Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.
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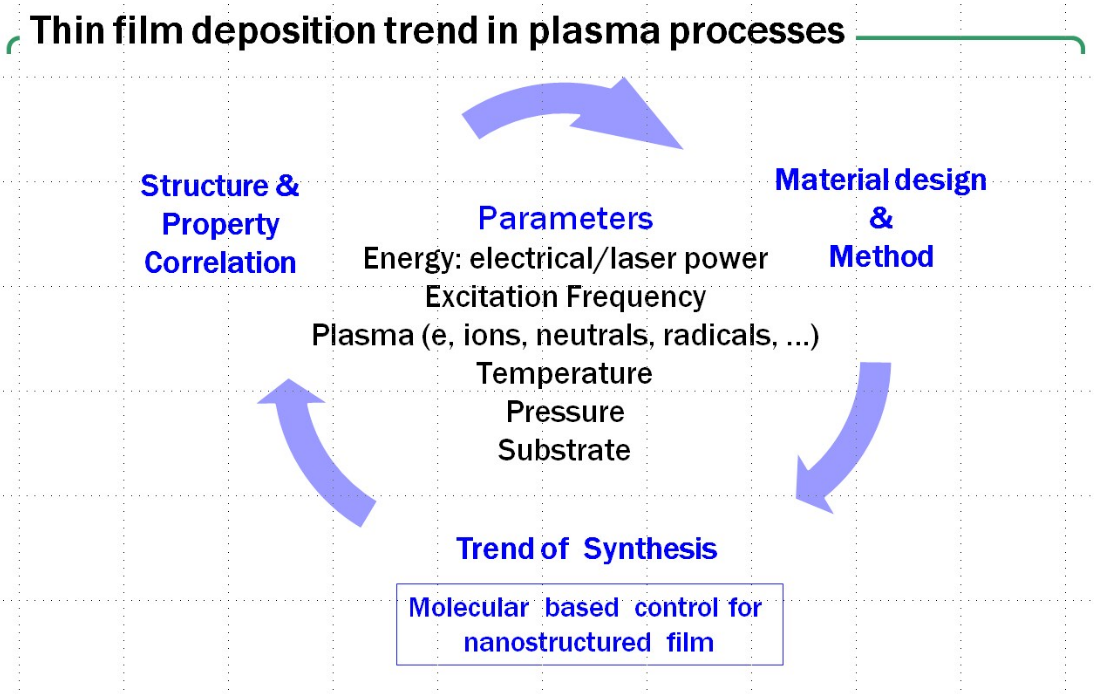
## Supplementary information

## Importance of RF/UHF dual frequency PECVD

Our earlier experience shows that RF/UHF dual frequency sources can produce significantly high plasma density even at low power. If we apply equal power by RF and UHF sources the plasma density is much smaller than that of their combined effect. Plasma density is also radially uniform, which favors the deposition of uniform film thickness up to larger area.



### Thin film deposition trend in plasma processes

**Material design & Method**

**Parameters**
Energy: electrical/laser power
Excitation Frequency
Plasma (e, ions, neutrals, radicals, ...)
Temperature
Pressure
Substrate

