Sol-Gel Process

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Contents

Reference

C.J. Brinker, G.W. Scherer, “Sol-Gel Science”, Academic Press, Inc., San Diego (1990).

I. Introduction

Colloid Systems:

- one substance is divided into minute particles (colloid particles) and dispersed throughout a second substance
- colloid particles are in the range of 10^{-7} m to 10^{-9} m (0.1μm – 1nm) and can be observed only by electronic scope
- Gravitational forces are negligible and interactions are dominated by short-range force (e.g. van der Waals force and surface charges)

Suspension: dispersed particles are larger than colloid particles (> 0.1μm)

Solution: particles of dissolved substance are of molecular size

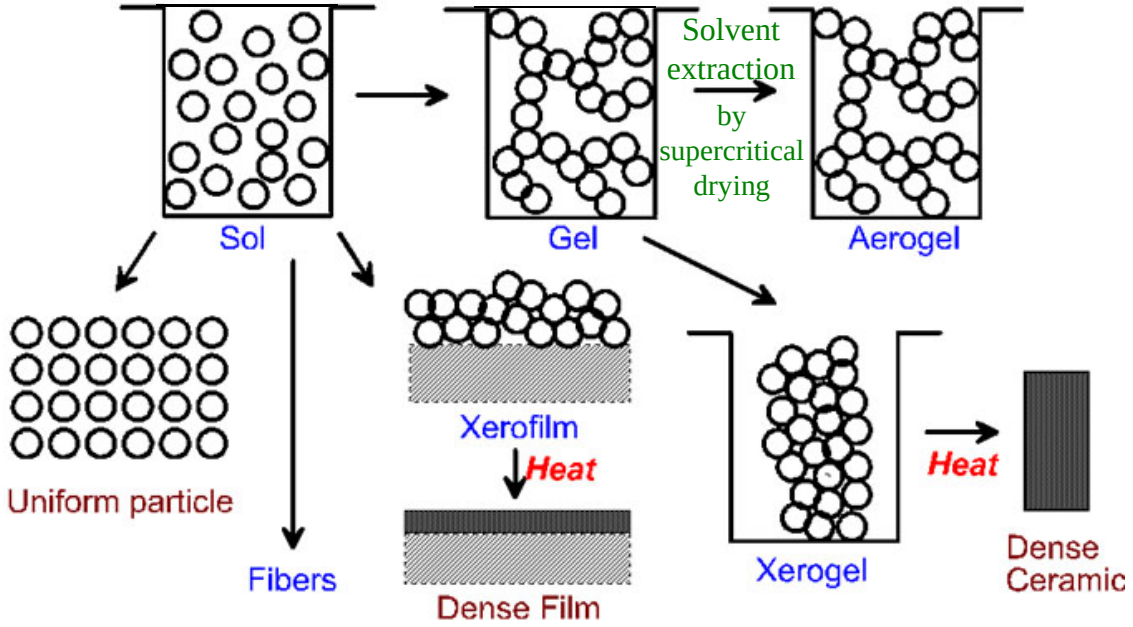
♦ Classification of Colloid systems

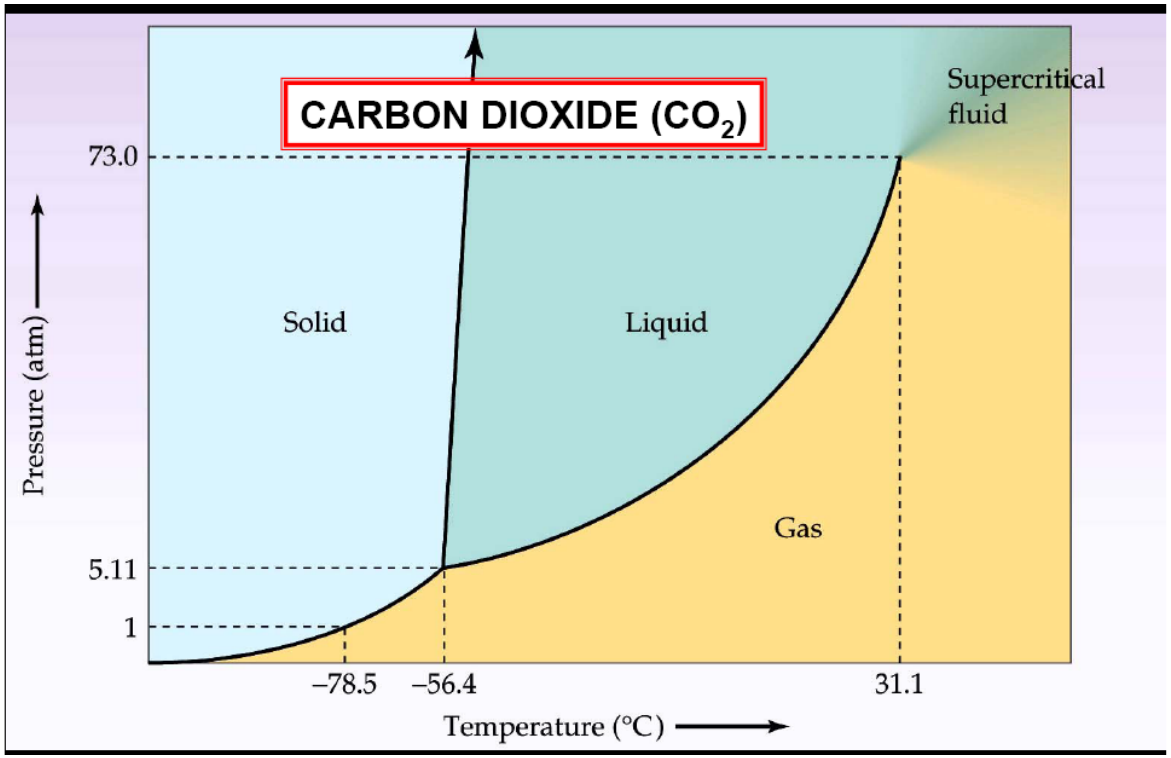
Dispersed substance / Medium of dispersion	GAS	LIQUID	SOLID
GAS		Aerosol (fog)	solid aerosol dust in air, smoke
LIQUID	Foam (shaving lather)	Emulsion (ice cream, oil/water)	Sol
SOLID	Solid foam (alumina foam)	Gel (jelly)	Solid sol (some alloys)

♦ Sol-Gel Process

