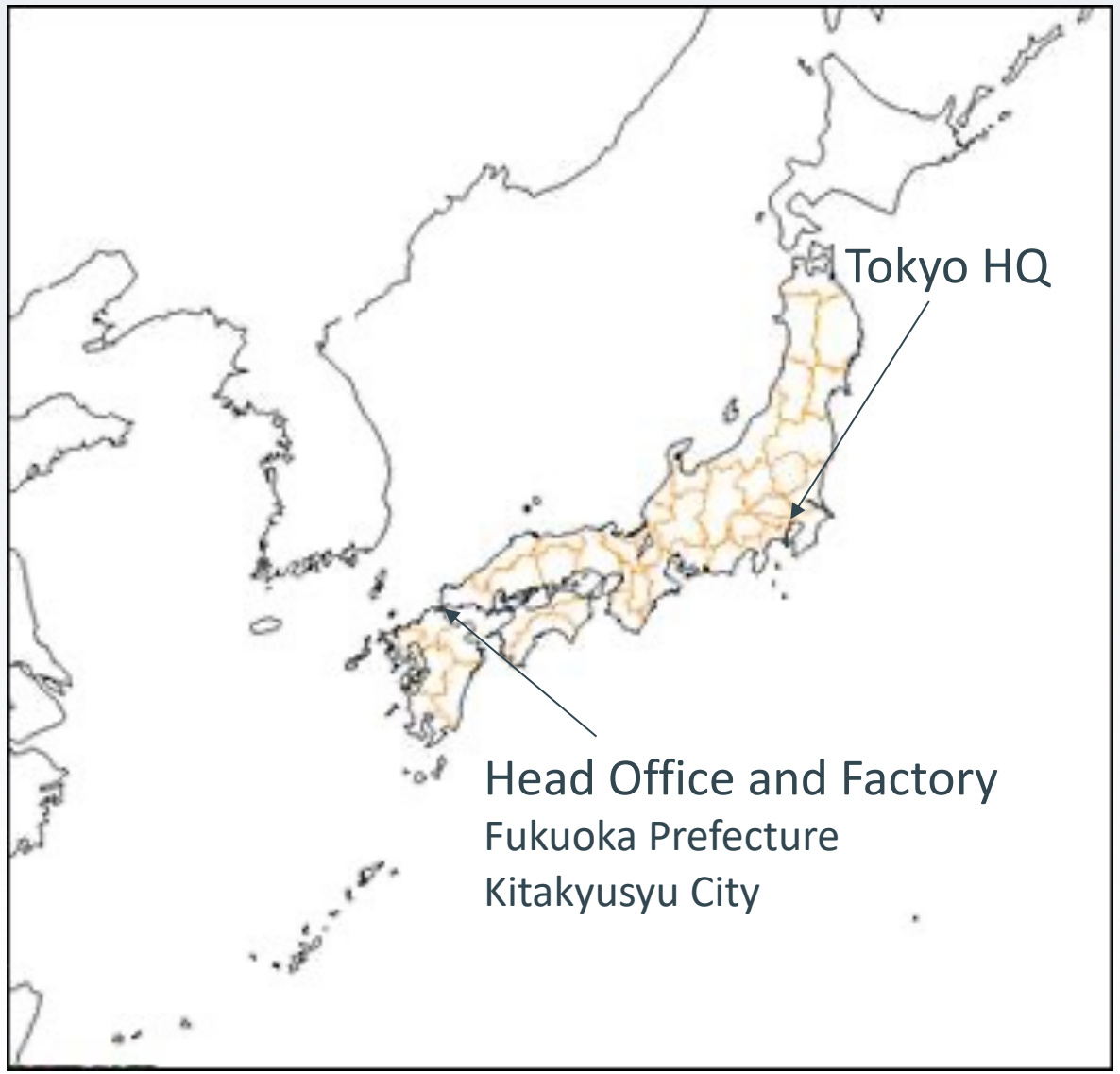
AGC Chemicals Americas, Inc.

RESiFA

SUNSPERA™ Fine Silica Microspheres for Catalyst Supports

AGCSI Manufacturing location



1985:	Started production of **M.S.GEL**
1990:	Started production of **SUNSPHERE**
1998:	Started production of **SUNLOVELY**

RESIFA™ SUNSPERA Production

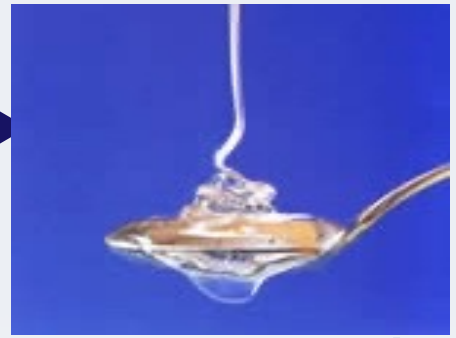
- AGC is a leader in microspherical silica
- ISO 9001:2015 certified
- Wide range of particle size and porosity
- Serving customers globally through AGC regional locations

