SILICYCLE

BRUNSCHWIG

SOLUTIONS FOR ORGANIC SYNTHESIS

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Founded in 1995, SiliCycle is specialized in the development, manufacturing and commercialization of high value silica gels and specialty products for chromatography, purification and synthesis.

Solutions for Organic Synthesis

SiliCycle Organic Synthesis Solutions

- **Easy product / API isolation and purification**
- **Eliminates or strongly reduces the need for laborious purifications**
- **Suitable for either batch or continuous flow applications**
- **Compares very favorably to polymer-based: no swelling, thermally and mechanically stable, and compatible with all solvents**

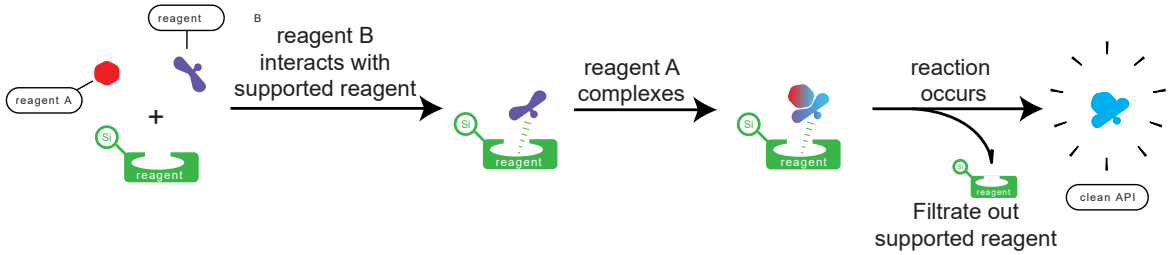
Silia*Bond*® Silica-Based Reagents and Oxidants

The use of heterogeneous reagents in organic synthesis and chemical production is growing in importance.

Although the strength of this technology has been acknowledged for a long time for applications in a large number of diverse and interesting chemical reactions – thanks to its efficiency and eco-friendly character – the number of available reagents has lagged behind. At this time, SiliCycle has developed the most complete offer of heterogeneous reagents and oxidants.

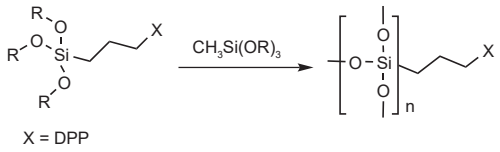
This technology is completely in line with the industries seeking improved sustainability and reduced ecological footprint. This strong trend is directly derived from the inherent benefits offered by silica-based heterogeneous reagents and oxidants stated herein.

Here is the reaction mechanism:



Silia*Cat*® Heterogeneous Catalysts

Inspired by the ORganically MOdified SILica (*ORMOSIL*) technology, the Silia*Cat* family is composed of new and innovative catalysts. Resulting from the co-condensation of two organosilane monomers by the sol-gel process, the hybrid organic-inorganic materials present the highest stability and reactivity available with heterogeneous catalysts. Furthermore, the highly cross-linked framework presents a better resistance compared to post-functionalization process.



What are Silia*Cat* Heterogeneous Catalysts?

Usually, heterogeneous catalysts supported on a silica matrix are immobilized by post-modification of the inorganic support.

These supports, however, present a high degree of leaching due to the poor stability of the immobilized phase.

For example, with Silia*Cat* the ligand is directly cross-linked in an organic-inorganic framework. This results in a high degree of stability of the catalysts.

Compared to homogeneous catalysts, Silia*Cat* exhibits a similar reactivity and selectivity with one major advantage being that the catalyst is eliminated from the reaction mixture by a simple filtration. Forget your purification problems with our Silia*Cat* catalysts family!

Heterogeneous Catalytic Reaction Basics

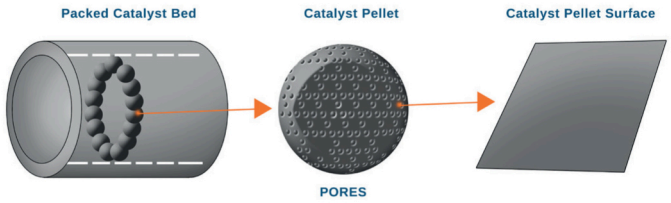
To maximize reaction rate on a porous catalyst, it is essential to maximize accessibility of all reactants to the active catalytic sites, which are dispersed through the internal pore structure of the catalyst.

Imagine a reactant **A** flowing through a bulk liquid and a bed of a heterogeneous catalyst reacting on the catalytic surface to form a species **B**.

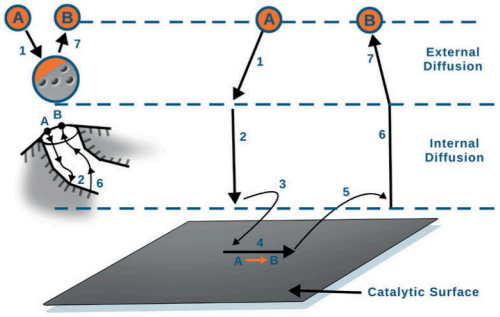
Schemes at right present the physical and chemical steps that must occur for **A** to convert to **B**:

1. Mass transfer (*diffusion*) of the reactant(*s*) (*e.g. species A*) from the bulk liquid and a separate liquid film surrounding each suspended catalyst particle to the external surface of the catalyst particle.
2. Diffusion of the reactant from the pore mouth through the catalyst pores to the immediate vicinity of the internal catalytic surface.
3. Adsorption of reactant A onto the catalyst surface.
4. Reaction on the surface of the catalyst (*e.g. A⟶B*).
5. Desorption of the products (*e.g. B*) from the surface.
6. Diffusion of the products from the interior of the pellet to the pore mouth at the external surface.
7. Mass transfer of the products from the external pellet surface to the bulk fluid.

Catalyst Packed-Bed Reactor - Schematic



Steps in a Heterogeneous Catalytic Reaction



Different Formats for Different Applications

Please refer to our Ordering Information section to learn more about all formats available and the corresponding part numbers.

Catalysts, Reagents and Oxidants as Bulk Silica

All our products can be used in bulk directly in your reaction flask or reactor, and are available from 5 g to 25 kg formats, up to multi-ton scale.

Reagents and Oxidants in Silia*Prep* SPE and Silia*Sep* Flash Cartridges

Almost all our reagents and oxidants are available in pre-packed cartridges.

- **Silia*Prep* SPE cartridges**
  From 3 mL / 200 mg to 12 mL / 2 g
- **Silia*Sep* OT (*Open Top*) flash cartridges**
  From 25 mL / 5 g to 150 mL / 70 g
- **Silia*Sep* flash cartridges**
  From 4 g to 1.6 kg bed weight

Quality and Regulatory Documentation

SiliaBond and SiliaCat are more and more used in GMP pharmaceutical, biotechnology, and fine chemical industries as well as contract research and manufacturing organizations. Many have run their own analysis proving that SiliaBond and SiliaCat can safely be used without compromising the purity of their compounds.

SiliCycle is committed to high quality standards and all products are manufactured in an ISO 9001:2015 compliant facility, and subjected to stringent quality control.

For any inquiries, please contact: support@silicycle.com

All products are shipped with the following information:

- Certificate of Analysis (*COA*)
- Safety Data Sheet (*SDS*)
- Technical Information

Other statements available under request:

- BSE / TSE Declaration (*non animal-derived*)
- GMO-Free Certificate
- Melamine-Free Certificate, etc.

SiliCycle can also work with you to provide customized regulatory documents, including specific analytical tests in line with your needs.

Manufacturing Capability

SiliaBond and SiliaCat are manufactured at our headquarters in Quebec City, where we can meet all customers production needs.

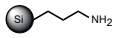
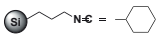
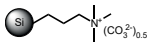
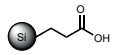
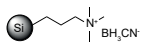
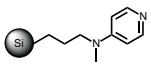
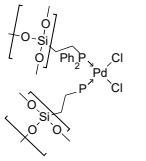
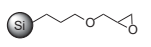
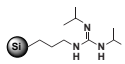
Our state of the art facilities include (*but are not limited to*):

- 1,000 L to 10,000 L reactors (*total capacity of 38,000 L*)
- Stainless steel and hastelloy nutsche filters (*3 m^2*)
- Bulk solvent tank farm (*60,000 L capacity*)

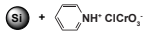
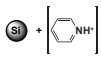
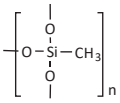
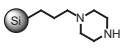
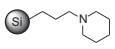
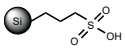
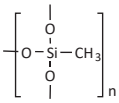
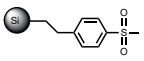
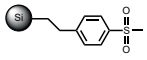
Enjoy a virtual tour of SiliCycle's facility

Silia*Bond* and Silia*Cat* Portfolio

Silia*Bond* Reagents and Oxidants / Silia*Cat* Heterogeneous Catalysts Technical Information

