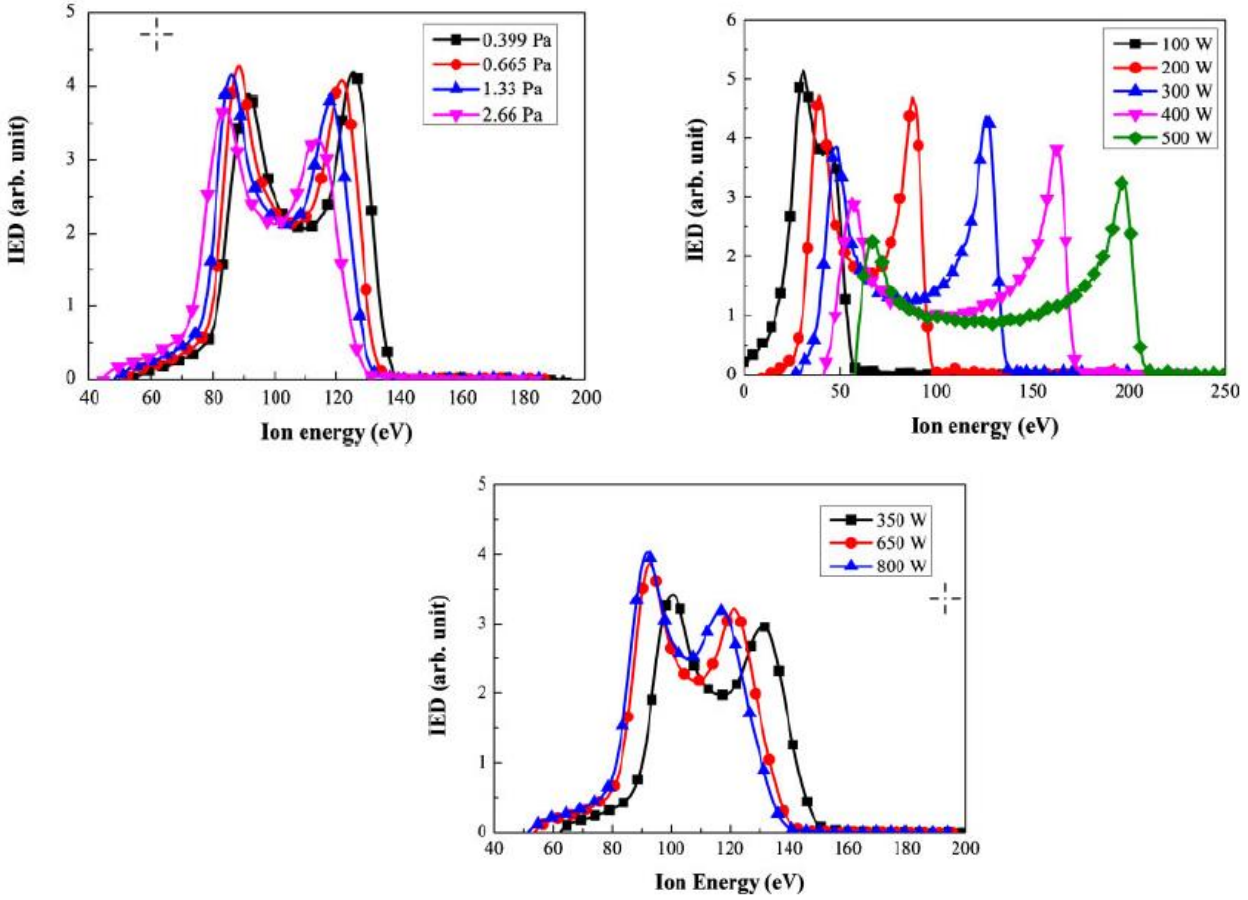
The etching parameter dependence of the reactive ion etch (RIE) lag of nanometer silicon trenches using HBr/O_2 plasma

Characteristics of reactive ion etching lag in HBr/O_2 plasma etching of silicon trench for nanoscale device

Wanjae Park et al, Plasma Laboratory, Department of Electrical Engineering and Computer Science, Seoul National University, Seoul, Korea

DOI: http://dx.doi.org/10.7567/JJAP.53.036502

This work investigates the effects of variations in etch parameters, such as O_2 gas flow rate, substrate temperature, pressure, bias power, and source power, on the RIE lag of nanometer silicon trenches using HBr/O_2 plasma in an ICP etcher.