Fine Silica Gels: Materials to Products

Silica sand

Soda ash

Sodium silicate cullet



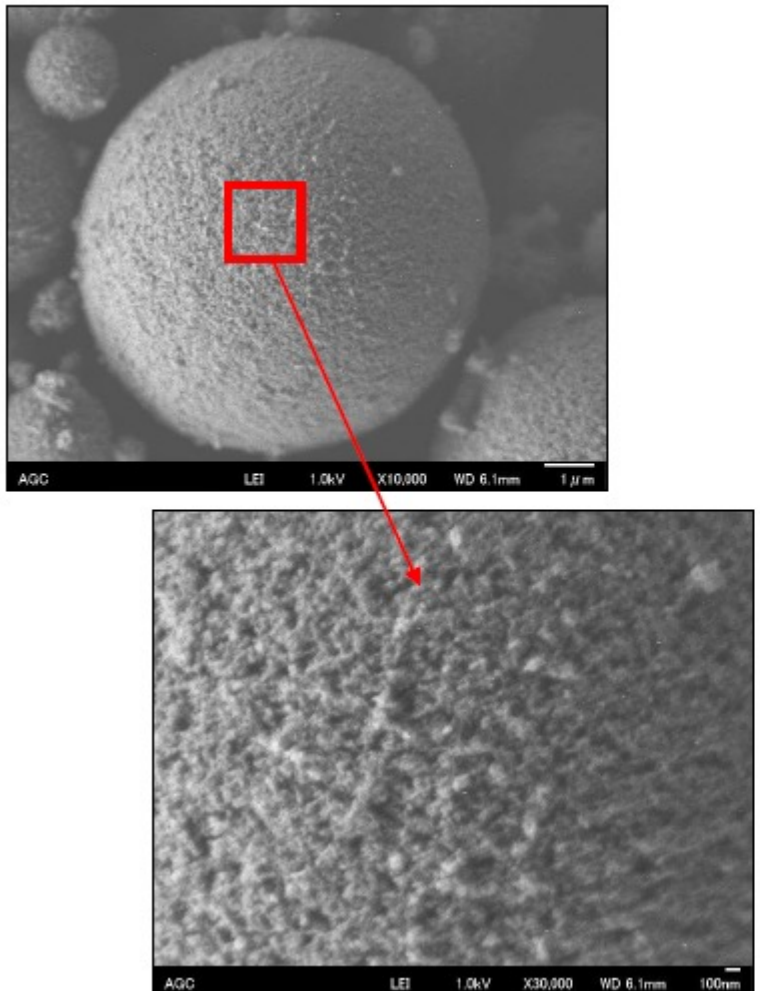
Sodium silicate solution

HPLC, Industrial

Cosmetic/Personal Care, Industrial, Other

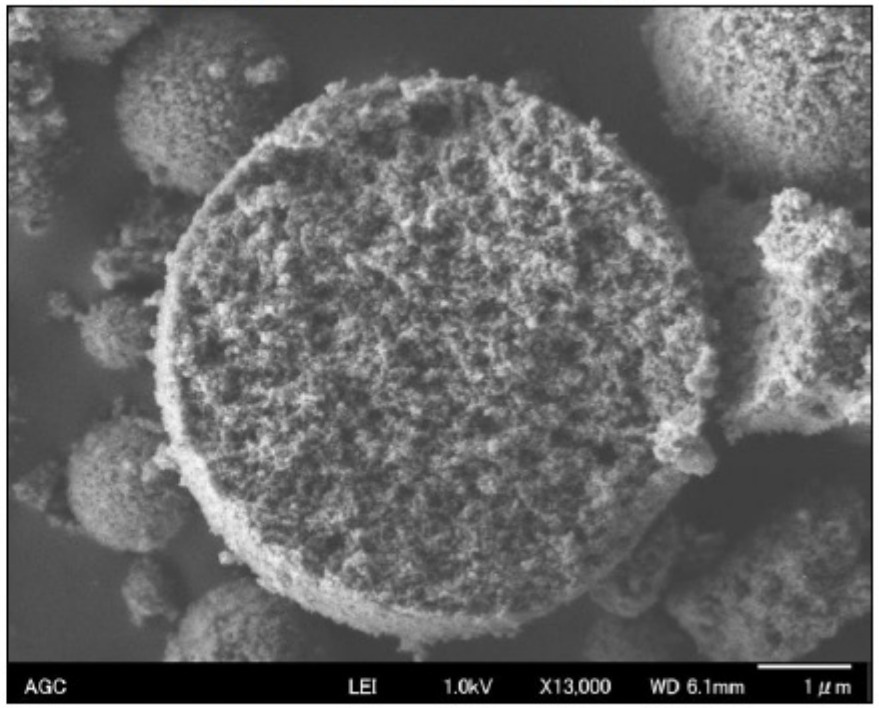
Catalyst supports

Material to Products



Enlarged photograph of surface

Photograph of Cross Section



...think of a spherical *sponge with uniform pores*

AGC

RESiFA

SUNSPERA™

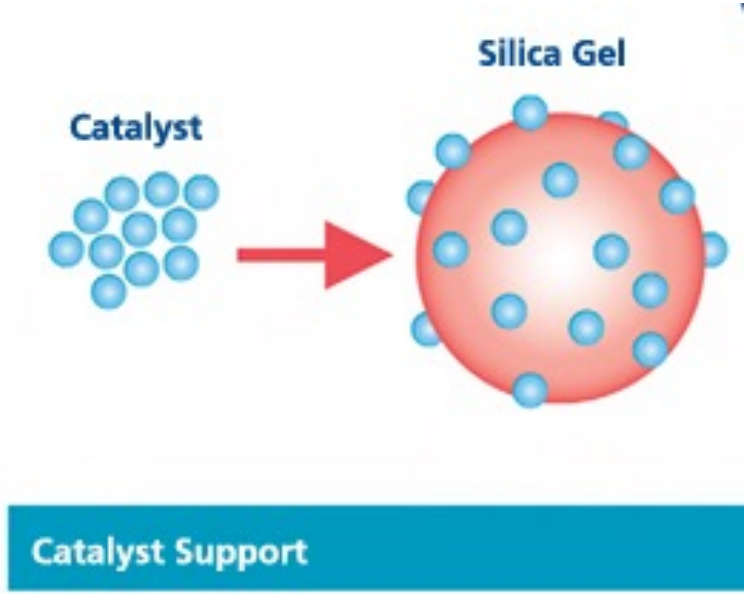
Selecting the right catalyst support…

AGC
Your Dreams, Our Challenge

…is important in optimizing the manufacturing process

Factors to consider:

- **Thermal Stability** affects the reaction rate between the catalyst and reacting material
- **Shape and Packing Density** can affect fluid flow rates and processes.
- **Compression Strength** of the catalyst carrier needs to withstand the various pressures and loads subjected during the chemical reaction and process.
- **Surface Area and Porosity** directly relate to the reactivity levels of the chemical process. The higher the surface area, the higher the number of sites for a catalyst to attach, which leads to higher reactivity levels.



RESIFA™ SUNSPERA™ silica

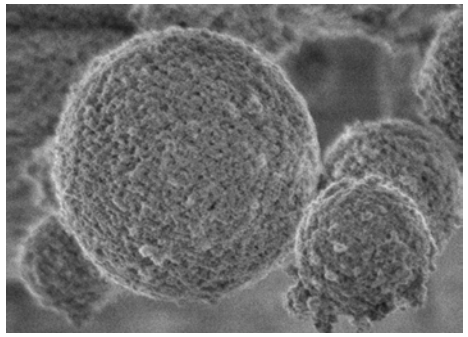
AGC
Your Dreams, Our Challenge

Key Attributes

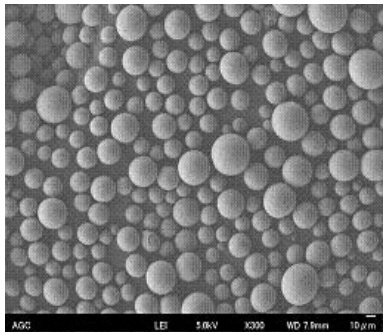
- Spherical shape
- Wide combination of particle size and porosity
  - Particle size range: 3µm - 70µm
  - Pore volume range: 0.7 - 2.3 ml/g
  - High and wide surface area range: 40 - 800 m^2/g
- Uniform porosity throughout particle
- Narrow particle size and pore size distribution

Benefits

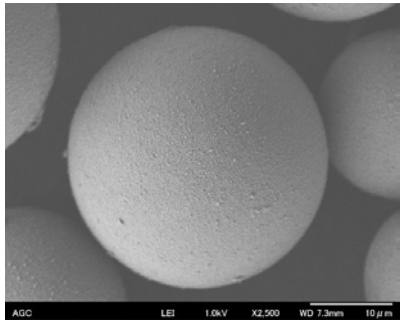
- Morphology helps control polymerization reaction
- High loading of catalyst leads to high catalyst activity
- Produces high specific gravity and high bulk density of the polymer
- Improved morphology of finished polymer
- Optimizes production
- Prevents reactor fouling