Products	Structure	Brief Description	Typical Reactions	Typical Characteristics [a, b]
Silia*Bond* Amine • PN: R52030B • Loading: ≥ 1.20 mmol/g • Endcapping: Yes		Used as an effective catalyst for Knoevenagel reactions as well as a support in solid-phase chemistry for peptide synthesis followed by enzymatic hydrolysis, and for Claisen rearrangement.	Knoevenagel reactions Peptide synthesis Claisen rearrangement	Color: Off-white Density: 0.700 g/mL Solvent Compatibility: 2 Prolonged Storage: 2 Shelf Life: 2 Years
Silia*Bond* Carbodiimide • PN: R70530B • Loading: ≥ 0.91 mmol/g • Endcapping: Yes		Most commonly used reagent in peptide synthesis and other amide bond-forming reactions of primary and secondary amines with carboxylic acids.	Amide coupling with acids, acyl chlorides, and amines	Color: Orange Density: 0.751 g/mL Solvent Compatibility: 3 Prolonged Storage: 3 Shelf Life: 2 Years
Silia*Bond* Carbonate • PN: R66030B • Loading: ≥ 0.46 mmol/g • Endcapping: Yes		Used as a heterogeneous catalyst in the Henry reaction in catalytic amounts drive the reaction forward to high yield with or without solvent.	Nitro-Aldol reactions (*Henry reaction*), free basing of amine	Color: Off-white Density: 0.608 g/mL Solvent Compatibility: 3 Prolonged Storage: 2 Shelf Life: 1 Year
Silia*Bond* Carboxylic Acid • PN: R70030B • Loading: ≥ 0.92 mmol/g • Endcapping: Yes		Acid used as a scavenger for amines or carbonates, and for the quench of alkoxides and organometallic reagents.	Acid used to quench alkoxides and organometallic reagents	Color: Off-white Density: 0.687 g/mL Solvent Compatibility: 1 Prolonged Storage: 1 Shelf Life: 2 Years
Silia*Bond* Cyanoborohydride • PN: R66730B • Loading: ≥ 0.87 mmol/g • Endcapping: Yes		Used in reductive amination and in the reduction of imines and aldehydes without having cyanide contamination issues.	Reductive amination	Color: Off-white Density: 0.705 g/mL Solvent Compatibility: 1 Prolonged Storage: 3 Shelf Life: 2 Years
Silia*Bond* DMAP • PN: R75630B • Loading: ≥ 0.53 mmol/g • Endcapping: Yes		Used as a nucleophilic catalyst in a wide variety of reactions such as acylations and Baylis-Hillman reactions.	Acylations, esterification	Color: Light brown to brown Density: 0.674 g/mL Solvent Compatibility: 1 Prolonged Storage: 3 Shelf Life: 1 Year
Silia*Cat* DPP-Pd • PN: RD-R390-100 • Loading: 0.2 - 0.3 mmol/g (*2.1 - 3.2 % Pd*) • Endcapping: Yes		Unique diphenylphosphine palladium (II) heterogeneous catalyst made from a leach-resistant organoceramic matrix used for coupling reactions.	Suzuki, Heck, Negishi, Borylation, Sonogashira, Kumada, Stille	Color: Orange Density: 0.300 - 0.400 g/mL Solvent Compatibility: 1 Prolonged Storage: 3 Shelf Life: 1 Year
Silia*Bond* Glycidoxy *nec* • PN: R36030B • Loading: ≥ 0.82 mmol/g • Endcapping: No		Used as a linker for further modification of the surface and for the immobilization of molecules bearing amino, hydroxy, mercapto and thiocarboxylic acid groups.	Linker	Color: Off-white Density: 0.662 g/mL Solvent Compatibility: 1 Prolonged Storage: 2 Shelf Life: 2 Years
Silia*Bond* Guanidine • PN: R68230B • Loading: ≥ 0.80 mmol/g • Endcapping: Yes		Used as a silica-bound guanidine moiety that is sufficiently basic to deprotonate moderately acidic hydrogens. It is most commonly used in Williamson ether synthesis.	Williamson ether synthesis, Strecker-type reactions, 1,4 addition reactions	Color: Light yellow Density: 0.732 g/mL Solvent Compatibility: 1 Prolonged Storage: 2 Shelf Life: 2 Years
Silia*Bond* $KMnO_4$ • PN: R23030B • Loading: 10 % w/w • Endcapping: No		Strong oxidant that will oxidize methyl groups and alcohols to carboxylic acids. With Si-$KMnO_4$, the manganese salt by-products stay adsorbed onto the silica.	Oxidation of alcohols to acids	Color: Purple Density: 0.593 g/mL Solvent Compatibility: 5 Prolonged Storage: 1 Shelf Life: 2 Years

SiliaBond Reagents and Oxidants / SiliaCat Heterogeneous Catalysts Technical Information

Products	Structure	Brief Description	Typical Reactions	Typical Characteristics [a, b]
SiliaBond Pyridinium Chlorochromate (*PCC*) • PN: R24030B • Loading: 20 % w/w • Endcapping: No		Used for the oxidation of alcohols to carbonyl, selective oxidation of allylic and benzylic alcohols, organometallic oxidation, oxidative transpositions, oxidative cleavages, allylic and benzylic oxidation and oxidative cyclizations.	Oxidation of alcohols to aldehydes or ketones	Color: Orange Density: 0.693 g/mL Solvent Compatibility: 5 Prolonged Storage: 2 Shelf Life: 2 Years
SiliaBond Pyridinium Dichromate (*PDC*) • PN: R24530B • Loading: 20 % w/w • Endcapping: No		Used for oxidizing allylic and benzylic alcohols, saturated with acid-sensitive groups, such as cyclopropane rings or ketal functions.		Color: Orange Density: 0.651 g/mL Solvent Compatibility: 5 Prolonged Storage: 2 Shelf Life: 2 Years
SiliaCat Pd⁰ • PN: RD-R815-100 • Loading: 0.2 - 0.3 mmol/g (*2.1 - 3.2 % Pd*) • Endcapping: Yes		Patent-protected sol-gel-entrapped Pd nanocatalyst used for hydrogenation and coupling reactions.	Selective debenzylation, selective hydrogenation, couplings (*Suzuki, Heck Sonogashira, Kumada, Stille*)	Color: Black Density: 0.300 - 0.400 g/mL Solvent Compatibility: 1 Prolonged Storage: 3 Shelf Life: 2 Years
SiliaBond Piperazine • PN: R60030B • Loading: ≥ 0.83 mmol/g • Endcapping: Yes		Used deprotecting and scavenging agent for Fmoc and Bsmoc amino protecting groups and as a solid-phase Knoevenagel catalyst. SiliaBond Piperazine may also be used to scavenge electrophiles.	Knoevenagel synthesis, Fmoc and Bsoc deprotection, organic scavenger	Color: Off-white Density: 0.671 g/mL Solvent Compatibility: 1 Prolonged Storage: 1 Shelf Life: 2 Years
SiliaBond Piperidine • PN: R71530B • Loading: ≥ 1.03 mmol/g • Endcapping: Yes		Used for the Knoevenagel condensation between carbonyl compounds and methylene malonic esters, to produce several important products, including nitriles used in anionic polymerization and unsaturated ester intermediates.	Knoevenagel condensation	Color: Off-white Density: 0.660 g/mL Solvent Compatibility: 1 Prolonged Storage: 2 Shelf Life: 2 Years
SiliaBond Propylsulfonic Acid (*SCX-2*) • PN: R51230B • Loading: ≥ 0.63 meq/g • Endcapping: Yes		Supported sulfonic acid presenting a slighly more non-polar character than the SCX, thus reducing secondary interactions.	Acid catalysts, strong cation exchanger (*SCX*) for the amine "Catch and Release" purification	Color: Off-white Density: 0.728 g/mL Solvent Compatibility: 1 Prolonged Storage: 1 Shelf Life: 2 Years
SiliaCat Pt⁰ • PN: RD-R820-100 • Loading: 0.15 - 0.25 mmol/g (*2.9 - 4.9 % Pt*) • Endcapping: Yes		Patent-protected sol-gel-entrapped Pt nanocatalyst used for selective reduction and hydrosilylation reactions.	Selective reduction of nitroarenes, hydrosilylation	Color: Black Density: 0.300 - 0.400 g/mL Solvent Compatibility: 1 Prolonged Storage: 3 Shelf Life: 2 Years
SiliaBond Tosic Acid (*SCX*) • PN: R60530B • Loading: ≥ 0.54 meq/g • Endcapping: Yes		SiliaBond Tosic Acid is a strong acid. The aromatic ring makes it slightly more acidic than other supported sulfonic acids Used as an acid catalyst for Fischer-Speier esterification provides excellent conversion.	Fischer-Speier esterification, deprotection of aromatic ethers, Fries rearrangement	Color: Off-white Density: 0.698 g/mL Solvent Compatibility: 2 Prolonged Storage: 1 Shelf Life: 2 Years
SiliaBond Tosyl Chloride • PN: R44030B • Loading: ≥ 0.63 mmol/g • Endcapping: Yes		SiliaBond Tosyl Chloride readily reacts with nucleophiles such as amines and alcohols. Reaction with alcohols yields the bound tosylate, which can then be used to synthesize amines and oxazolines.	Amine and oxazoline synthesis	Color: Off-white Density: 0.761 g/mL Solvent Compatibility: 4 Prolonged Storage: 3 Shelf Life: 6 months

[a] **Solvent Compatibility:**
1- All solvents, aqueous and organic
2- All organic solvents
3- Anhydrous aprotic solvents
4- Anhydrous aprotic solvents, unstable in DMF
5- Anhydrous CH_2Cl_2

[b] **Prolonged Storage:**
1- Keep dry
2- Keep cool (≤ *8°C*) and dry
3- Keep cool (≤ *8°C*), dry, and under inert atmosphere

Typical Reactions Selection Tables

Catalysts, Reagents, and Oxidants

A quick overview of how leach-free supported silicas can improve and ease your synthesis, either acting as:

1) supported catalysts, reagents or oxidants

2) metal / organic chelator to purify final mixtures contaminated by excess homogeneous reagent or metallic residue.

