
HALO®
CATALOG
Fused-Core® particle technology
for hyper-fast and super-rugged
UHPLC columns

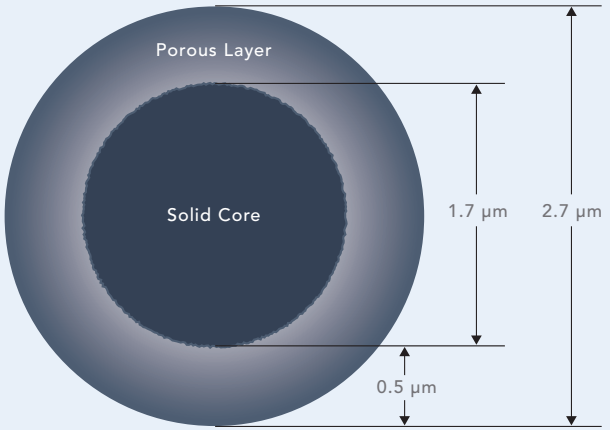
HALO®

The name that defines a new direction in UHPLC.

HALO® column packings are not made the typical way. Instead, the particles packed into HALO UHPLC columns are manufactured using Fused-Core® particle technology that was specially developed to deliver hyper-fast chromatographic separations while avoiding the reliability issues so often associated with UHPLC (*Figure 1*).

HALO columns generate significantly less back pressure compared to other UHPLC columns, putting less stress on the system and facilitating rugged reliable performance. It is this moderate back pressure of HALO columns that also permits them to be used with most conventional HPLC equipment for near-UHPLC performance. Furthermore, HALO columns utilize a column inlet frit with a porosity that is significantly larger than other UHPLC columns (2 µm versus 0.5 µm). This larger porosity column inlet frit reduces a problem that plagues UHPLC columns, inlet frit plugging. In fact the inlet frit on HALO columns is no smaller than that typically used on columns packed with 5 µm particles. Imagine that. A UHPLC column with the ease of use and reliability of a column packed with 5 µm particles.

FIGURE 1: HALO Fused-Core particle



Fused-Core particle technology was developed by Jack Kirkland to produce UHPLC columns that provide fast separations and high sample throughput without sacrificing column ruggedness and reliability. As the name implies, Fused-Core particles are manufactured by "fusing" a porous silica layer onto a solid silica particle.

> *"The fused-core silica column providing the reduced diffusional mass transfer path allows the use of shorter columns and higher flow rates to achieve remarkably fast high-resolution separations."*
>
> Analytical Chemistry, August 2007

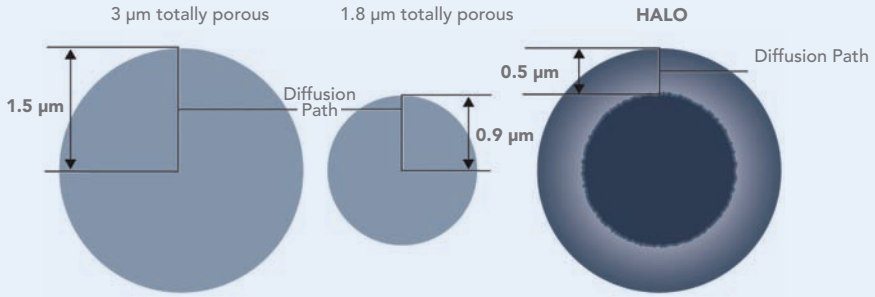
HALO® particles are designed for hyper-fast separations at modest column back pressure

The ability of HALO to generate hyper-fast separations comes not only from their small particle size (2.7 µm) but also from the unique Fused-Core® particle technology that creates a 0.5 µm porous shell fused to a solid core particle. As mobile phase flow rate is increased to speed up a separation, the slow mass transfer of solute molecules inside the particles limits resolving power. Fused-Core particle technology addresses this limitation by providing an incredibly small path (0.5 µm) for diffusion of solutes into and out of the stationary phase, thereby reducing the time solute molecules spend inside the particles and minimizing a major barrier to fast chromatographic separations (*Figure 2*).

HALO UHPLC columns deliver over 90% more separating power (theoretical plates) than a column of the same length packed with 3.5 µm particles and almost three times the plates of a column packed with 5 µm particles (*Figure 3*).

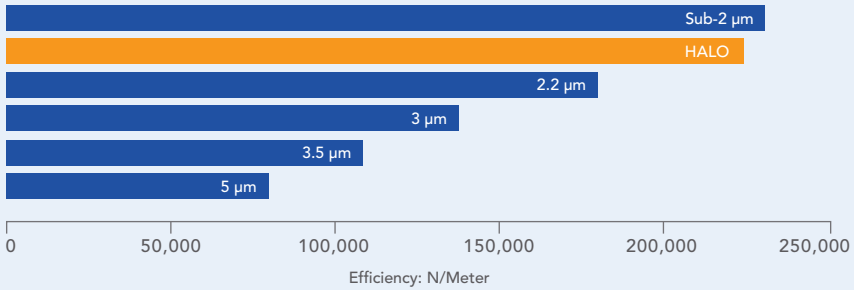
And, because of Fused-Core particle technology, HALO columns maintain their resolving power at high flow rates. This means that shorter columns and higher flow rates can be used to achieve remarkably fast high resolution separations (*Figure 4*).