H-32



H-201



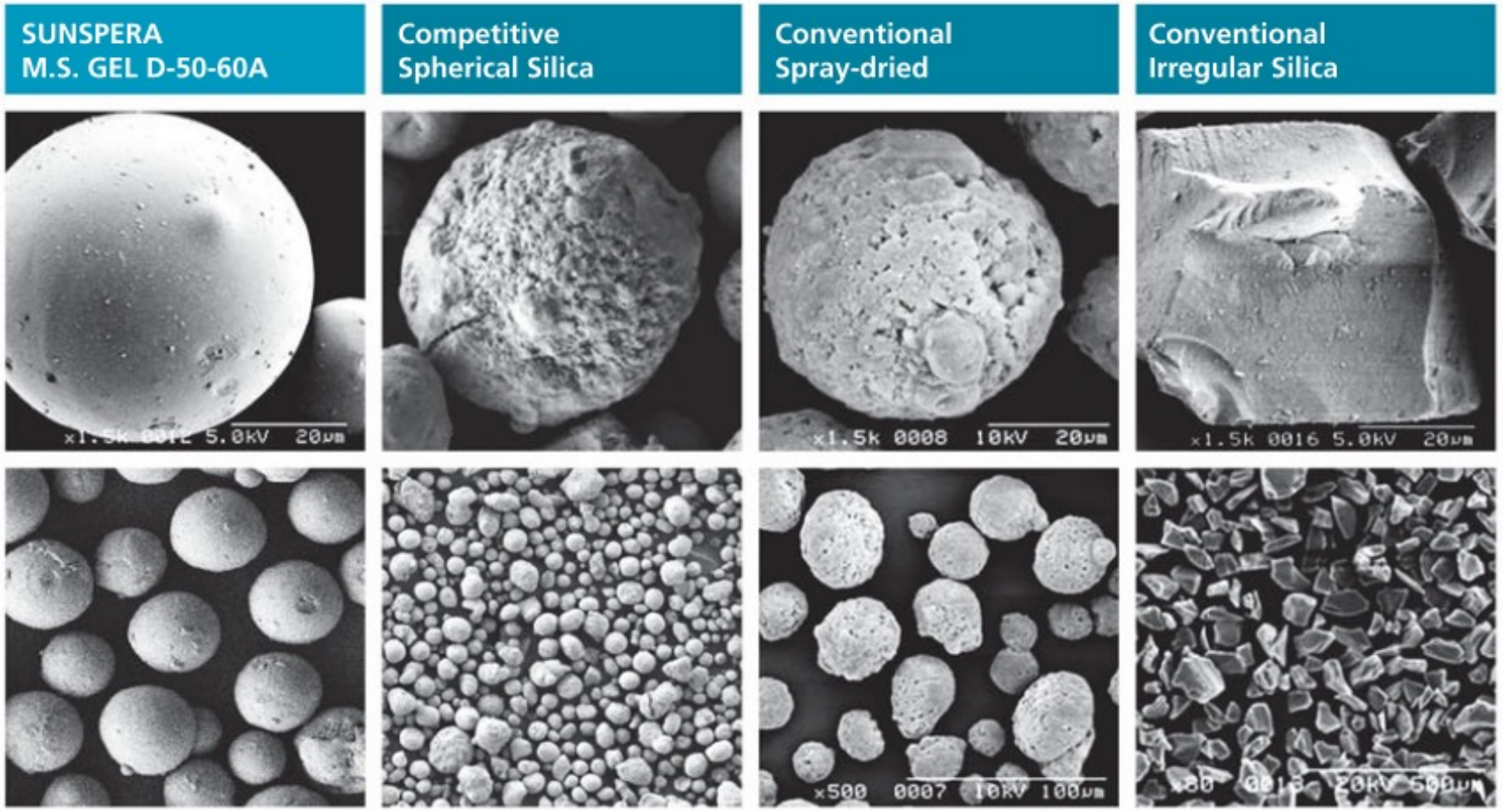
DM-L-303

SUNSPERA™ silica gels are chemically inert, have high surface areas and a range of porosity levels.

The properties of the SUNSPERA™ silica gel have a significant effect on the polymerization process and properties of the finished polymer.

How we compare...

AGC
Your Dreams, Our Challenge



Spherical, uniform structure leads to performance consistency

SUNSPERA™ Product Selection Guide

AGC
Your Dreams, Our Challenge

For Slurry/Cascade Polyolefin Polymerization Processes

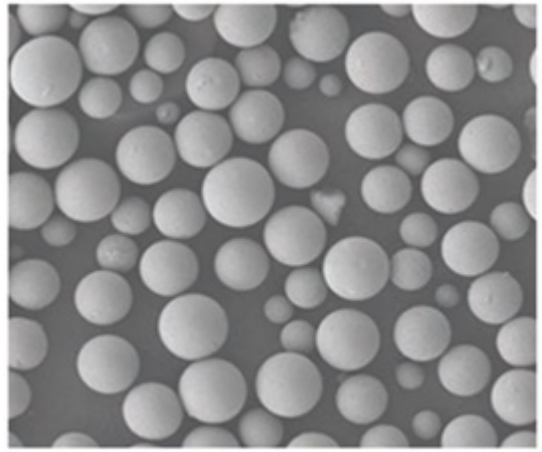
Grade	HH Series High Surface Area, Hard Particles				HB Series High Surface Area, Breakable Particles					LB Series Low Surface Area, Breakable Particles	
	H-31	H-51	H-121	H-201	H-32	H-52	H-122	H-33	H-53	L-52	L-123
Suitable for	Polyolefins not requiring transparency				Polyolefins requiring transparency such as HDPE and MDPE					Polyolefins requiring transparency such as LLDPE Metallocene	
Mean particle size (μm)	3	5	12	20	3	5	12	3	5	5	12
Specific surface area (m^2/g)	800	800	800	800	700	700	700	700	700	300	300
Pore volume (ml/g)	0.9	0.9	0.9	0.9	1.6	1.6	1.8	1.8	1.8	1.6	2.0
Pore diameter (nm)	4.5	4.5	4.5	4.5	-	-	-	-	-	12	50
Oil absoption capacity (ml/100g)	150	150	150	150	300	300	300	400	400	300	400
	• Small pore size allows for polymerization to occur on surface • Original shape is maintained throughout polymerization • High Surface Area leads to high catalyst activity				• Larger pore size allows for polymerization to occur on surface and at the core • Particle fragmentation during polymerization • High Surface Area leads to high catalyst activity					• Wide pore size allows for ethylene gas to impregnate inside the particle • High catalyst activity due to easy fragmentation of silica particles	

SUNSPERA™ Product Selection Guide

AGC
Your Dreams, Our Challenge

For Gas Phase Polyolefin Polymerization Processes

Grade	DM Series	
	DM L-303	D-70-120A(LV)
Average particle size (μm)	35	65
Specific surface area (m^2/g)	300	450
Pore volume (ml/g)	2.1	1.7
Pore diameter (nm)	60	15
Span value (-)	0.5	0.95
Mechanical strength (MPa)	2.9	6.3
	• Narrow Particle Size distribution • Resulting polyolefin morphology is excellent and has higher bulk density • The 300 and 500 series are recommended for Metallocene catalyst support • D-70 series are very suitable for Ziegler-Natta or Phillips catalysts	