SiliaBond Reagents and Oxidants / SiliaCat Heterogeneous Catalysts Reactions Selection Table

Reaction	Best SiliaBond / SiliaCat for Synthesis	Best SiliaBond Organic Scavenger to Remove Excess Reagent — OR — Best SiliaMetS Metal Scavenger to Remove Excess Metal from Catalyst
Acylation / Esterification	• **SiliaBond DMAP** • **SiliaBond Tosic Acid**	• Various SiliaMets Metal Scavengers to remove metallic residues from homogeneous catalyst
Alkylation / Etherification	• **SiliaBond Guanidine**	• Various SiliaMets Metal Scavengers to remove metallic residues from homogeneous catalyst • SiliaBond Carbonate to remove excess homogeneous HOBt
Amide Coupling	• **SiliaBond Carbodiimide**	• SiliaBond Amine to remove excess acid chloride • SiliaBond Carbamate or Tosic Acid to remove excess amine
Catalytic Hydrogenation	• **SiliaCat Pt^0**	• SiliaMetS Thiol, Thiourea or DMT to remove Pd • SiliaMetS DMT, Diamine or Triamine to remove Pt • SiliaMetS DMT, DOTA, Imidazole or TAAcONa to remove Ni
Coupling Reactions Buchwald Amination, Heck, Kumada, Negishi, Sonogashira, Stille & Suzuki Couplings, and more.	• **SiliaCat DPP-Pd** • **SiliaCat Pd^0**	• SiliaBond Carbamate or Tosic Acid to remove excess amine • SiliaMetS Thiol, Thiourea or DMT to remove Pd • SiliaMetS DMT, DOTA, Imidazole or TAAcONa to remove Ni • SiliaMetS DOTA, Imidazole or TAAcONa to remove Cu
Deprotection of Aromatic Ether	• **SiliaBond Tosic Acid**	-
Ether Formation	• **SiliaBond Tosic Acid**	-
Fmoc, Bsmoc Deprotection of Amino Acid	• **SiliaBond Piperazine**	• SiliaBond Amine, DMAP, Piperazine, SiliaMetS Diamine or Triamine to remove excess FMOC-Cl or Bsmoc-Cl
Fries-Speier Esterification	• **SiliaBond Tosic Acid**	-
Grubbs Metathesis	-	• SiliaMetS DMT or Cysteine to remove Ru
Immobilization of molecules bearing amino, hydroxy, mercapto and thiocarboxylic acid groups	• **SiliaBond Glycidoxy**	-
Knoevenagel Condensation	• **SiliaBond Amine** • **SiliaBond Piperidine** • **SiliaBond Piperazine**	-
Michael Addition	• **SiliaBond Guanidine**	• SiliaMetS TAAcONa to remove Li • SiliaMetS Thiol, Thiourea or DMT to remove Pd
Nitro-Aldol (*or Henry*) Reaction	• **SiliaBond Carbonate**	• SiliaMetS DOTA, Imidazole or TAAcONa to remove Cu
Oxidation — Alcohols to acids	• **SiliaBond $KMnO_4$**	-
Oxidation — Alcohols to ketones / aldehydes	• **SiliaBond PCC and PDC**	-
Reduction (*Reductive Amination, Alkylation, etc.*)	• **SiliaBond Cyanoborohydride**	• SiliaBond Tosic Acid to remove excess borohydride or excess amine
Ring-Opening Reactions & Hydrolysis	• **SiliaBond Glycidoxy**	-
Sharpless Dihydroxylation	-	• SiliaMetS Thiol, DMT, Cysteine, Imidazole, TAAcOH or TAAcONa to remove Os
Tosylate Formation	• **SiliaBond Tosyl Chloride**	-
Urea Synthesis	• **SiliaBond DMAP**	• SiliaBond Amine to remove excess isocyanate
Williamson Ether Synthesis	• **SiliaBond Guanidine**	-

Acids and Bases

SiliaBond Acids and Bases Typical Reactions Selection Table		
Classification	**Best SiliaBond Acids & Bases**	**Typical Reactions & Applications Examples**
Acids	**SiliaBond Carboxylic Acid**	• Nucleophilic acyl substitutions: ester hydrolysis, Fischer esterifications, amide hydrolysis, etc. • A chromatographic phase Weak Cation Exchanger at pH ≥ 6.8 that can be eluted at a pH ≤ 2.8
	SiliaBond Propylsulfonic Acid	• Nucleophilic acyl substitutions such as transesterifications, etc. • Carbon-carbon coupling reactions
	SiliaBond Tosic Acid	• A Strong Cation Exchanger that is permanently negatively charged (*pKa < 1*) • Ionic scavenging • Deprotections of aromatic ethers • Fries rearrangements
Bases	**SiliaBond Amine**	• Organic scavenging of electrophiles • Ionic scavenging • Nucleophilic-catalyzed reactions • Acid-catalyzed reactions: Aldol reactions, Retro-Claisen reaction, Mannich reactions, etc.
	SiliaBond Carbonate	• Ionic scavenging • Nitro-Aldol (*Henry*) reactions & Michael additions • Amine free-basing • Compatible with solvent-free conditions
	SiliaBond Guanidine	• Alkylations • Strecker-type reactions • Etherifications such as Williamson synthesis • Michael additions and more generally speaking 1,4 addition reactions • Ionic scavenging • Deprotonates moderately acidic hydrogens
	SiliaBond Piperazine	• Deprotecting and scavenging agent for Fmoc and Bsmoc amino protecting groups • Knoevenagel condensations • Ionic & nucleophile scavenger
	SiliaBond Piperidine	• Deprotecting and scavenging agent for Fmoc and Bsmoc amino protecting groups • Knoevenagel condensations • Ketones to enamines conversions • Production of dipiperidinyl dithiuram tetrasulfide (*rubber vulcanization accelerator*)

General Recommandations for Reagents and Oxidants

Number of mol % of SiliaBond

The number of molar equivalents to be used greatly varies according to reactions, synthetic conditions, substrates, etc. We suggest starting with 1 - 2 mol % of reagent for initial experiments. Afterward, this quantity can absolutely be optimized.

Solvent

All SiliaBond are compatible with a wide range of organic and aqueous solvents commonly used in laboratory and in process work, such as DMF, DMSO, THF, ACN, alcohols, ethers, chlorinated solvents, water, etc. However, the nature of the solvent does sometimes influence the catalytic efficiency. If yield is low or kinetics are too slow, changing solvent or adding a co-solvent should be considered.

Solution Concentration

At low substrate concentration, the activity of the reagent is directly proportional to the number of moles of substrate available. If you increase the concentration of the substrate, the activity will increase until the active sites become saturated. So the substrate concentration is a parameter that needs to be optimized to develop your synthetic conditions.

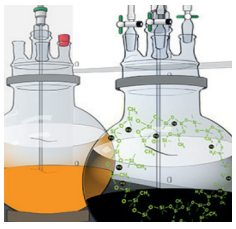
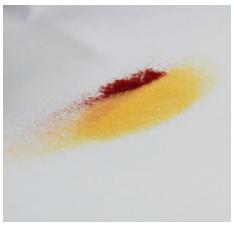
Temperature

We recommend running the experiments at room temperature. In the optimization step, the temperature can be adjusted, if needed.

Stirring

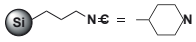
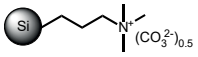
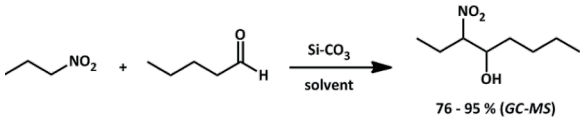
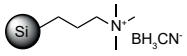
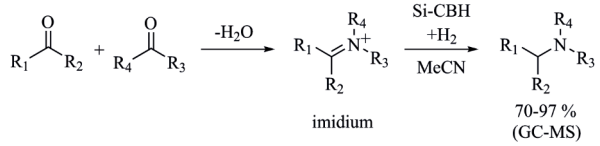
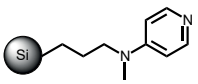
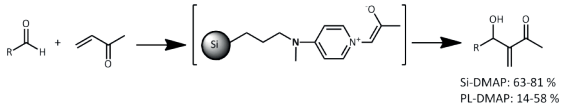
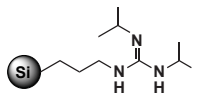
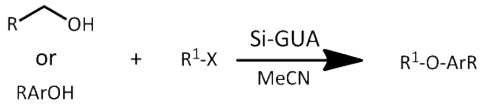
Mechanical stirring is recommended.



