Metallurgical and Materials Engineering Department

MME 2509 Materials Processing Laboratory

SOL-GEL DIP COATING

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1. Sol-gel Process

Sol-gel process is used for production of solid materials from small molecules. Oxides of silicon and titanium are the most popular materials for this process. The process involves conversion of monomers into a colloidal solution (sol) that acts as the precursor for an integrated network (or gel) of either discrete particles or network polymers [1].

Materials prepared by sol-gel technology can range from relatively simple inorganic glasses to more complex hybrid composites. By using composite thin films, advantages of both materials can be gained. Because of unique properties of sol-gel process, it has gained particular attention. Molecular scale homogeneity, low cost and easy control parameters are some advantages of sol-gel process. In addition, thin films that made by sol-gel process, shows excellent antiwear and friction reduction performances [1,2].

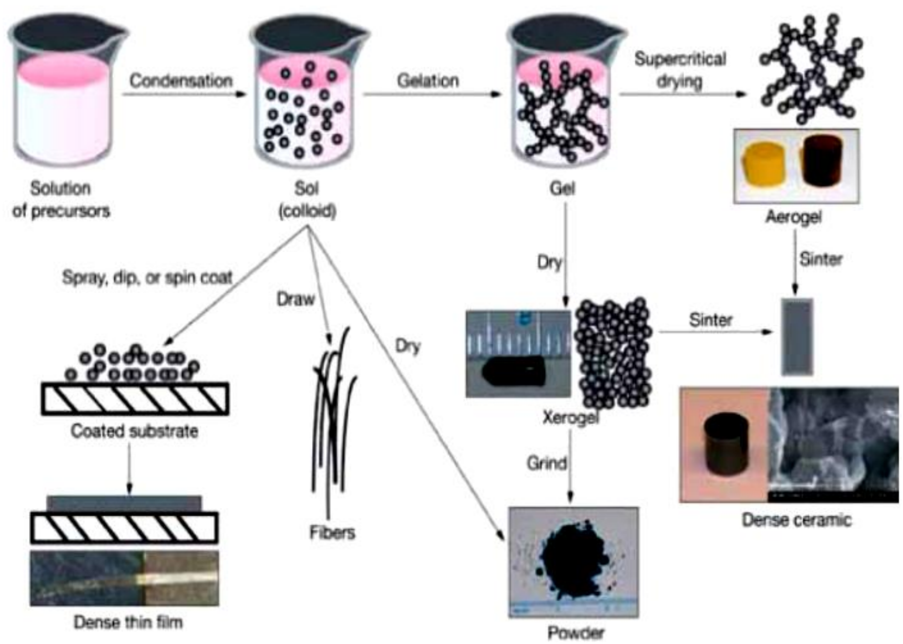

Figure 1: Sol-gel technology scheme

Two of the most common ways used in analytical applications are monolithic gels and thin films. Monolithic gels can be easily prepared by pouring sol into appropriate container. After gelation and drying, the monolithic piece is shaped by the container in which it was poured. Thin films can be prepared by dip coating, spin coating and spray-up techniques [1-3].

The chemical reactions that occur during the formation of the sol, gel, and xerogel strongly influence the composition and properties of the final product. The hydrolysis and condensation process of sol material should be known well. Rate of aging and drying, temperature, added dopants, the type and concentration of co-solvents, the type and concentration of catalyst and pH are known as factors that influence hydrolysis [1-3].

Materials that produced via sol-gel method have found various applications in the area of chemistry, biochemistry, engineering, and materials science. This particular attention comes from easy preparation and modification parameters of sol-gel technology. For example, the silicate glasses can be formed in different forms (thin films, monoliths, powders, fibers) and sizes, different physical and chemical properties (pore size, shape, distribution, surface area, refractive index, polarity). In addition, they can be readily doped with various polymers for any application [1-3].

These are the main usage area of materials that produced by sol-gel method:

- Thin films
- Chemical sensors (pH sensors, sensors for ions and neutral species, sensors for gases and vapors, biosensors)
- Chromatography
- Fabrication of selective materials
- Optical applications (nonlinear optical materials, optical waveguides, solid-state lasers, electroluminescent devices)

1.1. Dip coating

In this method, the substrate is normally withdrawn vertically from a desired coating solution, which causes a complex process involving gravitational draining with concurrent drying and continued condensation reactions. Environmental conditions (temperature, humidity, airflow) are very important parameters as much as pH of the solution and withdrawn speed. They all affect film parameters. The formation of thin films occurs through solvents evaporation (mainly ethanol and water), which concentrates nonvolatile species in the system, then leading to aggregation and gelation. The resulting film depends on these parameters:

- Withdrawal speed
- Size, structure and pH of precursors
- Substrate surface

It is the oldest and the most widely used deposition technique in industry because it is easy to use, high coating quality, flexibility and cost efficiency [1-3].