**Trend of Synthesis**

Molecular based control for nanostructured film

**Structure & Property Correlation**

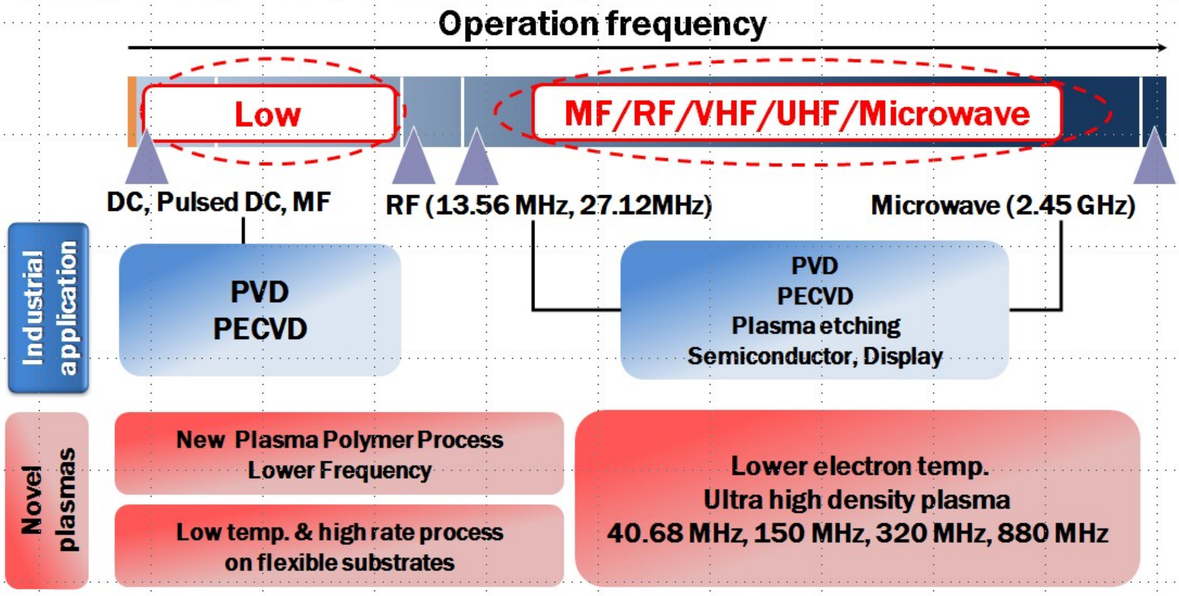
### How to control and make plasma based thin films?

**Design of Advanced Plasma Source and plasma process**

- **Control of electron temperature and plasma density**
  - -. **Advanced type of plasma sources (RF/UHF hybrid source)**
- **Control of plasma chemistry**
  - -. **Monitoring and controlling of plasma parameters and radicals**
- **Correlation of film formation mechanism in terms of plasma chemistry**
  - -. **Modeling and integrated plasma diagnostics**
  - -. **Film properties (depo. rate, microstructure, optical, electrical, etc.)**

**Nanostructured thin film growth and control**

## Exploring new plasmas and processes



**PVD**
**PECVD**

**PVD**
**PECVD**
**Plasma etching**
**Semiconductor, Display**

**New Plasma Polymer Process**
**Lower Frequency**

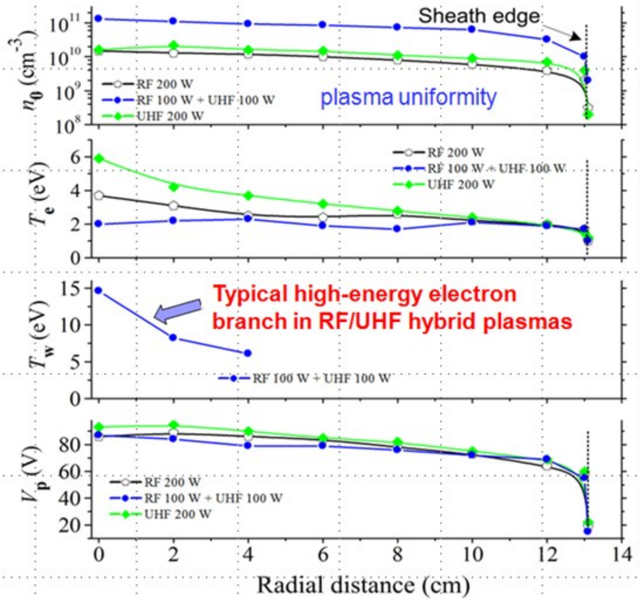
**Low temp. & high rate process**
**on flexible substrates**

**Lower electron temp.**
**Ultra high density plasma**
**40.68 MHz, 150 MHz, 320 MHz, 880 MHz**

One can lower reaction activation energy by increasing the plasma excitation frequency from radio frequency (RF) to very high frequency (VHF) and in the range of ultra high frequency (UHF) to microwave. J. Appl. Phys. 116, 134903 (2014).