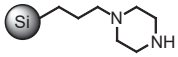
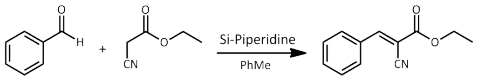
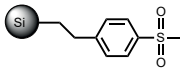
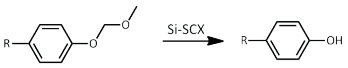
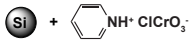
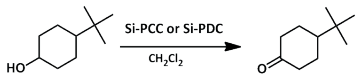
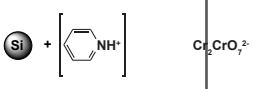



Typical Experimental Procedures

SiliaBond Reagents and Oxidants Typical Experimental Procedures

Type	Products	Structure	Typical Reactions	Reaction Examples and Procedure
REAGENTS	**SiliaBond Carbodiimide** • PN: R70530B • Loading: ≥ 0.91 mmol/g • Endcapping: Yes • Solvent Compatibility: Anhydrous aprotic • Storage: Cool (≤ 8°C), dry & under argon		Amide coupling with acids, acyl chlorides and amines	 The indomethacin (*0.56 mmol*) was placed in an oven-dried reaction vial in anhydrous dichloromethane (*5 mL*) under N_2. HOBt (*0.95 mmol*) and SiliaBond Carbodiimide (*1.12 mmol*) were added, and the mixture was stirred briefly (*5 min*). Then, the amine (*0.56 mmol*) was added to the vial, and the reaction was stirred at room temperature for 16 h. Finally, the crude product was directly purified on a short plug of silica gel (*hexane / EtOAc 1/1*) to yield pure amide.
	SiliaBond Carbonate • PN: R66030B • Loading: ≥ 0.46 mmol/g • Density: 0.608 g/mL • Endcapping: Yes • Solvent Compatibility: Anhydrous aprotic • Storage: Cool (≤ 8°C), dry		Nitro-Aldol reactions (*Henry reaction*), free basing of amine	 76 - 95 % (*GC-MS*) 1-nitropropane (*1 eq.*) was added to a solution containing THF (*5 mL*) and valeraldehyde (*1 equiv*). SiliaBond Carbonate (*0.1 equiv*) was added, and the mixture was stirred at room temperature for 6 h. The reaction mixture was then filtered and washed with THF and the crude product was evaporated. Pure product was obtained after flash chromatography purification using a mix of hexane / ethylacetate (*80/20*).
	SiliaBond Cyanoborohydride • PN: R66730B • Loading: ≥ 0.87 mmol/g • Density: 0.705 g/mL • Endcapping: Yes • Solvent Compatibility: All • Storage: Cool (≤ 8°C), dry & under argon		Reductive amination	 imidium 70-97 % (GC-MS) To 1 mmol of SiliaBond Cyanoborohydride, acetonitrile (*5 mL*), the aldehyde or ketone (*0.5 mmol*) and the amine (*0.5 mmol*) were added. The reaction mixture was stirred at room temperature for 16 h.
	SiliaBond DMAP • PN: R75630B • Loading: ≥ 0.53 mmol/g • Density: 0.674 g/mL • Endcapping: Yes • Solvent Compatibility: All • Storage: Cool (≤ 8°C), dry & under argon		Acylations, esterification	 Si-DMAP: 63-81 % PL-DMAP: 14-58 % Aldehyde (*1 mmol*) was placed in a flask, and THF, SiliaBond DMAP (*0.10 mmol*), water and the enone (*2 mmol*) were added. The mixture was stirred at room temperature for 6 to 96 h.
	SiliaBond Guanidine • PN: R68230B • Loading: ≥ 0.80 mmol/g • Endcapping: Yes • Solvent Compatibility: All • Storage: Cool (≤ 8°C), dry		Williamson ether synthesis, Strecker-type reactions, 1,4 addition reactions	 0.15 mmol of alcohol was added to acetonitrile (*4 mL*) and SiliaBond Guanidine (*0.3 equiv*). The solution was stirred for 1 h at room temperature. Next, the alkyl halide (*0.12 mmol*) was transferred to the reaction mixture, which was again stirred for 16 h at 60°C. Finally, the mixture was filtered and washed with 2 mL of acetonitrile.

SiliaBond Reagents and Oxidants Typical Experimental Procedures

Type	Products	Structure	Typical Reactions	Reaction Examples and Procedure
REAGENTS	**SiliaBond Piperidine** • PN: R71530B • Loading: ≥ 1.03 mmol/g • Density: 0.660 g/mL • Endcapping: Yes • Solvent Compatibility: All • Storage: Cool (≤ 8°C) & dry		Knoevenagel condensation	 75-90% (*GC-MS*) The reactor was charged with 10 mol % of SiliaBond Piperidine (*1.36 g*) and heated at 110°C using toluene as solvent. A mixture of 15 mmol of benzaldehyde, 1.5 eq. of ethylcyanoacetate in 110 mL of toluene was stirred at room temperature for 5 minutes. The mixture was then introduced in a glass bottle directly connected to the pump. Upon completion of the reaction, the reaction mixture was evaporated and the crude product analyzed by GC/MS to determine the conversion ratio.
	SiliaBond Tosic Acid (*SCX*) • PN: R60530B • Loading: ≥ 0.54 meq/g • Density: 0.743 g/mL • Endcapping: Yes • Solvent Compatibility: Organic solvents • Storage: Dry		Fischer-Speier esterification, deprotection of aromatic ethers, Fries rearrangement	 83-100% (*GC-MS*) A mixture of 1-(4-(MOM)phenyl)ethanone *(2.5 mmol)* and 0.05 equiv of SiliaBond Tosic Acid (*0.8 mmol/g*) in 10 mL of toluene / water (*10/0.5*) was stirred at 65°C for 4 h. The reaction mixture was filtered and the solvent was evaporated. The crude product obtained was analyzed by GC/MS.
OXIDANTS	**SiliaBond $KMnO_4$** • PN: R23030B • Loading: 10 % w/w • Density: 0.593 g/mL • Endcapping: No • Solvent Compatibility: Anhydrous dichloromethane • Storage: Dry		Oxidation of alcohols to acids	Add 1 - 2 equiv of SiliaBond $KMnO_4$ relative to the limiting reagent. Filter at the end of the reaction to remove spent reagent.
	SiliaBond Pyridinium Chlorochromate (*PCC*) • PN: R24030B • Loading: 20 % w/w • Density: 0.693 g/mL • Endcapping: No • Solvent Compatibility: Anhydrous dichloromethane • Storage: Cool (≤ 8°C) & dry		Oxidation of alcohols to aldehydes or ketones	 SiliaBond PDC or SiliaBond PCC (*2 equiv*) and acetic acid *(4 mmol)* were added to a solution of the alcohol in CH_2Cl_2 (*7.5 mL*). The resulting mixture was stirred for 6 h at room temperature. Ether (*15 mL*) was added, and after stirring for another 2 min, the solution was filtered and the solids were washed with ether (*4 x 9 mL*). Concentration under vacuum afforded the required product.
	SiliaBond Pyridinium Dichromate (*PDC*) • PN: R24530B • Loading: 20 % w/w • Density: 0.651 g/mL • Endcapping: No • Solvent Compatibility: Anhydrous dichloromethane • Storage: Cool (≤ 8°C) & dry			

Suzuki Couplings over SiliaCat DPP-Pd

Reaction in batch mode

- Using the appropriate apparatus recommended for the screening or for the reusability reactions, the aryl halide substrate and the reagents are added to the reaction solvent.
- The mixture is then warmed to the desired temperature after which SiliaCat DPP-Pd is added.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion is observed (*as determined by TLC or GC/MS analysis*).

Reaction in flow

- Solution Preparation:
  - Solution 1: aryl halide (*1 equiv*) in THF (*0.8 M*)
  - Solution 2: boronic acid (*1.25 equiv*) and base (*1.5 equiv*) in EtOH / H_2O
- Both solutions are pumped using the flow system and mixed in a T-piece device and are driven through a preheated glass column reactor with an adjustable end (*0.785 cm ID × 6.5 cm length*) packed manually with the SiliaCat DPP-Pd.

Work-up

Catalyst recovery

- Once the reaction is deemed complete (*as determined by TLC or by GC/MS analysis*), the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- The catalyst (*between 0.25 - 1.00 g*) is washed with EtOAc (*2 x 15 mL*), EtOH / H_2O (*v/v, 1/1, 3 x 15 mL*) and THF (*2 x 15 mL*).
- The catalyst is dried under air at room temperature and can be stored in a closed vessel prior to reuse. For prolonged storage, keep under argon at 8°C.

