**iCVD Process** – a new vapor-phase deposited polymer films

**Characteristics of iCVD Polymer films**
- Vaporized monomers are polymerized in the iCVD system
- *In-situ* polymerization
- Tunable polymer coatings with **high purity**
- **Co-polymerization/crosslinking** are freely applicable to polymer coatings
- **Room Temperature** Process
- **More than 60 polymers** have been successfully deposited using iCVD process

**Advantages of iCVD Polymer films**
- Highly conformal
- No damage to the substrate!
- Pin-hole free & flexible
- Patternable & Functionalizable
Mechanism of iCVD Process

**Gas Phase Reactions**

1. **Initiator Decomposition**
   \[ I(g) \xrightarrow{k_i} R \cdot (g) \] (1)

**Surface Reactions**

1. **Initiation**
   \[ R \cdot (ad) + M(ad) \xrightarrow{k_i} M_1 \cdot (ad) \] (4)

2. **Propagation**
   \[ M_n \cdot (ad) + M(ad) \xrightarrow{k_p} M_{n+1} \cdot (ad) \] (5)

3. **Termination**
   \[ M_n \cdot (ad) + M_m \cdot (ad) \xrightarrow{k_t} M_{n+m} (ad) \text{ and } M_n (ad) + M_m (ad) \] (6)

4. **Primary Radical Termination**
   \[ M_n \cdot (ad) + R \cdot (ad) \xrightarrow{k'_t} M_n (ad) \] (7)

5. **Primary Radical Recombination**
   \[ R \cdot (ad) + R \cdot (ad) \xrightarrow{k''_t} R_2 (ad) \] (8)

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**Diagram Description**

1. **Initiator Decomposition**
   - **Heated Filaments**
   - **Initiator Decomposition**
   - **Primary Radical and Monomer Adsorption**
   - **Surface Polymerization**

Conformality

Baxamusa, S. H.; Gleason, K. K., Thin Polymer Films with High Step Coverage in Microtrenches by Initiated CVD. *Chemical Vapor Deposition* 2008, 14, (9-10), 313-318.
PTFE coated Carbon Nanotubes

CVD polymer coating

40 nm PTFE coating

High aspect-ratio cylindrical nanostructure (75 nm diam.)

Scale = 2 µm

Scale = 166 nm

~ 1000 x thinner than coating on a nonstick pan!

Penetration into Porous Substrates

1H,1H,2H,2H-perfluorodecyl acrylate polymer

iCVD coating on non-porous substrate

(control)

iCVD coating on FOE membrane copolymer

Penetration into pores with a 120:1 aspect ratio & coating on the backside

iCVD conformality on Membranes
Hot Filament, Cool Substrate

Gentle enough to coat tissue paper

Uncoated Kleenex

PTFE Coated Kleenex
Multiple vinyls for controlled crosslinking

Trivinyl-Trimethyl-Cyclotrisiloxane ($V_3D_3$)
- Multiple reactive moieties
- Flexible Ring

50μm gold neural probe lead wire coated with
~2μm of $V_3D_3$ iCVD polymer

Crosslinked, insoluble film
- only possible by iCVD
- near complete vinyl consumption
- siloxane rings retained
- Excellent flexibility
- Resistivity >$10^{15}$ Ω-cm
- Stable for > 25 months under 37°C saline soak and constant bias

W.S. O'Shaughnessy, M.L. Gao ML, K.K. Gleason
Vapor Deposition of Hybrid Organic–Inorganic Dielectric Bragg Mirrors

iCVD polymers are stackable and thickness can be controlled very precisely!

Conformal Coverage on Particle without aggregation
Library of Functional iCVD Polymers

Functionalizable polymers
- Proprargyl methacrylate
- Furfuryl methacrylate
- Glycidyl methacrylate
- Poly(styrene-alt-maleic anhydride)

Anti-bacterial polymers
- Dimethylaminoethyl methacrylate
- Dimethylaminomethylstyrene

Bio-compatible polymers
- 2-Hydroxyethyl methacrylate
- Trivinyltrimethylcyclotrisiloxane

Smart polymers
- N-isopropylacrylamide (NIPAM)
- Allylamine
- Acrylic acid

Dielectric polymers
- Cyclohexyl methacrylate
- Isobornyl acrylate
- Perfluorodecyl acrylate

Hydrophobic polymers
- Vinyl pyrrolidone

Anti-biofouling polymers
- Poly(ethylene glycol) methacrylate

AND MANY MORE…
Poly (3,4-dioxyethylene thiophene) (PEDOT)

Vacuum deposited conducting polymer film

Conjugation – Charge path
Dopants – Charge concentration
The best conductivity
~ 1000 S/cm
CVD PEDOT films

*Courtesy of M. Ma in MIT

Damage free film

Uniform coating

Flexible coating

Conformal coating

Baytron P™ With surface treatment

Baytron P™ W/O surface treatment

CVD coated PEDOT
**Pattern of grafted PEDOT on Flexible substrates**

Questions?

Toilet Paper: Mark Wragg/iStockphoto; Circuit: iStockphoto