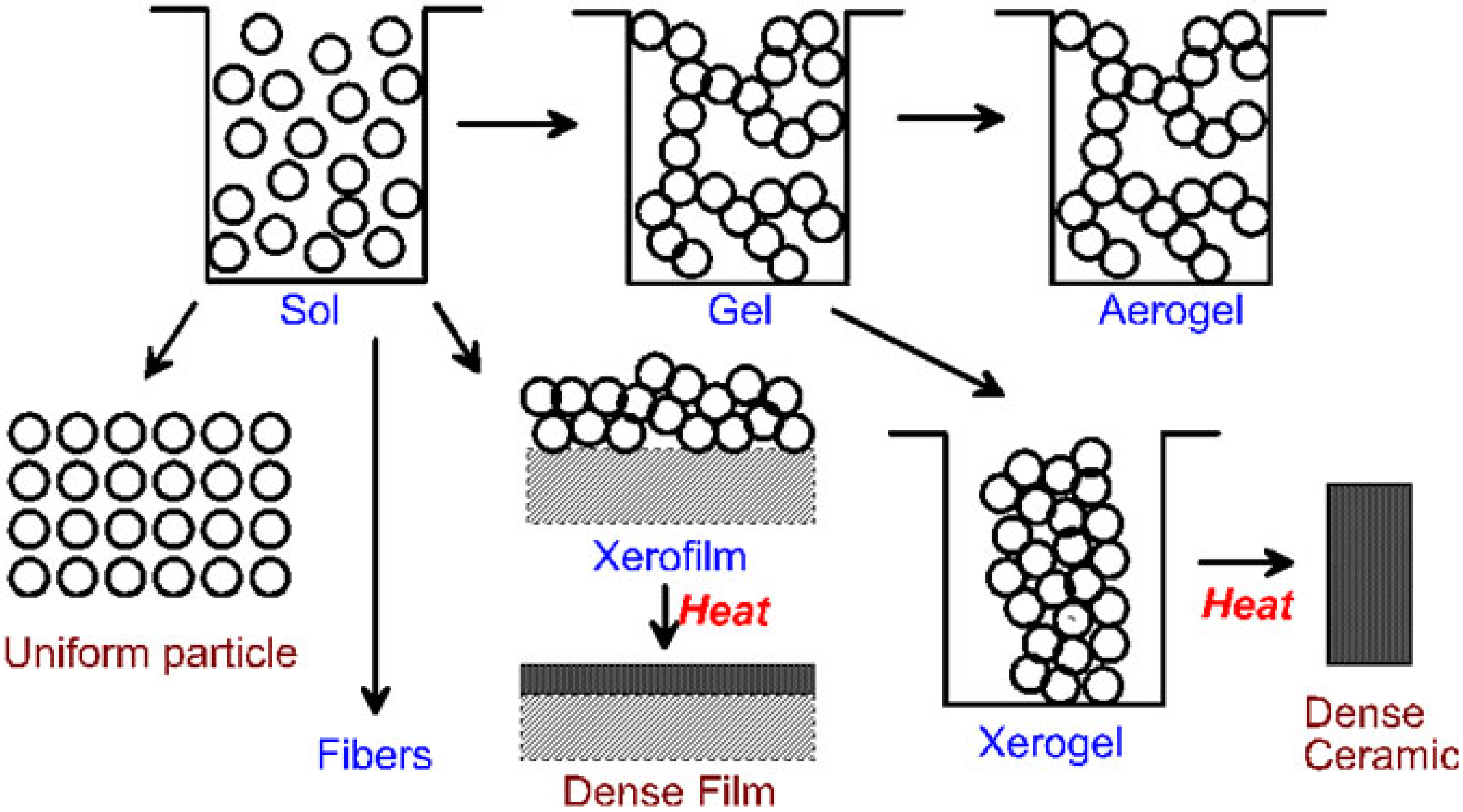
X. Applications of Sol-Gel Method

Overview of the sol-gel process



- Thin Films and Coatings

- Optical coating
  - *Titania films on glass (silica) surface*
- Electronic films
  - *High Tc superconductor films*
  - *Titania films for photoanode*
  - *Yttria/zirconia films for electrolytes*

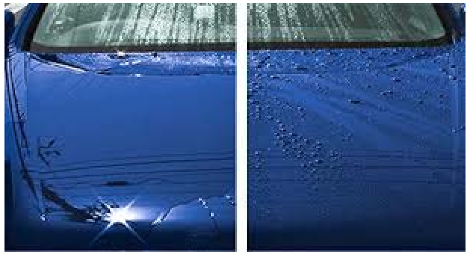
- Protective films

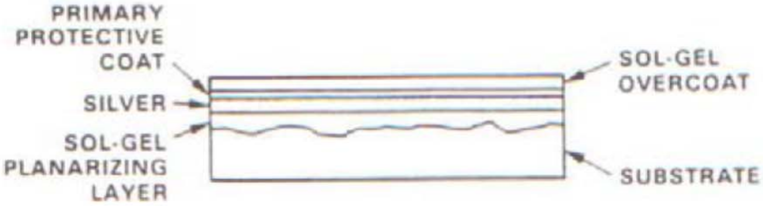
  To improve corrosion and abrasion resistance