Sol-gel processing refers to room temperature formation of solid inorganic materials from molecular precursors in liquid solution. Inorganic salt or metal organic compounds are dissolved in aqueous or organic solvents to form polymeric or particulate sols consisting of fine inorganic particles dispersed in the solvent. These sols are then condensed to various types of gels.

Overview of the sol-gel process





Supercritical drying:
a process of removing the liquid from the pores of wet gel above the critical temperature and critical pressure

♦ Basic Concepts

- Precursors: starting compounds in sol-gel process

- inorganic salts (e.g. $AlCl_3$)
- metal organic (-M-O-C-)
  (alkoxide e.g. $Al(OC_4H_9)_3$)
  (c.f.) organometallic (-M-C-)

- Ceramic: all metal oxides, carbides, nitrides (both crystalline & non crystalline), and other inorganic, nonmetallic materials being through a high temperature process

- Particulate sols: dispersed solid phase consisting of dense (nonporous, nonpolymeric) fine particles with a size larger than 1 nm.

- Polymeric (inorganic) sols: dispersed solid phase contains no dense particles (oxide) larger than 1 nm.

Polymer (macromolecule)

↓

consists of

Hundreds or thousands of

↓

Monomer

(capable of forming at least two bonds)

oligomer: molecule of intermediate size,
much larger than "mono",
but much less than "macro"