DM-L-303

SUNSPERA™ Product Selection Guide

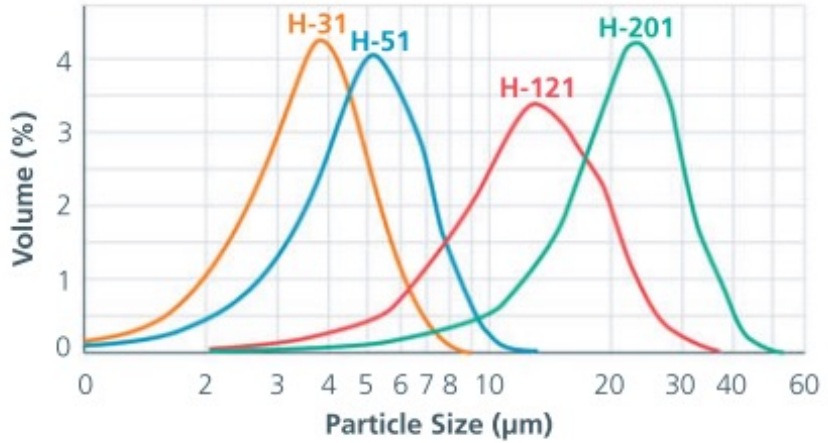
AGC
Your Dreams, Our Challenge

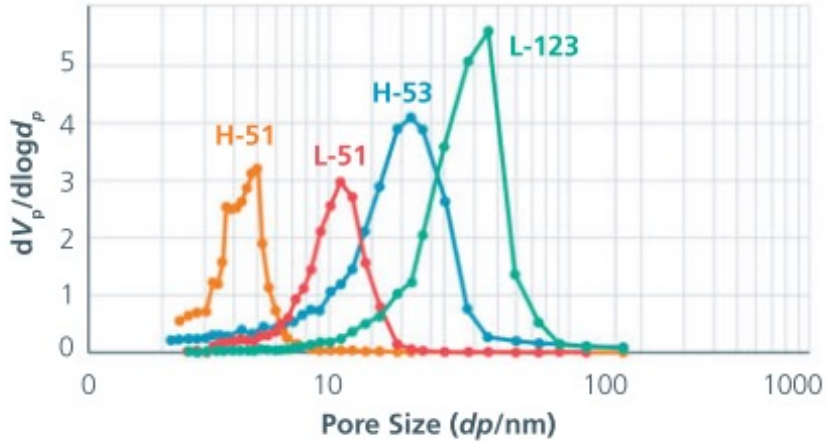
For Organic Synthesis of Organic Compounds

Grade	H-31	H-51	H-121	H-201	D-50-60A	D-100-60A	D-150-60A
Mean particle size (μm)	3	5	12	20	50	100	150
Specific surface area (m^2/g)	800	800	800	800	700	700	700
Pore volume (ml/g)	0.9	0.9	0.9	0.9	1.15	1.15	1.15
Pore diameter (nm)	4.5	4.5	4.5	4.5	6.5	6.5	6.5
Oil absoption capacity (ml/100g)	150	150	150	150	-	-	-

Other grades with different particle sizes and larger pore sizes are available.

Pore Size & Particle Size Distribution





Experienced with Calcination

AGC
Your Dreams, Our Challenge

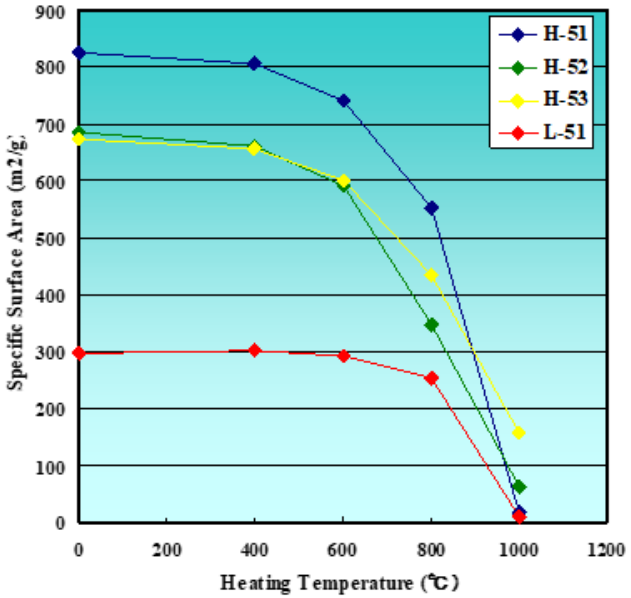
Effect on Surface Area

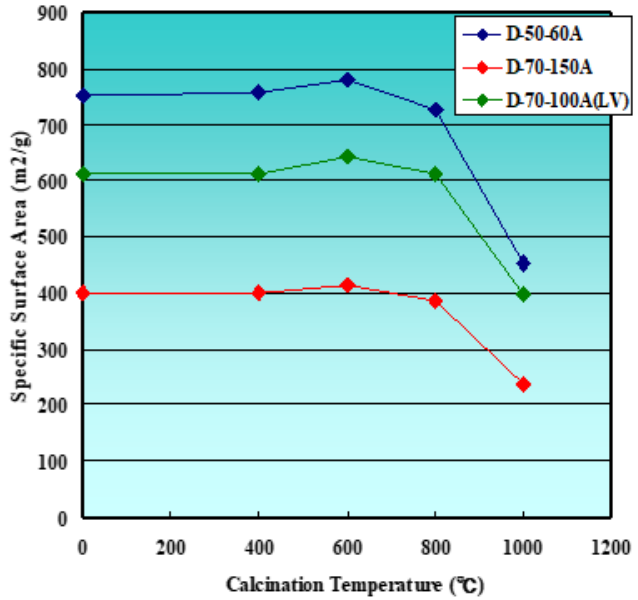
Effect of Calcination Treatment on Surface Area