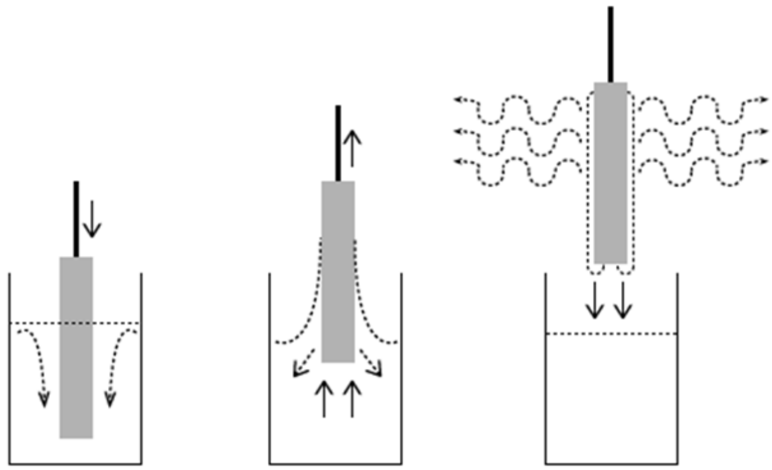

Figure 2: Schematic view of dip coating process

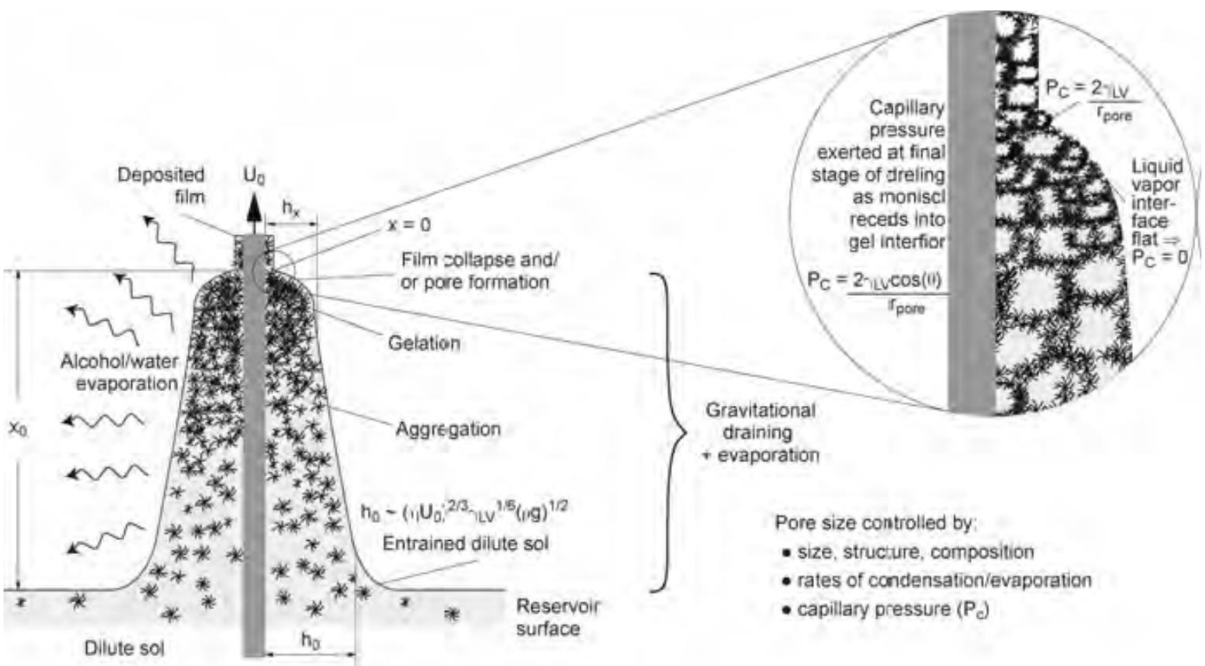

Figure 3: Schematic of the steady-state dip-coating process, showing the sequential stages of structural development

2. Questions

1. Make a proper list of the materials and equipment used during the experiment. (25 points)
2. Which precursor solution is used? How the calculations of the different chemical component amounts are made? (25 points)
3. Briefly explain the experiment with your own words. (25 points)
4. Briefly explain what obstacles you encountered during the experiments. (25 points)

3. References

[1] C.J. Brinker, A.J. Hurd, “Fundamentals of sol-gel dip-coating”, J. Phys. III France 4 (1994) 1231-1242

[2] C.J. Brinker, “Dip coating”, “Chemical Solution Deposition of Functional Oxide Thin Films”, T. Schneller et al. (eds.), DOI 10.1007/978-3-211-99311-8_10, Springer-Verlag Wien 2013

[3] C. McDonagh, F. Sheridan, T. Butler, B.D. MacCraith, “Characterisation of sol-gel-derived silica films”, Journal of Non-Crystalline Solids 194 (1996) 72-77