## Importance and suitability of RF/UHF hybrid plasma

Plasma ionization features (Equal power)



$n_o$: Plasma density
$T_e$: Electron temperature
$T_w$: High energy electron
$V_p$: Plasma potential

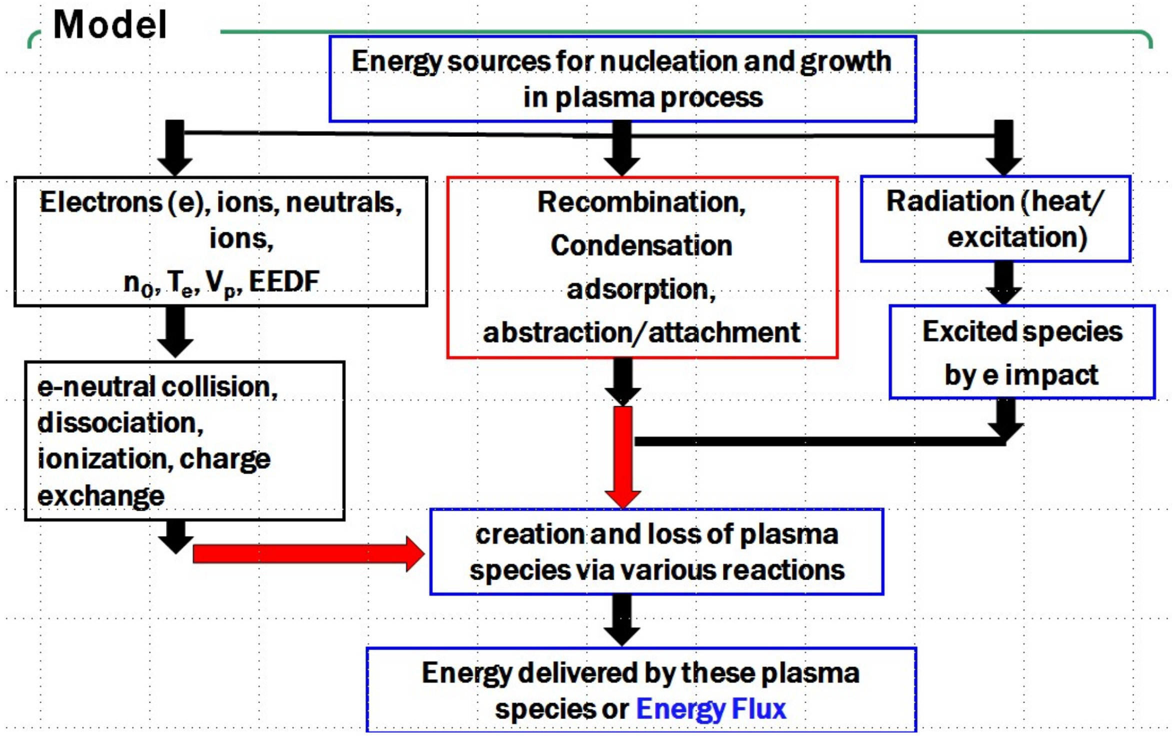
Significantly higher (at least one order) ionization efficiency using RF/UHF hybrid plasmas

$n_o$ (RF) < $n_o$ (UHF) << $n_o$ (RF/UHF)

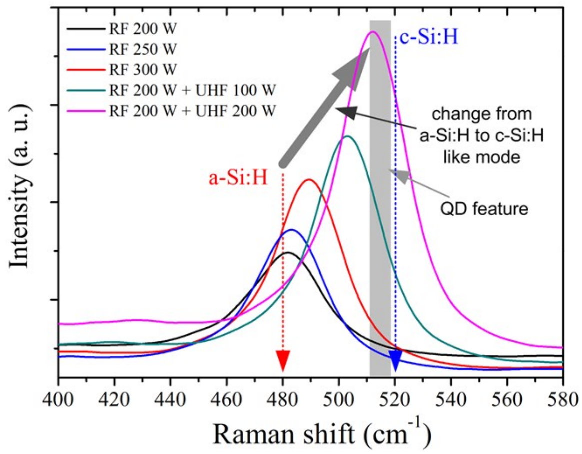
Plasma is quite uniform (up to ~ 6-8 cm) radially in hybrid plasma

Hybrid plasma have found to produce a very high $n_o$ at low $T_e$ and high energy tail in EEDF

Better plasma uniformity can provide better film uniformity



**Process optimization: RF and UHF equal power has given the best QD feature.**



Raman spectra of the deposited films prepared at various operating powers. The figure also depicts the change in the film microstructure represented by the change in the peak positions at various applied powers.