Product Name	H-51	H-52	H-53	L-51	D-50-60A	D-70-100A(LV)	D-70-150A(LV)
Non Heating	826	680	750	296	753	611	401
400℃×2Hr	807 (97.7)	661 (96.4)	657 (97.8)	301 (100.0)	757	613	401
600℃×2Hr	740 (89.6)	592 (86.3)	602 (89.6)	291 (96.7)	781	642	414
800℃×2Hr	553 (66.9)	347 (50.6)	435 (64.7)	253 (84.1)	728 (96.7)	611 (100.0)	385 (96.0)
1000℃×2Hr	18 (2.2)	62 (9.0)	157 (23.4)	10 (3.0)	453 (60.2)	397 (65.0)	238 (59.4)

( ): Decreasing ratio to surface area of non heating product (%)

Specific Surface Area vs. Calcination Temperature





Only L-51 in SOLESPHERE does not decrease the surface area, other grades begin to decrease gradually at a temperature of 400℃. On the other hand M.S.GEL can keep the surface area at temperatures up to 800℃.

Experienced with Calcination

AGC
Your Dreams, Our Challenge

Effect on Pore Volume

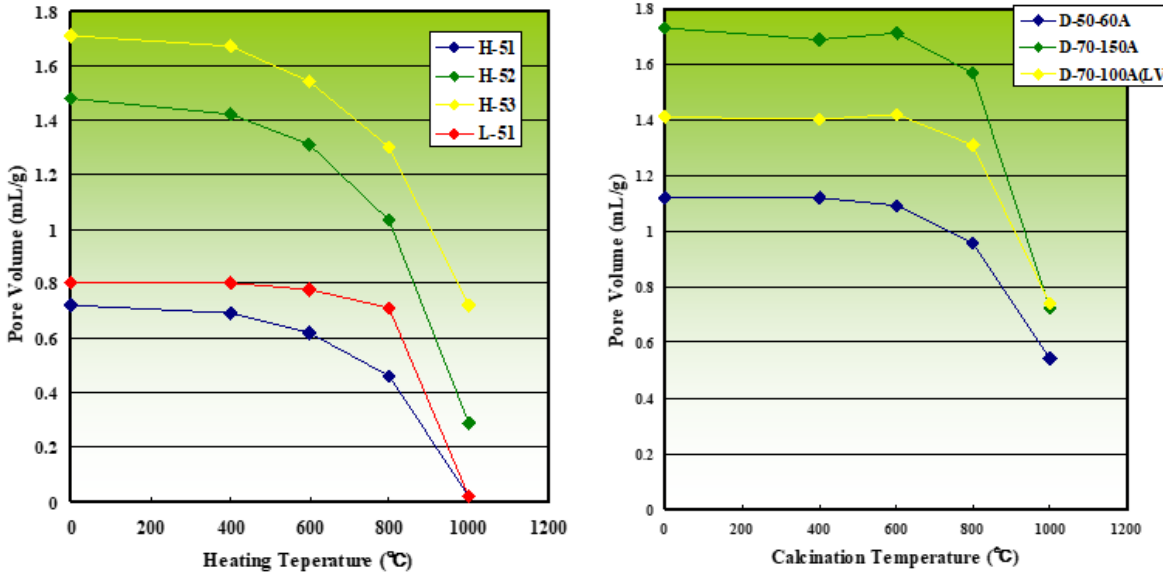
Effect of Calcination Treatment on Pore Volume

unit: m2/g

Product Name	H-51	H-52	H-53	L-51	D-50-60A	D-70-100A(LV)	D-70-150A(LV)
Non Heating	0.72	1.48	1.71	0.80	1.12	1.41	1.73
400℃×2Hr	0.69 (95.8)	1.42 (95.9)	1.67 (89.6)	0.80 (100.0)	1.12 (100.0)	1.40	1.69
600℃×2Hr	0.62 (86.1)	1.31 (88.5)	1.54 (90.1)	0.78 (97.5)	1.09 (97.3)	1.42 (100.0)	1.71 (100.0)
800℃×2Hr	0.46 (63.9)	1.03 (69.6)	1.30 (76.0)	0.71 (88.8)	0.96 (85.7)	1.31 (92.9)	1.57 (90.8)
1000℃×2Hr	0.02 (2.8)	0. 29 (19.6)	0.72 (42.1)	0.02 (2.5)	0.54 (48.2)	0.74 (52.5)	0.72 (41.6)

( ): Decreasing ratio to pore volume of non heating product (%)