Isolation of the coupling product

- The filtrate is concentrated in vacuo and the residue is dissolved in EtOAc or Et_2O.
- The organic layer is then washed twice with water.
- The organic layer is dried using anhydrous magnesium sulfate and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Suzuki Coupling Reactions in Flow over SiliaCat DPP-Pd

Substrates	*Solution 1*: Aryl-Halide 0.79 M in THF (*HPLC Grade*)
Boronic Acid	*Solution 2*: Boronic acid (*1.25 equiv*) and base K_2CO_3 (*1.5 equiv*) in EtOH / H_2O (*1:1.15, v/v, 0.45 M in regards to boronic acid*)
SiliaCat Catalyst	Preheated glass column reactor with an adjustable end (*0.785 cm ID × 6.5 cm length*) charged with SiliaCat DPP-Pd.
Temperature	70°C
Residence Time	2.85 min
Flow Rate	For 0.75 mL/min: *solution 1:* 0.25 mL/min & *solution 2:* 0.50 mL/min

Suzuki Coupling Reactions over SiliaCat DPP-Pd

Substrates	Aryl-Iodide (*1 equiv*)	Aryl-Bromide (*1 equiv*)	Aryl-Chloride (*1 equiv*)
Boronic Acid	1.2 equiv		
Base [K_2CO_3]	1.5 equiv [*alternate bases: Na_2CO_3, $KHCO_3$, $NaHCO_3$, NaOH, KOH, NaOAc, KOAc*]		
SiliaCat Loading	≤ 0.5 mol % Pd		≤ 1.0 mol % Pd
Best Solvents & Temperature	MeOH or EtOH	EtOH	
	[*alternate solvents: n-PrOH, i-PrOH, 2-BuOH, THF / H_2O (20 %), Toluene / H_2O (20 %)*] ; 1 - 2°C under boiling point		
Reaction Time	0.5 - 2.0 h		
Typical Scale	• Under magnetic stirring for screening: 6 mmol scale of aryl halide in 12 mL solvent. • Under mechanical stirring for reusability: 25 mmol scale of aryl halide in 50 mL solvent.		

Optimization steps (*can be used for all coupling reactions*)

If the reaction fails or if the conversion of the aryl halide is not complete, optimization steps can be undertaken. The example below presents the pathway (*order*) you need to follow to optimize your reaction. Always using 1.0 mol % SiliaCat DPP-Pd:

Step 1: Solvent Screening
Different solvents may be tried, such as: MeOH, EtOH, *n*-PrOH, *i*-PrOH, 2-BuOH, THF / H_2O (*20 %*) or Toluene / H_2O (*20 %*).

↓

Step 2: Solvent Concentration Optimization
Once the best solvent has been determined, different concentrations (*from 0.25 M to 1.0 M*) should be explored.

↓

Step 3: Base Concentration Screening
Using the best solvent and concentration, different amounts of K_2CO_3 (*from 1.25 equiv to 2 equiv*) should be tried.

↓

Step 4: Amount of Boronic Acid
Then, the number of molar equivalents of boronic acid (*from 1.1 equiv to 1.5 equiv*) should be varied.

↓

Step 5: SiliaCat Palladium Loading (*mol %*)
Finally, the loading of SiliaCat DPP-Pd should be optimized.

↙ ↘

If the reaction **is not complete**, the amount of catalyst should be increased up to 1.0 mol % of SiliaCat DPP-Pd.

If the reaction **is complete**, the catalyst loading can be decreased to as low as 0.1 mol % Pd (*or less in some cases*).

Borylation over Silia*Cat* DPP-Pd

Reaction in batch mode

- Using the appropriate apparatus recommended for the screening or for the reusability reactions, bis(pinacolato)diboron and the base are added to the reaction solvent.
- After 5 minutes stirring, the aryl halide is added to the resulting mixture.
- The mixture is then warmed to the desired temperature after which Silia*Cat* DPP-Pd is added.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion is observed (*as determined by TLC or GC/MS analysis*).

Work-up

Catalyst recovery

- Once the reaction is deemed complete (*as determined by TLC or by GC/MS analysis*), the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- The catalyst (*between 0.25 - 1.00 g*) is washed with EtOAc (*2 x 15 mL*), EtOH / H_2O (*v/v, 1/1, 3 x 15 mL*) and THF (*2 x 15 mL*).
- The catalyst is dried under air at room temperature and can be stored in a closed vessel prior to reuse. For prolonged storage, keep under argon at 8°C.

Isolation of the coupling product

- The filtrate is concentrated in vacuo and the residue is dissolved in EtOAc or Et_2O.
- The organic layer is then washed twice with water.
- The organic layer is dried using anhydrous magnesium sulfate and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Miyaura Borylation Reactions over Silia*Cat* DPP-Pd

Substrates	Aryl-Iodide (*1 equiv*)	Aryl-Bromide (*1 equiv*)	Aryl-Chloride (*1 equiv*)
Bis(pinacolato)diboron	1.2 equiv		1.5 equiv
Base KOAc	2.2 equiv		3.0 equiv
Silia*Cat* Loading	≤ 2.0 mol % Pd		
Best Solvents (*anhydrous*)	*i*-PrOH (*0.75 M*)*		*i*-PrOH (*1.25 M*)*
	[*alternate solvents: 2-BuOH, DMF, EtOH (anhydrous solvents)*]		
Temperature	80 - 82°C		
Reaction Time	0.5 - 3.0 h		3.0 - 20 h
Typical Scale	• Under magnetic stirring for screening: 10 mmol scale of aryl halide in 30 mL solvent (*for Ar-Br and Ar-Cl*) or in 20 mL solvent (*for Ar-I*) • Under mechanical stirring for reusability: 20 mmol scale of aryl halide in 60 mL solvent (*for Ar-Br and Ar-Cl*) or in 40 mL solvent (*for Ar-I*).		

* Molar concentration compared to the substrate

One-Pot Miyaura Borylation / Suzuki Coupling

Step 1: Miyaura borylation reaction

- Using the appropriate apparatus recommended for the screening or the reusability reactions, the bis(pinacolato)diboron and the base are added to the reaction solvent.
- After 5 minutes of stirring, the aryl halide (*substrate 1*) is added to the resulting mixture and is then warmed up to the desired temperature after which Silia*Cat* is added.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion is observed (*as determined by TLC or GC/MS analysis*). No work-up is performed after the borylation in the first step.

Step 2. Suzuki-Miyaura coupling reaction

- After maximum conversion of substrate 1 (*as determined by TLC or GC/MS analysis*), substrate 2 (*aryl bromide or aryl chloride*) and an aqueous K_2CO_3 solutions are added to the reaction mixture.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion of boronic acid obtained in step 1 is reached (*as determined by TLC or GC/MS analysis*).

Work-up

Catalyst recovery

- Once the reaction is deemed complete as determined by TLC or by GC/MS analysis, the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- Silia*Cat* (*between 0.25 - 1.00 g*) is washed with EtOAc (*2 x 15 mL*), EtOH / H_2O (*v/v, 1/1, 3 x 15 mL*) and THF (*2 x 15 mL*).
- Silia*Cat* is dried under air at room temperature and can be stored in a closed vessel prior to reuse in these conditions.

Isolation of the coupling product

- The filtrate is concentrated in vacuo and the residue is dissolved in ethyl acetate (*EtOAc*) or diethyl ether (*Et_2O*).
- The organic layer is then washed twice with water.
- The organic layer is dried using anhydrous magnesium sulfate and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Step 1: Miyaura Borylation Reaction Using Silia*Cat* DPP-Pd

Substrates 1	Aryl-Bromide (*1 equiv*)	Aryl-Chloride (*1 equiv*)
Bis(pinacolato)diboron	1.1 equiv	
Base: KOAc	2.2 equiv	
Silia*Cat* Loading	≤ 2.0 mol % Pd	
Best Solvents (*anhydrous*)	*i*-PrOH (*0.75 M*)	*i*-PrOH (*0.75 M*) or 2-BuOH (*1.00 M*)
	Molar concentration with respect to the substrate and the bis(pinacolato)diboron	
Temperature	80 - 82°C	
Reaction Time	0.5 - 3 h	3 - 20 h

Step 2: Suzuki-Miyaura Coupling Using Silia*Cat* DPP-Pd

Substrates 2	Aryl Bromide (*1.2 equiv*)	Aryl Chloride (*1.2 equiv*)
Base K_2CO_3	2.3 equiv	
Co-solvent	H_2O (*i-PrOH / H_2O, 3.5:1, v/v*)	H_2O (*2-BuOH / H_2O, 2.6:1, v/v*)
Temperature	80 - 80°C	96 - 98°C
Reaction Time	2 - 4 h	2 - 17 h
Typical Scale	• Under magnetic stirring for screening: 10 mmol scale of aryl halide in 30 mL of *i*-PrOH or in 20 mL of 2-BuOH. • Under mechanical stirring for reusability: 20 mmol scale of aryl halide in 60 mL of *i*-PrOH or in 40 mL of 2-BuOH.	

Negishi Couplings in Flow Using SiliaCat DPP-Pd

Reaction

- Solution Preparation:
  - *Solution 1*: aryl halide (*1 equiv*) in dry THF (*0.20 M*)
  - *Solution 2*: organozinc reagent (*1.3 equiv*) in dry toluene (*0.30 M*)
- The two solutions are pumped using the flow system.
- The solutions, mixed in a T-piece device, are driven through a preheated glass column reactor with an adjustable end (*0.785 cm ID × 6.5 cm length*) packed manually with SiliaCat DPP-Pd (*1 g*).
- The conversion of the aryl halide is monitored at the reactor outlet using GC/MS.