  To promote adhesion

  To increase strength

  To provide planarization





- Porous films

  Zeolite crystalline films embedded on silicate sol-gel matrices for surface acoustic wave device

- Monoliths (dimension > 1 mm)

Sol
↓
Shaping
(molding or water/liquid emulsion)
↓
Drying
↓
Calcining
↓
Sintering
↓
Final Product

- Optical glasses and fiber-optic preforms
- Aerogel transparent insulation
- Substrates
- Near netshape optical components
- Adsorbent granules

- Powder and Spheres

Powder and spheres

↙ ↘ directly used

Press in mold

↓

Sintering at high T

↓

Polycrystalline ceramic body

Catalysts

Pigments

Abrasives

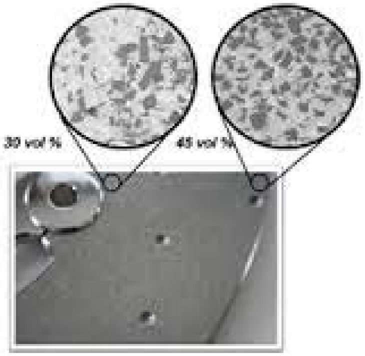
Fillers

- Fibers

- Not appropriate for optical fiber applications (noncircular cross-section)
- But potential applications as
    - *Reinforcement fibers*
    - *High Tc superconductor fibers*
    - *Refractory textile*

- Composites

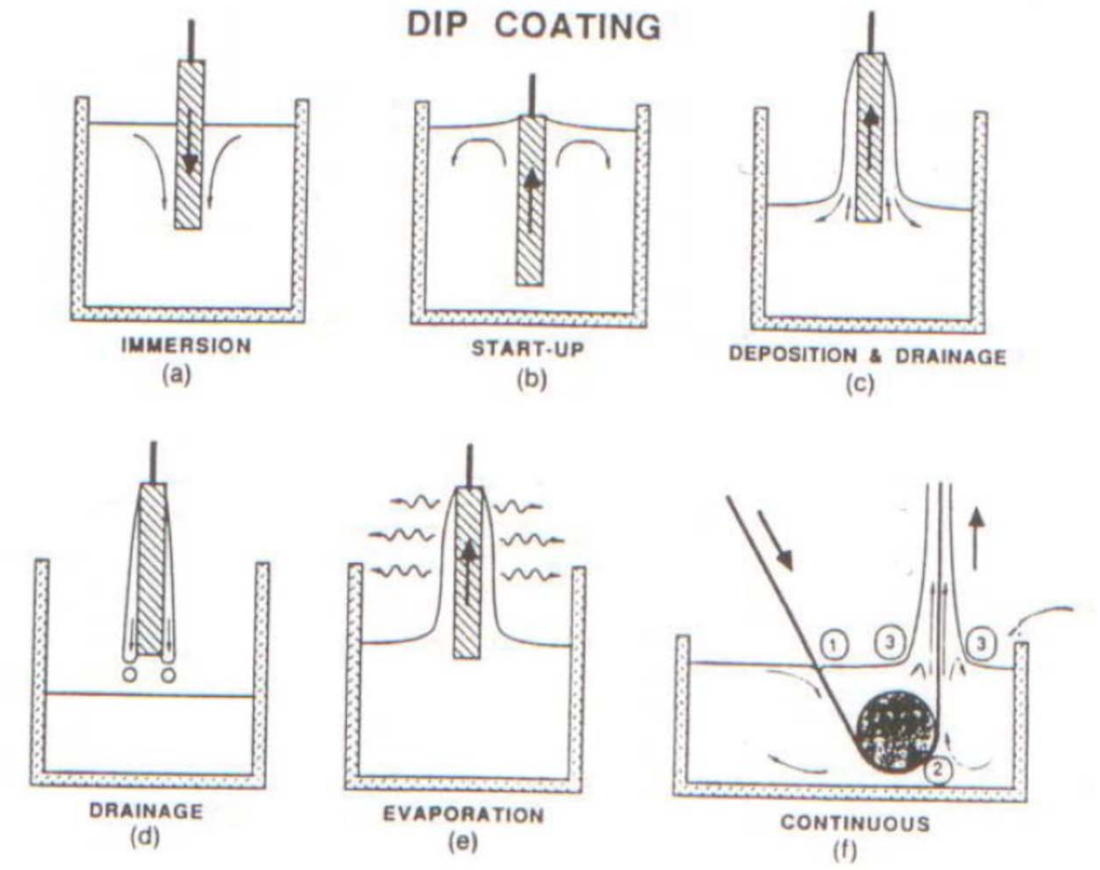
- Fiber-reinforced sol-gel matrix
- Ceramic-ceramic or ceramic-metal composite
- Glass or ceramic-organic