Pore Volume vs. Calcination Temperature



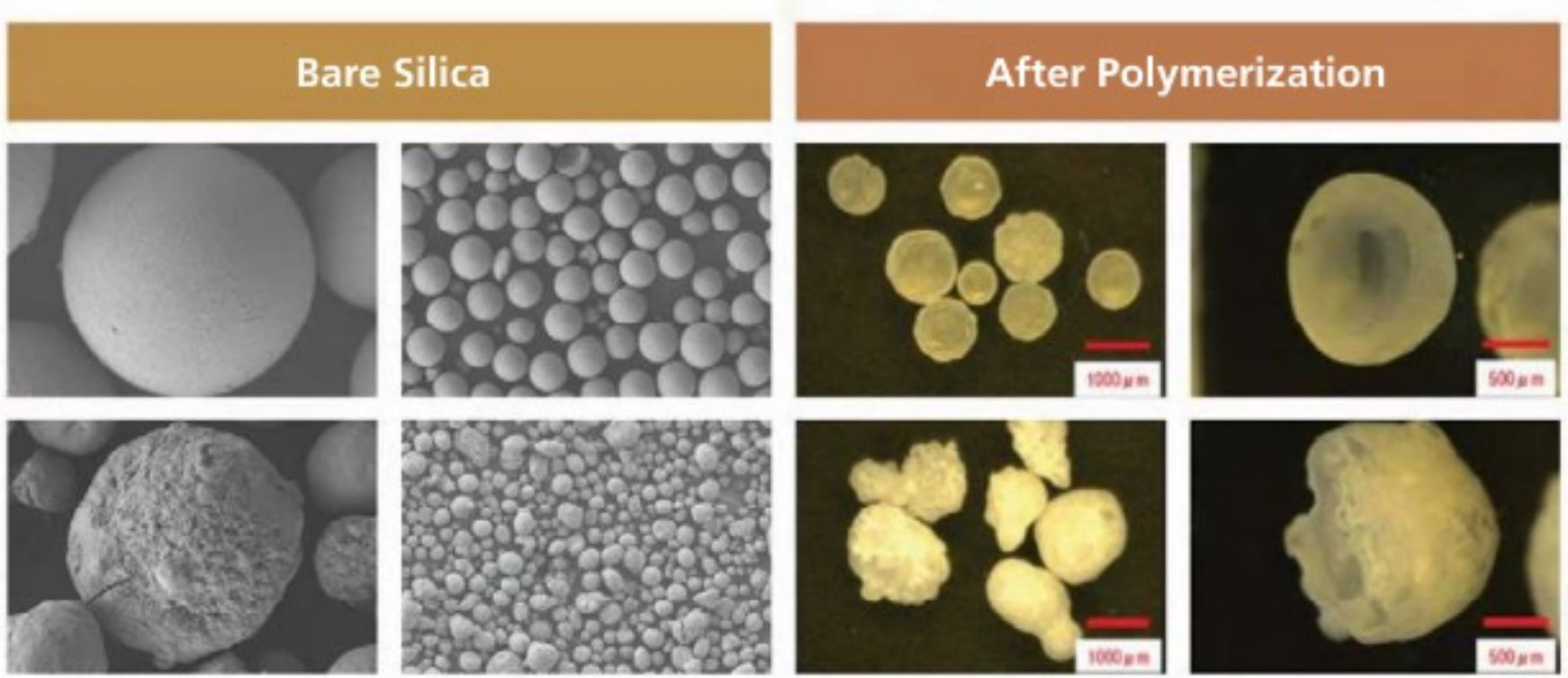
SOLESPHERE beside L-51 begin to decrease gradually the pore volume at a temperature of 400℃. The decreasing of the pore volume for M.S.GEL begins at a temperature of 600℃.