Work-up

Isolation of the coupling product

- The outlet solution is concentrated in vacuo and the residue is redissolved in ethyl acetate (*EtOAc*) or diethyl ether (Et_2O).
- The organic layer is then washed twice with water and once with brine.
- The organic layer is separated, dried using anhydrous magnesium sulfate, filtered and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Negishi Coupling in Flow Using SiliaCat DPP-Pd

Substrates	Solution 1: Halide & Pseudohalide Solution, 0.25 M in Anhydrous THF (*1 equiv*)
R_1R_2Zn	Solution 2: Organozinc solution, 0.30 M in anhydrous toluene (*1.3 equiv*)
SiliaCat Catalyst (*column reactor*)	Preheated glass column reactor with an adjustable end (*0.785 cm ID x 6.5 cm length*) charged with 1 g supported catalyst.
Temperature	60°C
Residence Time	3 min
Flow Rate	Solution 1: 0.20 mL/min Solution 2: 0.30 mL/min

Heck Couplings over SiliaCat DPP-Pd

Reaction in batch mode

- Using the appropriate apparatus recommended for the screening or for the reusability reactions, the aryl halide substrate and the reagents are added to the reaction solvent.
- The mixture is then warmed to the desired temperature after which SiliaCat DPP-Pd is added.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion is observed (*as determined by TLC or GC/MS analysis*).

Work-up

Catalyst recovery

- Once the reaction is deemed complete as determined by TLC or by GC/MS analysis, the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- The catalyst (*between 0.25 - 1.00 g*) is washed with EtOAc (*2 x 15 mL*), EtOH / H_2O (*v/v, 1/1, 3 x 15 mL*) and THF (*2 x 15 mL*).
- The catalyst is dried under air at room temperature and can be stored in a closed vessel prior to reuse. For prolonged storage, keep under argon at 8°C.

Isolation of the coupling product

- The filtrate is concentrated in vacuo and the residue is dissolved in EtOAc or Et_2O.
- The organic layer is then washed twice with water.
- The organic layer is dried using anhydrous magnesium sulfate and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Heck Coupling Reactions over SiliaCat DPP-Pd

Substrates	Aryl-Iodide (*1 equiv*)	Aryl-Bromide (*1 equiv*)
Olefin	1.5 equiv	
Base	1.5 equiv [Et_3N or NaOAc]	1.5 equiv [NaOAc]
SiliaCat Loading	≤ 0.5 mol % Pd	
Best Solvents & Temperature	MeCN (*80°C*) or DMF (*120°C*)	DMF (*120°C*)
Reaction Time	20 - 24 h	
Typical Scale	• Under magnetic stirring for screening: 20 mmol scale of aryl halide in 15 mL MeCN or in 20 mL DMF. • Under mechanical stirring for reusability: 40 mmol scale of aryl halide in 30 mL MeCN or in 40 mL DMF.	

Sonogashira Couplings over SiliaCat

Reaction in batch mode

- Using the appropriate apparatus recommended for the screening or for the reusability reactions, the aryl halide substrate and the reagents are added to the reaction solvent.
- The mixture is then warmed to the desired temperature after which SiliaCat DPP-Pd or Pd^0 is added.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion is observed (*as determined by TLC or GC/MS analysis*).

Work-up

Catalyst recovery

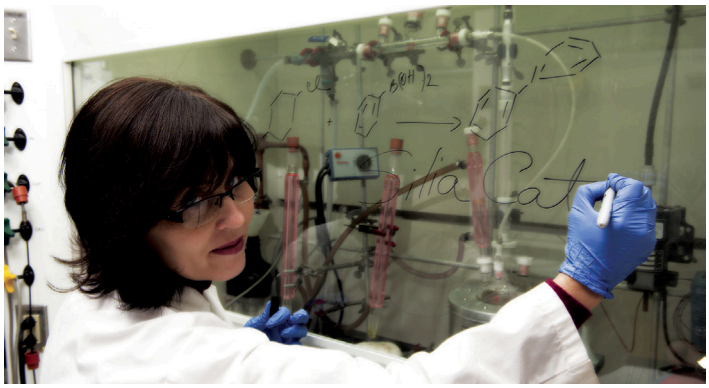
- Once the reaction is deemed complete (*as determined by TLC or by GC/MS analysis*), the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- The catalyst (*between 0.25 - 1.00 g*) is washed with EtOAc (*2 x 15 mL*), EtOH / H_2O (*v/v, 1/1, 3 x 15 mL*) and THF (*2 x 15 mL*).
- The catalyst is dried under air at room temperature and can be stored in a closed vessel prior to reuse. For prolonged storage, keep under argon at 8°C.

Isolation of the coupling product

- The filtrate is concentrated in vacuo and the residue is dissolved in EtOAc or Et_2O.
- The organic layer is then washed twice with water.
- The organic layer is dried using anhydrous magnesium sulfate and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Sonogashira Coupling Reactions over SiliaCat Catalysts

Products	Aryl Iodide	Aryl Bromide
Alkyne	1.2 equiv	1.3 equiv
Base	K_2CO_3 2.0 equiv	KOAc 2.0 equiv
SiliaCat Catalyst	SiliaCat DPP-Pd or Pd^0 (*CuI free*)	
SiliaCat Loading	≤ 1.0 mol % (*DPP-Pd*) ≤ 0.5 mol % (*Pd^0*)	≤ 2.0 mol %
Best Solvent (*HPLC Grade*) & Temperature	MeOH (*63°C*) or EtOH (*77°C*)	DMF or DMAc (*80°C*)
Reaction Time	0.5 - 4.0 h	2.0 - 4.0 h
Typical Scale	• Under Magnetic Stirring for Screening: 6 mmol scale of aryl iodide in 60 mL MeOH or EtOH. • Under Mechanical Stirring for Resusability: 20 mmol scale of aryl bromide in 40 mL solvent.	



Stille & Kumada Couplings over SiliaCat DPP-Pd

Reaction in batch mode

- Using the appropriate apparatus recommended for the screening or for the reusability reactions, the aryl halide substrate and the reagents are added to the reaction solvent.
- The mixture is then warmed to the desired temperature after which SiliaCat DPP-Pd is added.
- The reaction mixture is then vigorously stirred (*700 RPM*) until maximum conversion is observed (*as determined by TLC or GC/MS analysis*).

Work-up

Catalyst recovery

- Once the reaction is deemed complete as determined by TLC or GC/MS analysis, the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- The catalyst (*between 0.25 - 1.00 g*) is washed with EtOAc (*2 x 15 mL*), EtOH / H_2O (*v/v, 1/1, 3 x 15 mL*) and THF (*2 x 15 mL*).
- The catalyst is dried under air at room temperature and can be stored in a closed vessel prior to reuse. For prolonged storage, keep under argon at 8°C.

Isolation of the coupling product

- The filtrate is concentrated in vacuo and the residue is dissolved in EtOAc or Et_2O.
- The organic layer is then washed twice with water.
- The organic layer is dried using anhydrous magnesium sulfate and then concentrated in vacuo, yielding a high purity crude product that typically does not require extensive purification. If needed, a flash chromatography can be done.

Stille Coupling Reactions over SiliaCat DPP-Pd

Substrates	Aryl-Iodide (*1 equiv*)	Aryl-Bromide (*1 equiv*)
$R'SnBu_3$	1.1 equiv	
Additive (*CsF*)	2.0 equiv (*if needed for higher conversion*)	
SiliaCat Loading	≤ 2.0 mol % Pd	≤ 10 mol % Pd
Best Solvent & Temperature	Dioxane (*100°C*) or Toluene (*100°C*)	
Reaction Time	18 - 24 h	
Typical Scale	• Under magnetic stirring for screening: 3 mmol scale of aryl halide in 30 mL solvent. • Under mechanical stirring for reusability: 5 mmol scale of aryl halide in 50 mL solvent.	

Kumada Coupling Reactions over SiliaCat DPP-Pd

Substrates	Aryl-Iodide (*1 equiv*)	Aryl-Bromide (*1 equiv*)
R'MgBr	2.0 equiv Ph MgBr, *i*-BuMgBr, *i*-PrMgBr	
SiliaCat Loading	≤ 2.0 mol %	≤ 10 mol %
Best Solvent & Temperature	THF (*60°C*)	
Reaction Time	18 - 24 h	
Typical Scale	• Under magnetic stirring for screening: 3 mmol scale of aryl halide in 35 - 60 mL anhydrous solvent under inert conditions. • Under mechanical stirring for reusability: 3 mmol scale of aryl halide in 35 - 60 mL anhydrous solvent under inert conditions.	

Hydrosilylation Reactions Using SiliaCat Pt⁰

Note: The reaction can be performed without solvent or in anhydrous solvent. The catalytic tests were run under an atmosphere of air, in a classic 100mL glass reactor equipped with mechanical stirring and temperature control systems. The stirring rate was 700 rpm.

- Using mechanical stirring setup and dry vessel, the desired amount of SiliaCat Pt⁰ is added.
- Olefin (*or olefin solution*) is added.
- Under mechanical stirring, the olefin (*or olefin solution*) / catalyst mixture is heated up to the desired temperature. Then, the silane is added at 1 mL/min with an additional ampoule.
- Temperature of the reaction medium was maintained (*without specifications*) between 65°C and 85°C removing partly or totally the heating mantles.
- Reaction mixture is then vigorously stirred (*700 rpm*) until maximum conversion is observed.
- Samples are regularly collected, diluted in anhydrous CH_2Cl_2 and analysed by GC/MS checking for SiH or olefin conversion (*calibration curve, internal standard used: 1-fluoronaphatalene, mesitylene*).