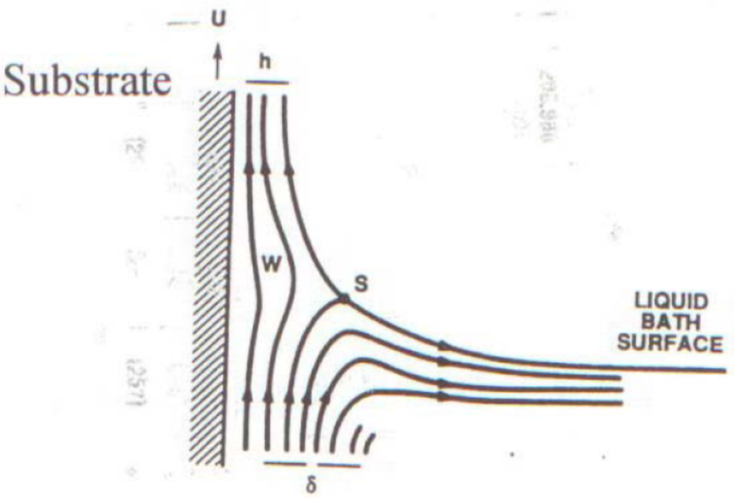
e.g. SiC reinforced alumina (for turbine blades)

FILM-FORMATION BY SOL-GEL METHOD

- Dip-Coating: Film coating (on dense substrate)



Detail of liquid flow pattern at point (c)



U: withdraw speed

s: stagnation point

δ: boundary layer

h: thickness of fluid film

Six forces involved in this dip-coating process

(1) Viscous drag upward on the liquid by the moving substrate

(2) Gravity

(3) Surface tension in the concavely curved meniscus

(4) Inertial force of the boundary layer liquid in the deposition region

(5) Surface tension gradient

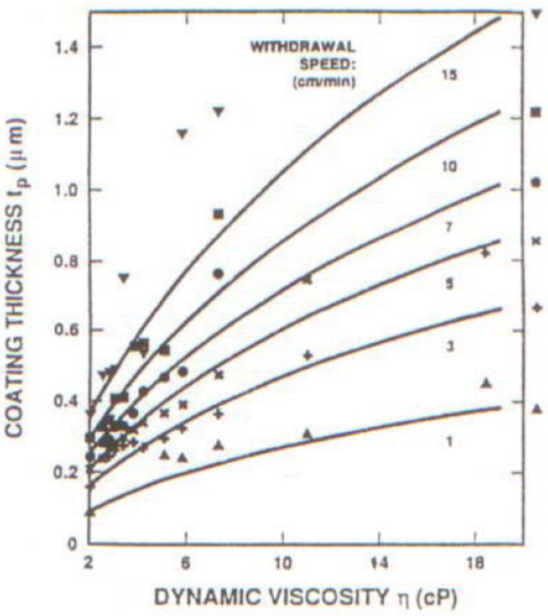
(6) Disjoining or conjoining pressure

If only forces 1 and 2 are important, force balance gives:

$$\underset{\substack{\uparrow \\ \text{force (1)}}}{\mu U/h} = \underset{\substack{\uparrow \\ \text{force (2)}}}{c(\rho g h)} \quad \text{(c: proportionality constant)}$$