How we compare after Polymerization

AGC
Your Dreams, Our Challenge

RESiFA
SUNSPERA™

Competitor



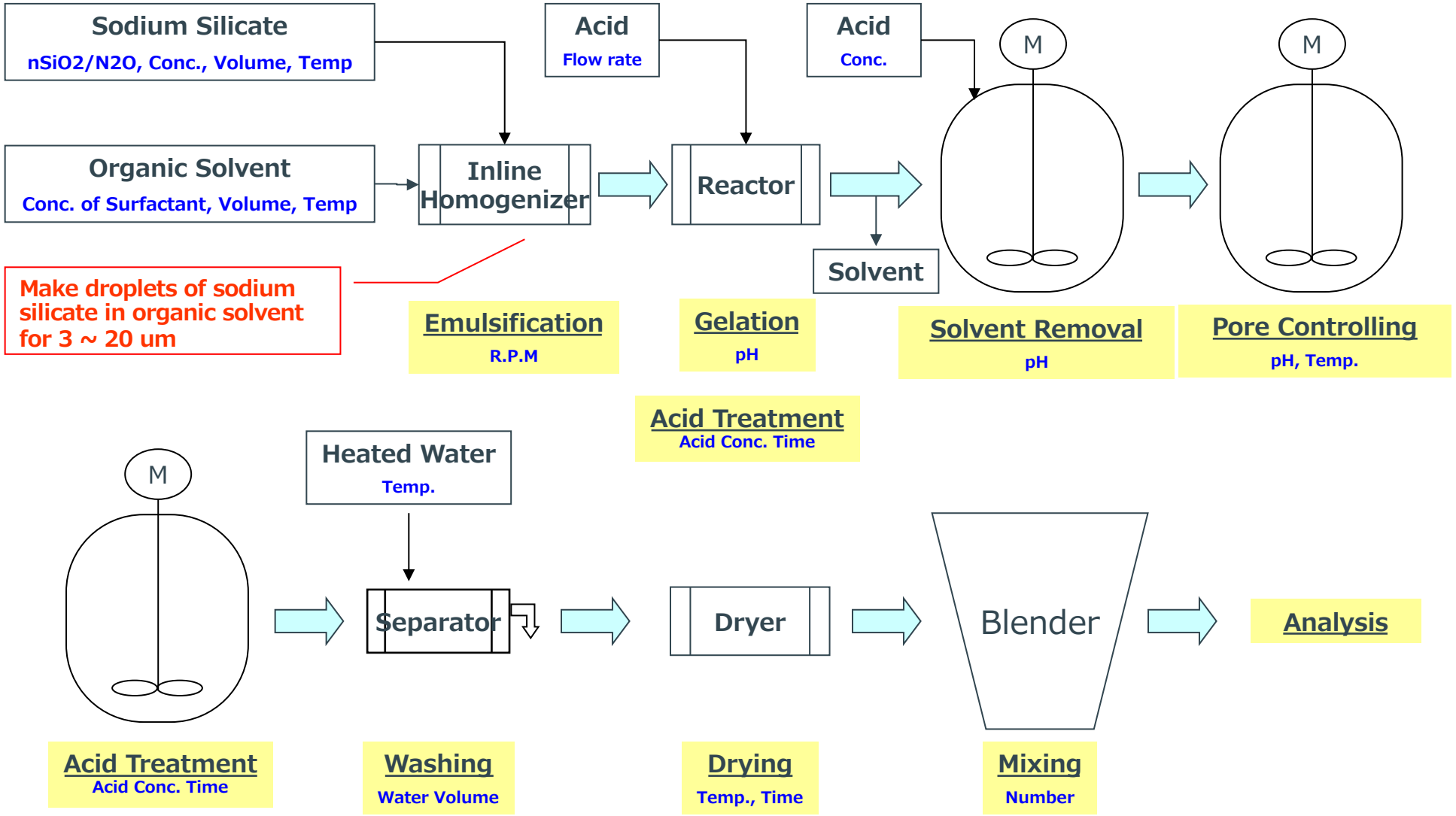
AGC

RESiFA

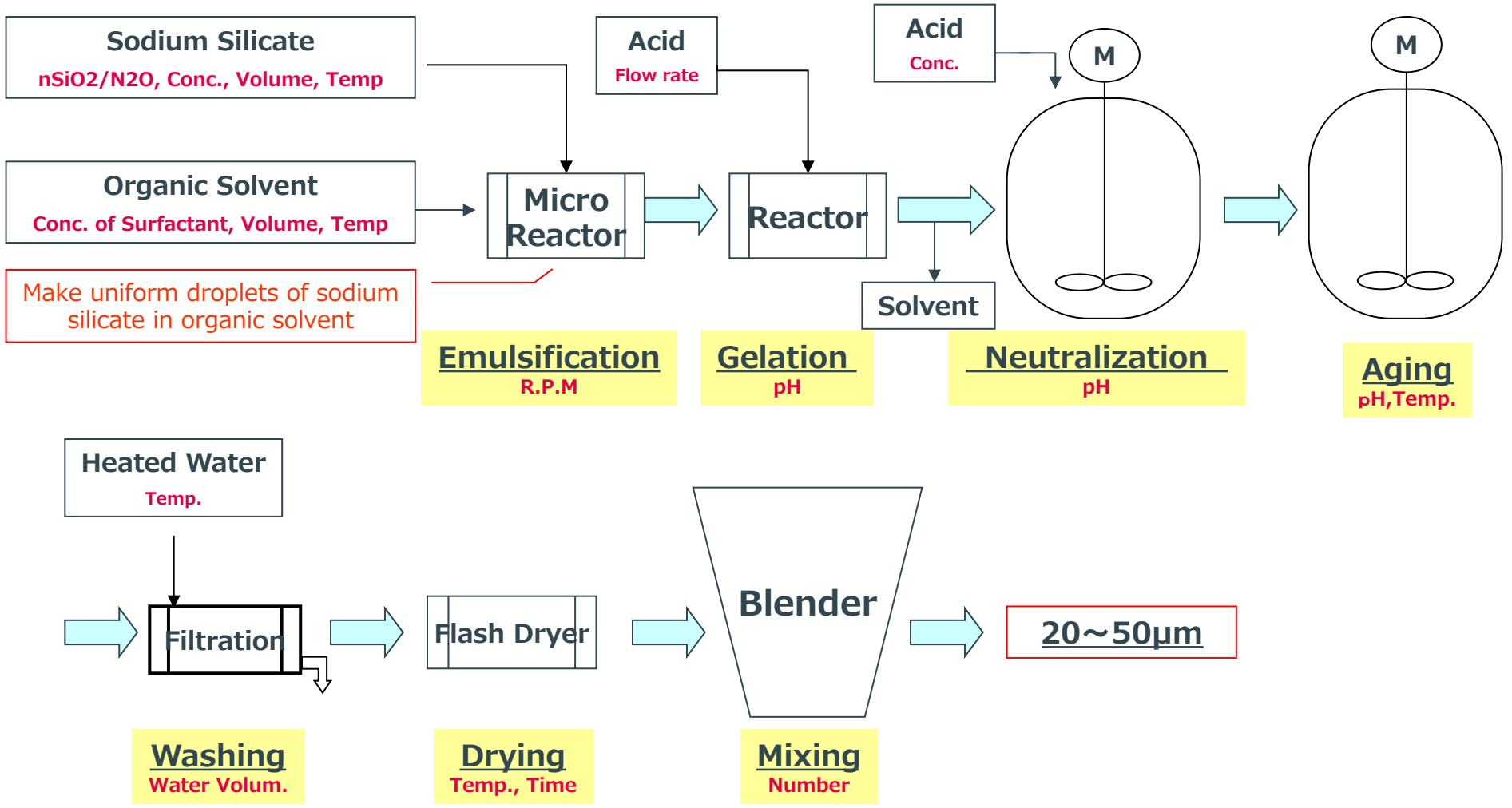
SUNSPERA™

for Catalyst Supports

Process of SUNSPHERE



Process of SUNSPHERE DM grade



How to make DM grade?

AGC
Your Dreams, Our Challenge

Mechanism to make emulsified drop-let without balloon shape