Work-up

Catalyst recovery

- Once the reaction is deemed complete as determined by TLC or by GC/MS analysis, the catalyst is recovered by filtration at room temperature through a Büchner funnel using a glass fiber filter (*grade 691*).
- The catalyst (*between 0.25 - 1.00 g*) is washed with toluene (*3 x 15 mL*) and anhydrous CH_2Cl_2 (*3 x 15 mL*).
- SiliaCat is dried under air at room temperature and can be stored in a closed vessel prior to reuse in these conditions.

Isolation of the coupling product

- When a solvent is used in the reaction, the filtrate is concentrated under vacuum and the crude product is purified by distillation.
- When the reaction is run without solvent, the crude product is directly purified by distillation.

Optimization steps

If the reaction fails or if the conversion of the primary alcohol is not complete, optimization steps can be undertaken.

Step 1: handling

- Check if the reaction temperature is adequate.
- Check if the reaction mixture, which must be a two phase system, is vigorously stirred at 700 RPM.

Always using 2.0 mol % SiliaCat Pt⁰:

Step 2: solvent concentration optimization

- Always using anhydrous toluene as solvent, different alkene solvent concentrations (*from 0.25 M to 1.0 M*) should be explored.

Step 3: SiliaCat loading (*mol %*)

- Finally, the loading of SiliaCat Pt⁰ may be optimized:
  a. If the reaction is not complete, the amount of catalyst should be increased from 2.0 mol % to 2.5 mol % Pt.
  b. If the reaction is complete, the catalyst loading can be decreased from 2.0 mol % to 1 mol % or to 0.05 mol % Pt.

Hydrosilylation Reactions Using SiliaCat Pt⁰

Substrates	Olefin (*3 M in anhydrous toluene*) 1 equiv
$HSi(OEt)_3$	0.67 - 1.25 equiv
SiliaCat Catalyst	SiliaCat Pt⁰(*0.25 mmol/g Pt loading*)
SiliaCat Loading	0.01 - 0.1 mol % Pt
Best Solvent	Neat reaction of Anhydrous Toluene, CH_2Cl_2, THF
Temperature	40 - 75°C
Reaction Time	1 - 4 h
Typical Scale	Under mechanical stirring for reusability: (i) 75 mmol scale of olefins in 25 mL anhydrous solvent; (ii) 100 mmol scale olefins without solvent

Hydrogenation Using SiliaCat Pd⁰ & Pt⁰

Palladium on carbon (*Pd/C*) frequently ignites when it first comes in contact with methanol (*and to a lesser extent, any flammable organic solvent*) and as such represents a significant safety risk. Even if SiliaCat is a safer alternative, these procedures are recommended whenever this catalyst is used in conjunction with hydrogen gas.

Hydrogenation using a H_2-filled balloon *

1. Weigh out SiliaCat and transfer into a round bottom flask equipped with a condenser and a stirring bar (*we suggest using a two-neck flask*).
2. Add solvent and the reaction substrate.
3. Attach a balloon of hydrogen to the condenser with an adapter that allows the balloon to be closed off from the reaction flask.
4. While stirring, the reaction mixture is purged by cycling an inert gas (*nitrogen or argon*) and vacuo twice.
5. The reaction mixture is degassed twice with hydrogen for one minute by opening the balloon adapter OR by bubbling H_2 directly in reaction mixture.
6. The reactor is now ready for the hydrogenation reaction.

* *Bubbling H_2 in reaction mixture until achieving full H_2 atmosphere is also acceptable.*

Hydrogenation using a high pressure reactor (*bomb reactor*)

1. Weigh out SiliaCat and transfer into the appropriate bomb reactor.
2. Add solvent and the reaction substrate and seal the reactor.
3. While stirring, the reaction mixture is purged by cycling an inert gas (*nitrogen or argon*) and vacuo twice.
4. Fill the reactor with hydrogen up to the desired pressure using the gauge.
5. Seal the reactor by closing off the hydrogen source and disconnect the reactor from the regulator.
6. You can now run your hydrogenation reaction.

Work-up procedures: when the hydrogenation is finished, please use the following procedure for the work-up.

Destructive work-up (*if you do not want to reuse SiliaCat*)

1. Remove the hydrogen balloon from the flask (*for balloon reactions*) or slowly allow the reactor to return to atmospheric pressure.
2. Purge reaction vessel twice with an inert gas (*nitrogen or argon*).
3. The reaction mixture can also be purged through bubbling of nitrogen or argon for 10 - 15 minutes for added safety.
4. Under a moderate vacuum, filter the reaction mixture through a Büchner funnel using a glass fiber filter (*grade 691*).
5. Rinse the flask with your preferred solvent (*we suggest using an aprotic solvent like ethyl acetate (EtOAc) or tetrahydrofuran (THF) for safety reasons*).
6. Using the same solvent as step 5, wash SiliaCat on the Buchner to make sure any product of interest is not adsorbed on the catalyst.
7. Disconnect the Büchner funnel from the receiving flask and then add several mL of water to the filter.
8. Discard the wet SiliaCat and filtering aid in a dedicated waste jar that contains water.

Nondestructive work-up (*if you want to reuse SiliaCat for another reaction*)

Note: reusability study for large scale in progress.

1. Follow steps 1 - 4 from the procedure above (*"Destructive work-up"*).
2. Under vacuum, rinse the SiliaCat on the Buchner with an aprotic solvent (*EtOAc or THF*) using 4-fold the amount of catalyst used. DO NOT DRY COMPLETELY THE CATALYST.
3. Transfer the humid SiliaCat in a round flask and dry the solid under argon during several hours (*overnight*).
4. Store the catalyst under normal conditions, in a closed vessel prior to reuse. For prolonged storage, keep under argon at 8°C.

Caution! The catalyst can be isolated by filtration under vacuum but it should not be dried under vacuum in presence of air / methanol.

If for any reason the catalyst is dried completely under vacuo, the adsorbed hydrogen can slowly react (*after a few minutes of drying*) with oxygen to create an exothermic reaction (> *320°C*). If the catalyst is dried completely, close the vacuum and wash with water.

Squalene Hydrogenation Using SiliaCat Pd⁰

Substrates	Squalene	
SiliaCat Loading	0.1 - 1.0 mol % Pd	
Best Solvents	EtOH	EtOH or neat
Temperature	50°C	50 - 150°C
H_2 Pressure *	1 atm	1 - 20 atm
Reaction Time	4 - 8 h	2 - 24 h
Typical Scale	• Under magnetic stirring for screening: 10 mmol scale of squalene in 30 mL solvent (*HPLC grade*). • Under mechanical stirring for reusability: 50 mmol scale of squalene in 150 mL solvent (*HPLC grade*).	

Debenzylation Reactions Using SiliaCat Pd⁰

Substrates	Benzyl Protected Group
SiliaCat Loading	≤ 0.5 mol % Pd
Best Solvents	EtOH [MeOH]
Temperature	30°C
H_2 Pressure *	1 atm
Reaction Time	0.5 - 4 h or 24 h
Typical Scale	• Under magnetic stirring for screening: from 10 mmol to 20 mmol scale of benzyl protected group in 20 mL solvent (*HPLC grade*). • Under mechanical stirring for reusability: 75 mmol scale of benzyl protected group in 50 mL solvent (*HPLC grade*).

Nitroarene Hydrogenation Reactions Using SiliaCat

Substrates	Nitroarenes & Nitro-Functionalized Aryl Halides	
SiliaCat Catalyst	SiliaCat Pd⁰	SiliaCat Pt⁰
SiliaCat Loading	≤ 1.0 mol % Pd or Pt	
Best Solvents	MeOH, THF, MeTHF, EtOH	MeOH, THF, MeTHF, EtOAc, EtOH, hexane
Temperature	20 - 22°C	
H_2 Pressure *	1 atm	
Reaction Time	0.5 - 4 h	
Typical Scale	• Under magnetic stirring for screening: 2 mmol scale of functionalized nitroarene in 20 mL solvent (*HPLC grade*). • Under mechanical stirring for reusability: 20 mmol scale of functionalized nitroarene in 200 mL solvent (*HPLC grade*).	

Alkene Hydrogenation Reactions Using SiliaCat Pd⁰

Substrates	Non-Functionnalized and Functionnalized Alkenes
SiliaCat Loading	≤ 0.5 mol % Pd
Best Solvents	MeOH or EtOH [THF, MeTHF, MeOH / THF (*1:1, v/v*)]
Temperature	20 - 22°C
H_2 Pressure *	1 atm
Reaction Time	0.5 - 4 h
Typical Scale	• Under magnetic stirring for screening: 6 mmol scale of alkene in 25 mL solvent (*HPLC grade*). • Under mechanical stirring for reusability: 50 mmol scale of alkene in 200 mL solvent (*HPLC grade*).

Vegetable Oil Hydrogenation Reactions Using SiliaCat Pd⁰

Substrates	Vegetable Oils
SiliaCat Loading	≤ 0.5 mol % Pd
Best Solvents	MeOH (*0.25 M or 0.5 M*), THF, MeTHF, EtOAc, EtOH, THF / MeOH (*5:1, v/v*)
Temperature	20 - 40°C
H_2 Pressure *	1 atm
Reaction Time	0.5 - 6 h
Typical Scale	• Under magnetic stirring for screening: 15 mmol scale of fatty acid (*or vegetable oil*) in 60 mL solvent (*HPLC grade*). • Under mechanical stirring for reusability: 50 mmol scale of fatty acid (*or vegetable oil*) in 200 mL solvent (*HPLC grade*).