so

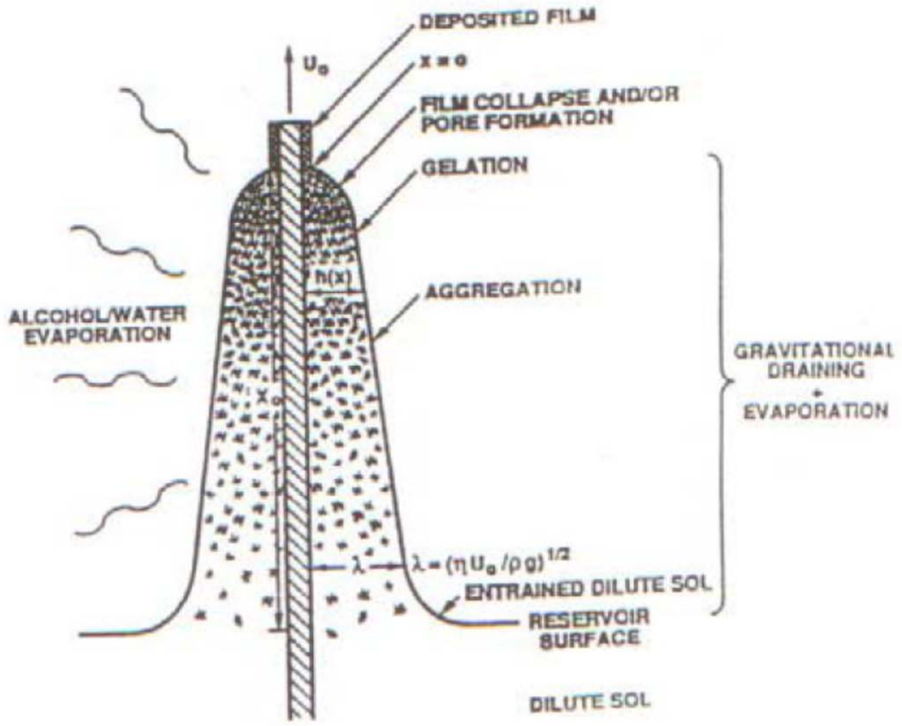
$$h = c'\,(\mu U/\rho g)^{1/2}$$



$$h \propto \mu^{1/2}$$

$$h \propto U^{1/2}$$

- Structural Evolution During Dip-Coating Process

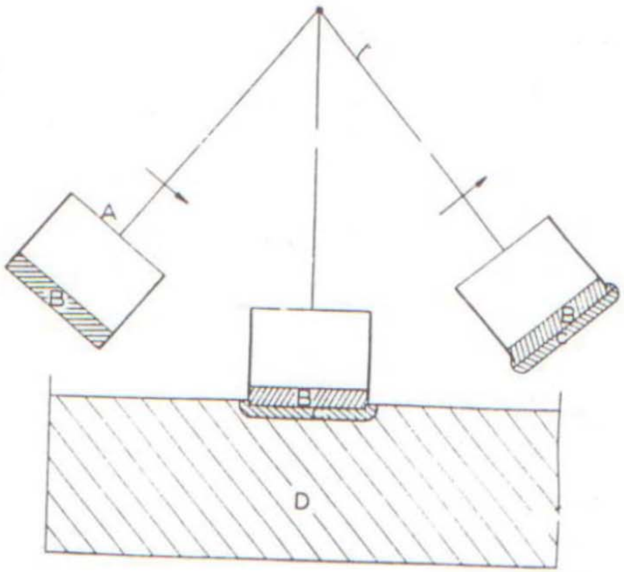


Evaporation rate

$q = k\,(P_s - P_i)$

- Dip-Coating: Slipcasting Process (on Porous Substrate)

The dip-coating process for ceramic membrane fabrication, with porous substrate.



(Rate of Accumulation of Solid in the Gel Layer) =

(Solvent Flow Rate) × (Concentration of Solid in the Sol)

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(Solvent Flow Rate) × (Concentration of Solid in the Sol)

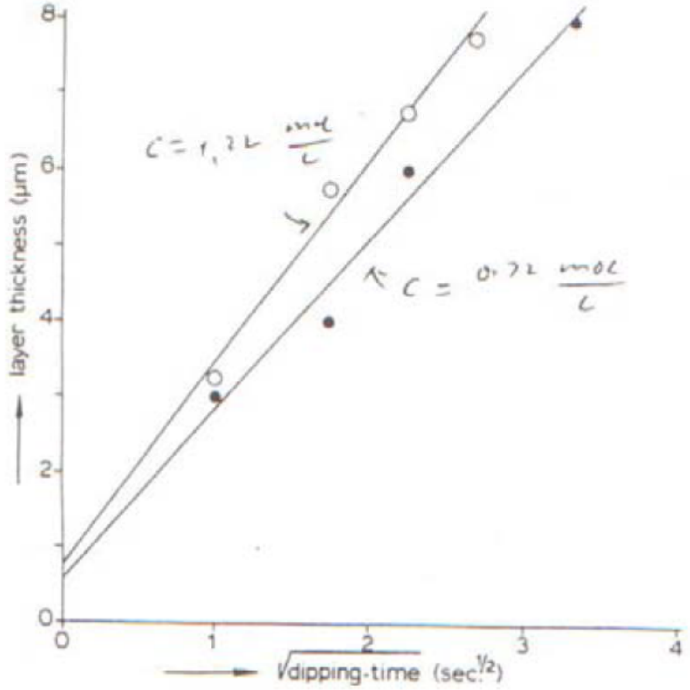
Thus, film thickness h is related to:

$$h \propto \left(\frac{C_s P_g t}{\mu} \right)^{1/2}$$

C_s: solid concentration in the sol

P_g: capillary pressure

t: dip-coating contact time



- Other Coating Method

Spin Coating

Centrifugal force =

Viscous force