f: functionality of a monomer

f =1	×
f =2	bifunctional
f =3	trifunctional
f =4	tetrafunctional

• for bifunctional monomer f =2,

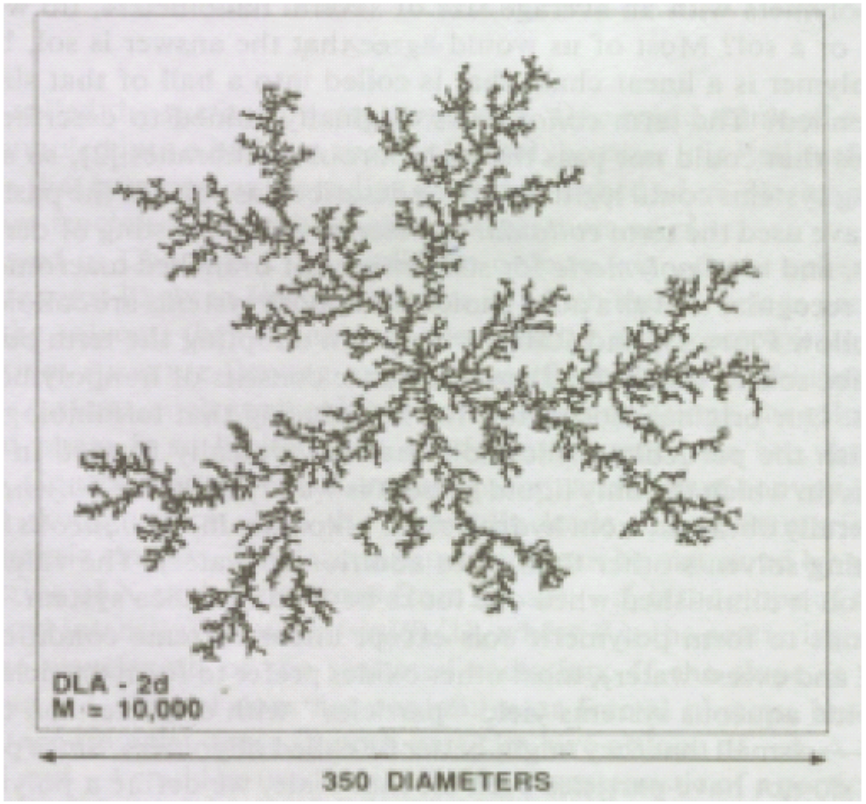
DIMER : HO-M-O-M-OH

CHAIN : HO-(M-O)$_{n-1}$-M-OH

RING : O-(M-O)$_{n-1}$-M

• for polyfunctional with f>2

crosslinks branching

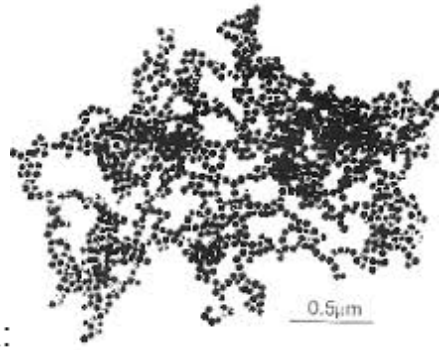


⇒ fractal polymer

** fractal structures:

• monomers (f>2) form bonds in random way

• particulate sol aggregates



* Mass of dense spherical ball:

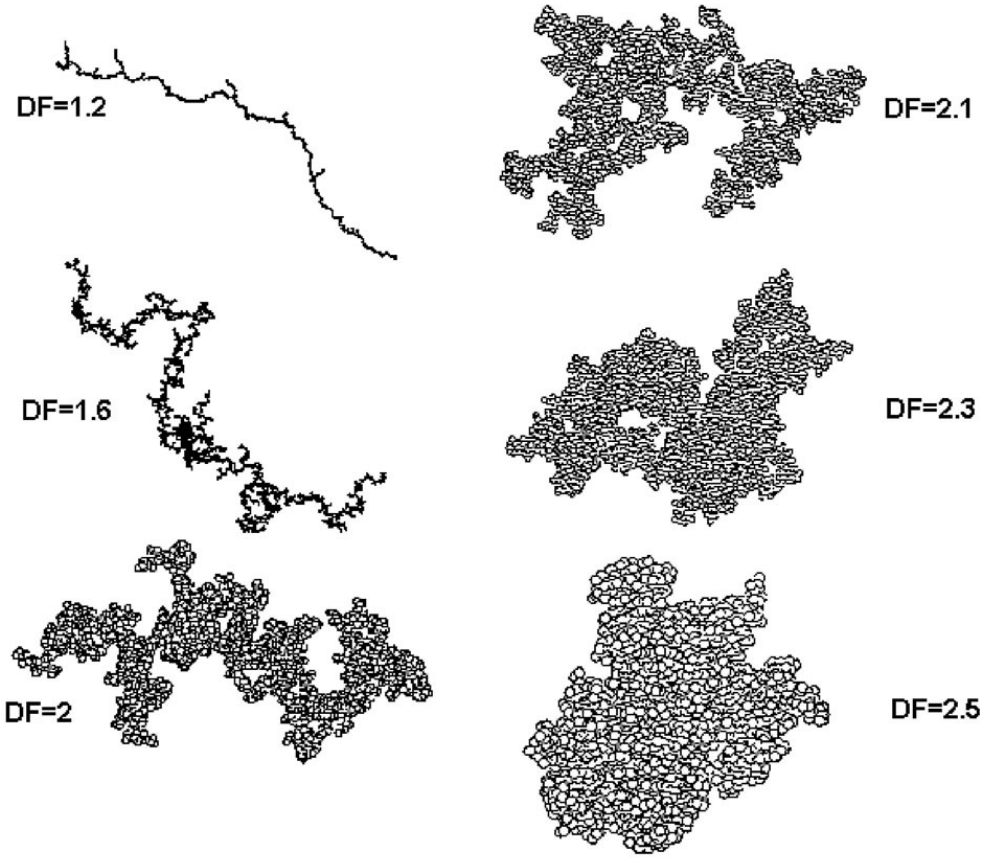
Mass=$(4/3)\pi R^3\rho$

* "Euclidean" object: Mass $\propto R^3$

* Mass Fractal: Mass $\propto R^{df}$,

d_f(mass fractal dimension) < 3

Fractal structures as a function of d_f (mass fractal dimension)



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