Optimization Steps

If the reaction fails or if the conversion is incomplete, optimization steps can be undertaken. The alkene hydrogenation example presents the pathway (*order*) you need to follow for each type of hydrogenation.

Step 1: Handling

- Ensure that the degassing step by vacuum-inert gas cycling followed by H_2 purge is performed adequately.
- Ensure that the internal reaction temperature is at least 20°C. The hydrogenation reaction is an exothermic reaction.

Always using 0.1 mol % SiliaCat Pd^0:

Step 2: Solvent Screening

Different solvents may be tried such as MeOH, EtOH, EtOAc, THF, MeTHF, hexane.

For substrates poorly soluble in MeOH, the preferred solvent system is MeOH-THF (*1:1, v/v*).

Step 3: Solvent Concentration Optimization

Once the best solvent has been determined, different alkene solvent concentrations (*from 0.25 M to 1.0 M*) should be explored.

Step 4: SiliaCat Loading (*mol %*)

Finally, the loading of SiliaCat Pd^0 should be optimized.

If the reaction **is not complete**, the amount of catalyst should be increased from 0.1 mol % to 0.5 mol % or to 1.0 mol % Pd.

If the reaction **is complete**, the catalyst loading can be decreased from 0.1 mol % to 0.05 % or to 0.01 mol % Pd.

Catalyst Services

CONFIDENTIALITY GUARANTEED

You can take advantage of SiliCycle's expertise in catalysis, and our R&D team can assist you in your catalysis challenges. Our Catalyst Services provide a turnkey solution with an easy technology transfer.

Working with the substrates you identify, our chemists can quickly develop the most efficient catalysis process or optimize an existing one, test the feasibility of a new one, understand metal-catalyzed reaction, etc.

As a catalyst manufacturer with multiple patents, our skilled and competent catalysis group can investigate any reaction parameter (*catalyst loading, solvent, ligand, base / additive nature, concentration, temperature, time, etc.*) to maximize yields and purity as well as to reduce wastes and costs.

Our most popular catalysis services include the following:

- Catalyst evaluation, testing and screening services
- Catalytic process optimization
- Scale-up of catalytic reactions
- Tailor-made catalyst development to fit your requirements
- Scavenging of residual metal catalyst

Contact us to discuss how we can help you reach your goals.

Ordering Information

Batch Reactor Mode (*Bulk*)

All Silia*Bond* products particle size and pore size are respectively 40 - 63 µm and 60 Å, and are available from 10 g to 25 kg formats.

To build your own product number, just add the quantiy to the Phase PN: [**Phase PN**]-[**Quantity**]

Example: 100 g of DMAP silica gel, 40 - 63 µm, 60 Å: R75630B-100G

Silia*Bond* and Silia*Cat*	
Product Names	**Phase PN**
Silia*Bond* Amine	R52030B
Silia*Bond* Carbodiimide	R70530B
Silia*Bond* Carbonate	R66030B
Silia*Bond* Carboxylic Acid	R70030B
Silia*Bond* Cyanoborohydride	R66730B
Silia*Bond* DMAP	R75630B
Silia*Cat* DPP-Pd	RD-R390-100
Silia*Bond* Glycidoxy *nec*	R36030B
Silia*Bond* Guanidine	R68230B
Silia*Bond* $KMnO_4$	R23030B

Silia*Bond* and Silia*Cat*	
Product Names	**Phase PN**
Silia*Bond* Pyridinium Chlorochromate (*PCC*)	R24030B
Silia*Bond* Pyridinium Dichromate (*PDC*)	R24530B
Silia*Cat* Pd^0	RD-R815-100
Silia*Bond* Piperazine	R60030B
Silia*Bond* Piperidine	R71530B
Silia*Bond* Propylsulfonic Acid (*SCX-2*)	R51230B
Silia*Cat* Pt^0	RD-R820-100
Silia*Bond* Tosic Acid (*SCX*)	R60530B
Silia*Bond* Tosyl Chloride	R44030B

Fixed-Bed Mode Formats (*SPE or Flash Cartridges*)

Silia*Prep* SPE Cartridges and Silia*Sep* Flash Cartridges

To build your SPE or flash cartridge Product Number, simply start with the **Prefix SPE** or **FLH**, followed by the **Phase PN of the reagent or oxidant** you wish your cartridge to be packed with, followed by the **Format code**.

Examples:
- Silia*Prep* Amine, 6 mL, 500 mg = SPE-R52030B-06P
- Silia*Sep* Open-Top Carbonate, 70 mL, 10 g = FLH-R66030B-70Y
- Silia*Sep* Tosic Acid, 4 g = FLH-R60530B-ISO04

Silia*Prep* SPE and Silia*Sep* OT Cartridges			
Formats Available	**Prefix**	**Code**	**Units / Box**
3 mL / 200 mg	SPE	03G	50
3 mL / 500 mg	SPE	03P	50
6 mL / 500 mg	SPE	06P	50
6 mL / 1 g	SPE	06S	50
6 mL / 2 g	SPE	06U	50
12 mL / 2 g	SPE	12U	20
25 mL / 5 g	FLH	20X	20
70 mL / 10 g	FLH	70Y	16
70 mL / 15 g	FLH	70i	16
70 mL / 20 g	FLH	70Z	16
150 mL / 25 g	FLH	95K	10
150 mL / 50 g	FLH	95M	10
150 mL / 70 g	FLH	95N	10

Silia*Sep* Flash Cartridges			
Formats Available	**Prefix**	**Code**	**Units / Box**
4 g	FLH	ISO04	2
12 g	FLH	ISO12	1
25 g	FLH	ISO25	1
40 g	FLH	ISO40	1
80 g	FLH	ISO80	1
120 g	FLH	IS120	1
220 g	FLH	IS220	1
330 g	FLH	IS330	1
800 g	FLH	IS750	1
1,600 g	FLH	I1500	1

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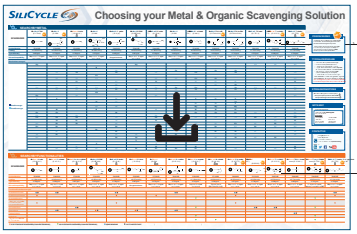
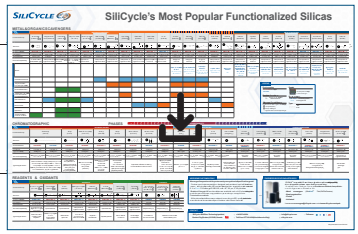
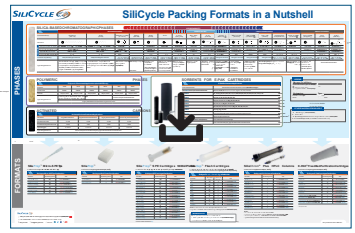


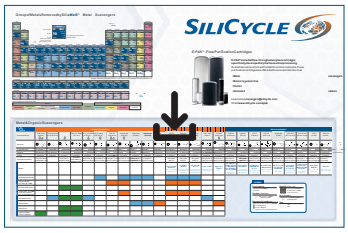
Choosing your metal & organic scavenging solution



SiliCycle's most popular functionalized silicas



SiliCycle packing formats in a nutshell



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Metal scavenging using bulk Silia*MetS* functionalized silica

How to calculate the amount of scavenger needed

What are the parameters that influence scavenging efficiency?

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Scale-up impurity scavenging with E-PAK

E-PAK cartridge housings, from lab to commercial scale

See how easy it is working with E-PAK

Flash separation of dye mixture with Silia*Sep* Premium

How does flash chromatography work?

Understanding Column Volume

What is the relationship between retention factor and column volume

The 5 steps of a solid phase extraction (SPE)

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What pH range is suitable for functionalized silica?

What is the sample mass loading capacity of preparative TLC plates?

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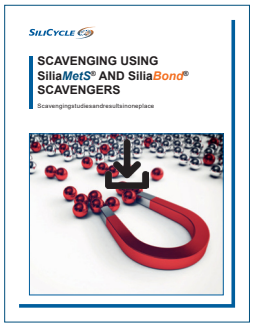
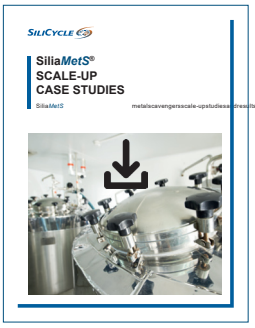


A collection of various case studies and application notes using scavengers



A collection of scale-up case studies and application notes using scavengers

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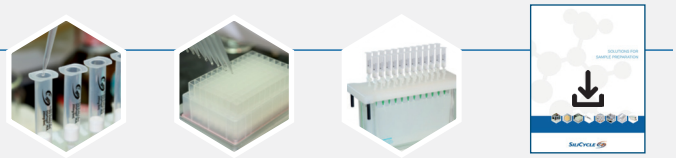

ANALYTICAL AND PREPARATIVE CHROMATOGRAPHY

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Silia*Chrom*® – HPLC Columns

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Silia*Bond*® – Reagents and Oxidants
Silia*Cat*® – Heterogeneous Catalysts

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