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

Supplementary information

Barrier properties: general consideration

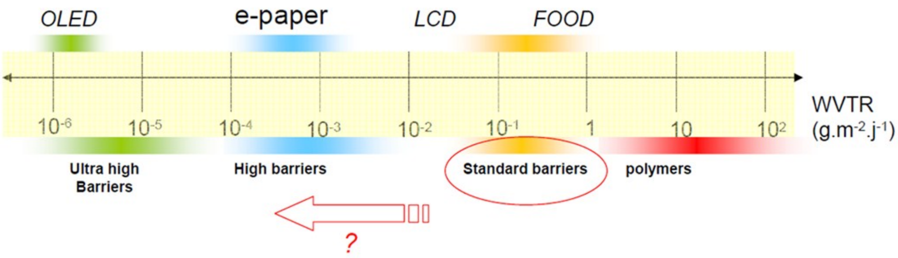
> O_2/H_2O ingress : device degradation, poor lifetime

> *Need for encapsulation with gas barrier materials*

> New flexible devices (organic electronic, inorganic/organic PV)

> *Need for gas barrier films*

> Common gas barrier films (polymer) have limited properties



How improve gas barrier properties of polymer

Factors that may affect the film properties

1. Film density should be high. For this we need high deposition rate
2. Higher N bonding in the film → Higher N_2 dissociation → High density plasma
3. Reduction/ stress control
   (possible due to higher energy ion bombardment)
4. Simple fabrication using single layer

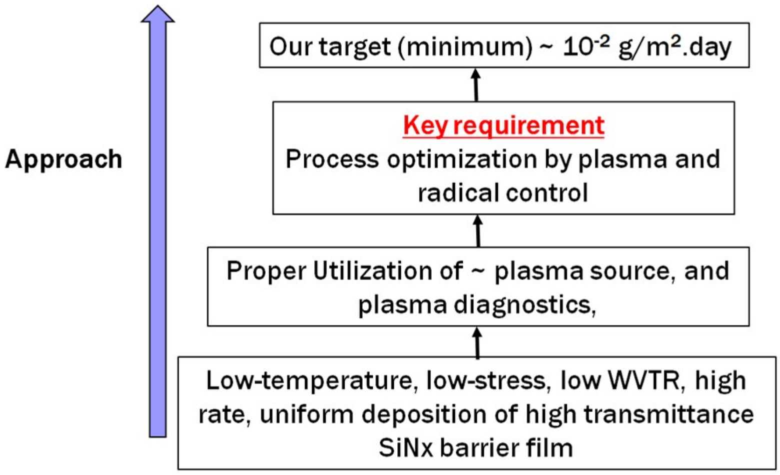
How to design and control plasma and films ?

Design of Advanced Plasma Processes and Films

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

Thin film growth and control

Strategy and plan for accomplishment



Low pressure consideration

- Small mean free path of electrons (due to frequent collisions at high pressure) requires to apply **strong electric fields** (high voltage).
- Consequently given size of electron avalanche is developing in substantially smaller volume comparing to low pressure.
- As the result plasma at high pressure occurs in **narrow discharge channels**.
- Low pressure operation will be conducive for the efficient discharge.
- Low pressure operation will reduce the concern of particle/dust generation.
- Low pressure operation will favor cost effective deposition with utilization of low-content (low gas flow rate) of chemical precursor.

Consideration of ionization mean free path

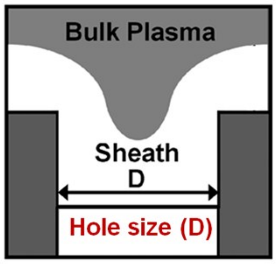
The ion flow in the cylindrical region of the orifice is diffusion limited because of the short collision mean free path for charge exchange with the neutrals.

Neutral density = n_n

The mean ion mean free path for ionization =

$\lambda_i = 1/(n_0\ \sigma_i)$

S. C. Brown, *Basic Data of Plasma Physics 2nd edn* (Cambridge, MA: MIT Press) (1967)



Cross section for ion	p = 60 mTorr		p = 120 Torr	
	n_n (cm^{-3})	λ_i (mm)	n_n	λ_i (mm)
$\sigma_i \approx 10^{-14}\ cm^2$	2×10^9	0.505	3×10^9	0.303

Requirement: Hole size $\geq \lambda_i$

Showerhead design for multi-holes hollow cathode discharge