SOL-GEL PROCESS

So-Gel process is a synthesis of an oxide ceramic in a liquid solution of an alkoxide based precursor in which submicron particles of a solid phase suspended in the liquid (**Sol**) are obtained and then condensed forming **Gel** - a 3-D network of polymerized macromolecules surrounded with the solution.

Applications of Sol-Gel process:

- ⊡ Thermal insulation.
- ⊡ Acoustic insulation.
- ⊡ Protective optical coatings.
- ⊡ Lightweight materials.
- ⊡ Tough ceramics.
- ⊡ Membranes and microfilters.
- ⊡ Nuclear waste storage.
- ⊡ Ultra fine powder abrasives.
- ⊡ Encapsulation of biomolecules for controlled drug release.

The stages of the Sol-Gel process

- ⊡ **Hydrolysis of precursor (sol formation)**
- ⊡ **Polycondensation (gelataion)**
- ⊡ **Aging**
- ⊡ **Drying**
- ⊡ **Calcination**
- ⊡ **Properties of some aerogels**

Hydrolysis of precursor (sol formation)

The precursor is an aqueous solution of the metal **M** alkoxide: **M-OR**, where **R** is the alkyl group (e.g., C_2H_5).

The metal alkoxide reacts with the surrounding water and forms the colloidal suspension (sol) of the metal hydroxide **M-OH** according to the hydrolysis reaction:

M-OR + H-OH = M-OH + R-OH

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Polycondensation (gelataion)

Polycondensation of the hydrolyzed precursor occurs according to the reactions:

Reaction with the non-hydrolyzed metal alkoxide **M-OR** resulting in alcohol formation **R-OH**:
M-OH + M-OR = M-O-M + R-OH

Reaction with the hydrolyzed metal alkoxide **M-OH** resulting in water formation **H_2O**:
M-OH + M-OH = M-O-M + H_2O

Polycondensation stage results in a formation of the **Gel** - a rigid 3-D network built of polymeric molecules and surrounded with the solvent.

The gel structure obtained from the acidic solutions with PH<6 (acid catalyzed) is uniform and weakly cross-linked.
The gel structure obtained from the basic or neutral solutions with PH>6 (base catalyzed) consists of separate clusters .

Aging

During the aging stage the ploycondensation reactions continue completing the formation of the gel.
The gel structure is reinforced with additional cross-links, which cause contraction of the gel matrix and expulsion of the solution from the shrinking pores.

Drying

The water and other liquids entrapped within the pores of the gel structure are removed during this stage.
Drying is performed at a temperature of about 400ºF (~200ºC).
After drying the gel converts into a monolith micro-porous structure called **Xerogel**.
Drying at super-critical conditions preventing collapsing of the gel network results in a formation of a macro-porous low density structure called **Aerogel**.

Calcination

Calcination is performed at increased temperatures varying within the range 750-1470ºF (400-800ºC).
During the calcination stage the dry gel structure is dehydrated according to the reaction:

$2M(OH)_n = 2MO_{n/2} + nH_2O$

Example:
$2Al(OH)_3 = 2Al_2O_3 + 3H_2O$

Volatile organics are also removed in this stage.

Source : http://www.substech.com/dokuwiki/doku.php?id=sol-gel_process