Example of Ion Energy Distribution (IED) as a function of gas pressure, Bias power and source power.

RIE CCP (Nanomaster NRE 3500)

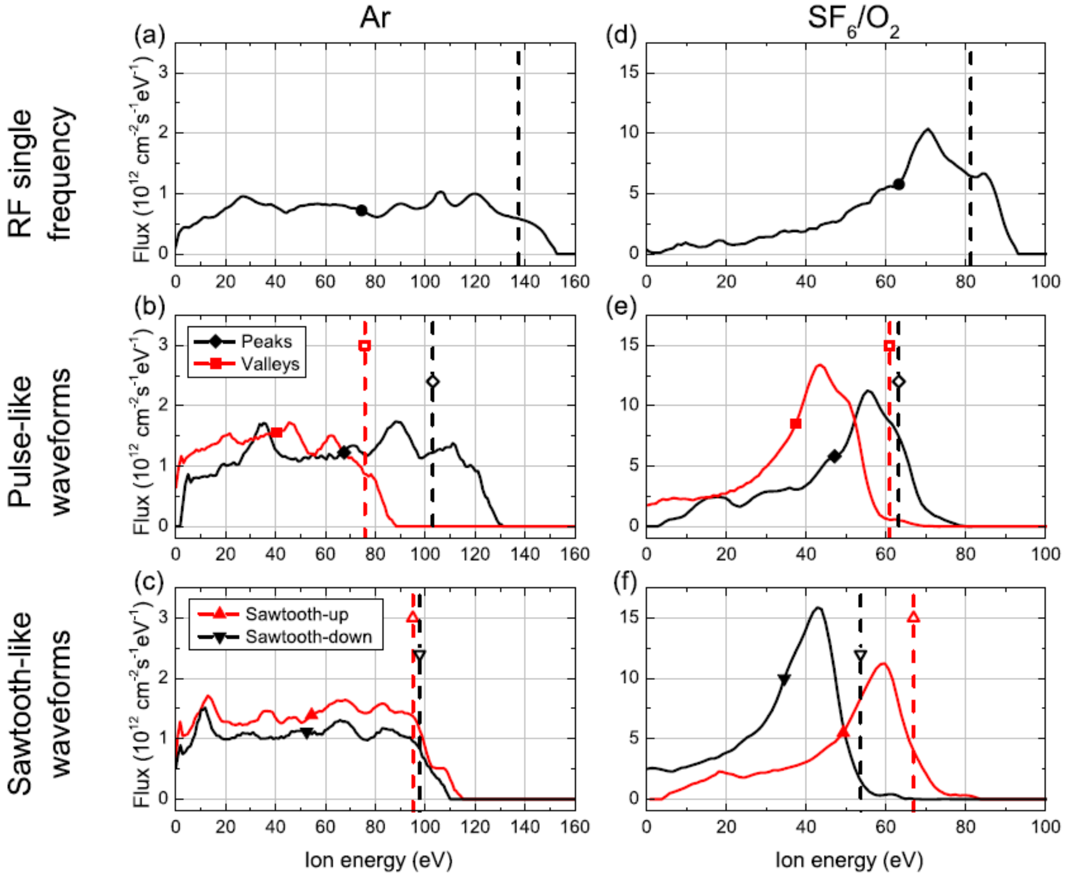
Control of surface ion bombardment energy using Tailored Voltage Waveforms

Excitation of Ar, O_2, and SF_6/O_2 plasma discharges using tailored voltage waveforms: control of surface ion bombardment energy and determination of the dominant electron excitation mode

G Fischer et al, Institut Photovoltaïque d'Ile-de-France (IPVF), Palaiseau, France
LPICM, CNRS, Ecole Polytechnique, Université Paris-Saclay, Palaiseau, France
Total SA Renewables, 24 cours Michelet, La Défense 10, Paris la Défense Cedex, France

DOI: https://doi.org/10.1088/1361-6595/aaca05

The objective of this work was to explore the use of tailored voltage waveforms as a technique to control the ion bombardment energy at a surface for various plasma compositions, namely Ar, O_2, and mixtures of SF_6+O_2. The effectiveness of this technique in controlling the ion energy has been directly demonstrated through the measurement of ion energy distribution functions (IEDFs).



Examples of RFEA measurements in Ar and SF_6/O_2 plasma for single frequency RF excitation (a), (d), peak-like waveforms (b), (e) and saw tooth-like waveforms

Ion Beam
(Bühler Leybold Optics Boxer Pro)

Distribution of the ion current density on stationary and rotating spherical cap substrate holders

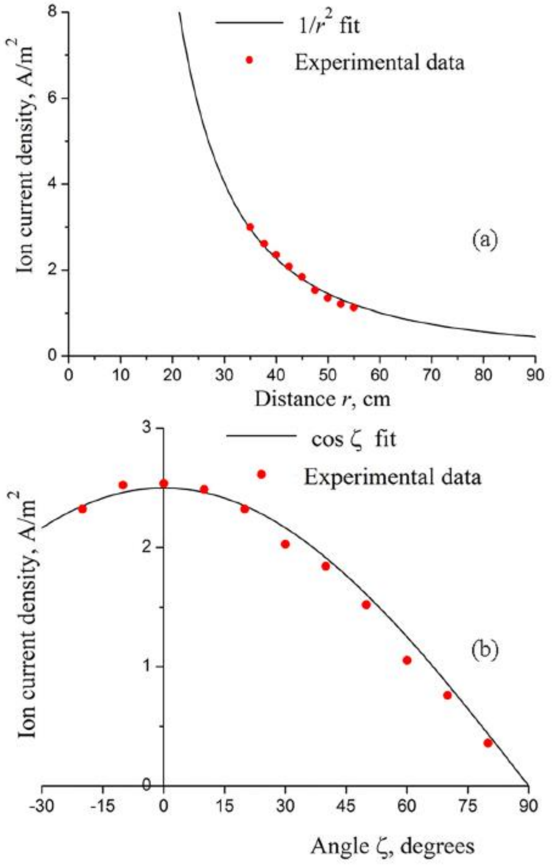
Distribution of ion current density on a rotating spherical cap substrate during ion-assisted Deposition

Viktor Marushka et al, Engineering Physics Department, Polytechnique Montréal, Montreal, Canada

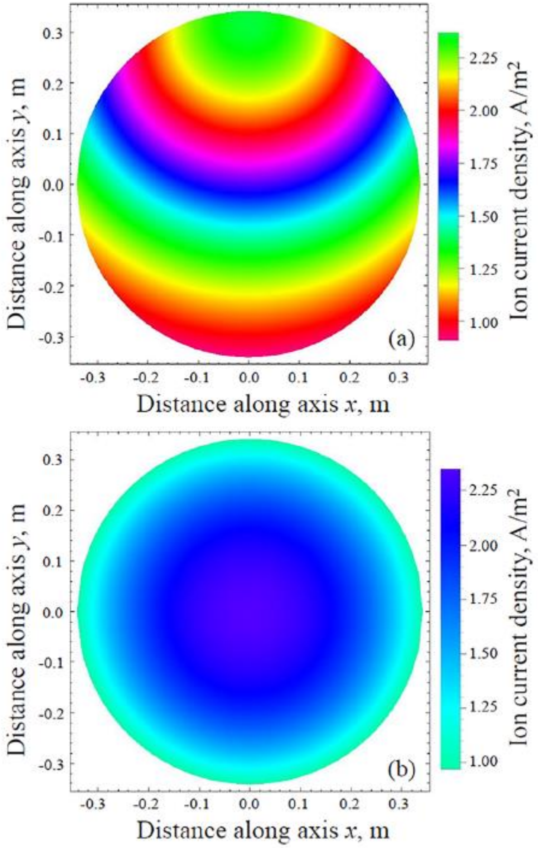
DOI: https://doi.org/10.1116/1.4900541

This work presents detailed calculations of the distribution of the ion current density on stationary and rotating spherical cap substrate holders, for different positions and inclinations of the ion source.

Some example data is shown to the right



Ion beam characterization using RFEA (I_d = 3A, V_d = 208V, and O_2 flow = 16 sccm)



Projection of the distribution of the ion current density on xy plane for a discharge current of 3A on a (a) stationary and (b) rotating substrates

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