FIGURE 2: The shorter diffusion path of HALO reduces axial dispersion



The shorter diffusion path of HALO particles reduces axial dispersion of solutes and minimizes peak broadening. Because of the shorter diffusion path, the performance advantages of HALO become even more apparent when separating larger solute molecules and operating at faster mobile phase flow rates.

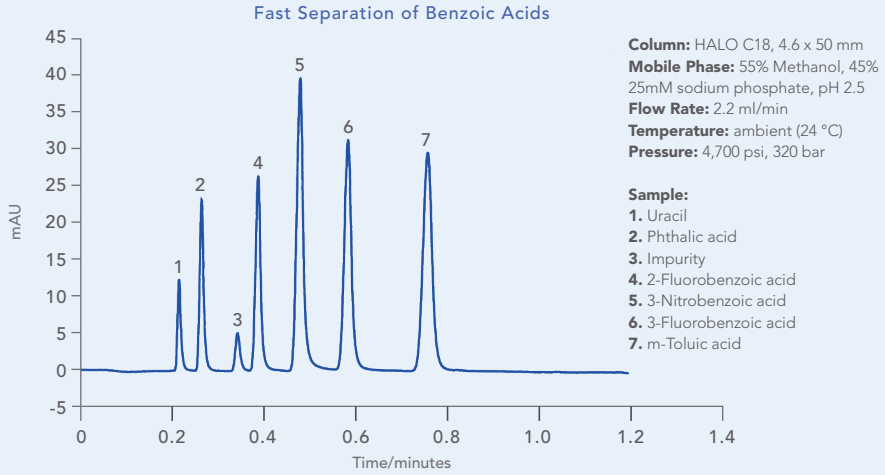
FIGURE 3: HALO UHPLC columns deliver more separating power



HALO UHPLC columns deliver over 90% more separating power (theoretical plates) than columns of the same length packed with 3.5 µm particles and almost three times the separating power of columns packed with 5 µm particles.

Note: N/Meter values were calculated at the optimum mobile phase linear velocity for each of these stationary phases.

FIGURE 4: HALO columns are designed for hyper-fast UHPLC separations.



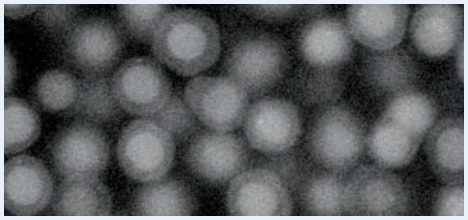
HALO columns are designed for hyper-fast separations so that higher sample throughput can be achieved. In this example, the HALO column separated seven compounds in less than 48 seconds with better than baseline resolution for all peak pairs.

> *"The unusually high efficiency for columns of these particles is believed to be a feature of the very narrow particle size distribution and the higher particle density."*
>
> American Laboratory, April 2007

HALO® UHPLC columns are designed to be super-rugged

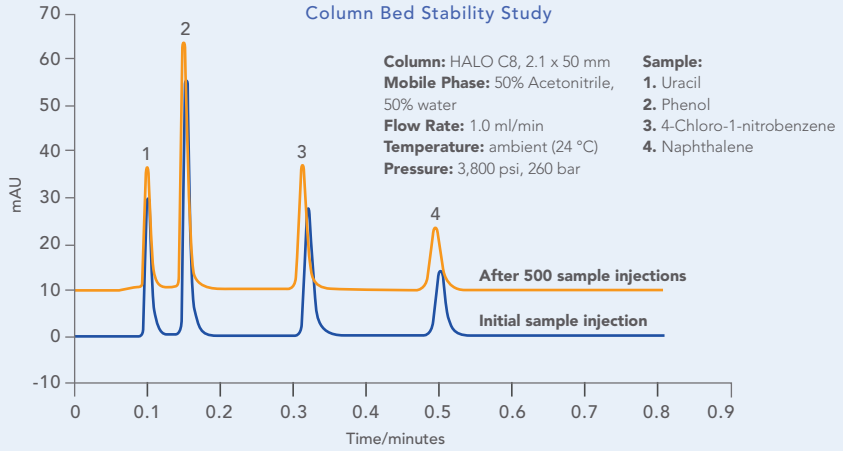
Packing HPLC columns can be as much art as it is science. There are many variables that have to be optimized in order to pack a column well for even non-high throughput applications. But, the demands placed upon columns used in high speed applications, i.e., high flow rate and high pressure, make it especially difficult to pack a column that will hold up for a satisfactory period of time. HALO particles facilitate the packing process in two ways. First, the unique Fused-Core® particle technology produces particles that have extremely narrow size distribution. Second, these particles are significantly more dense than conventional totally porous particles, allowing them to be more easily packed into stable and efficient columns. This combination of extremely narrow particle size distribution and very dense particles allows the production of columns that are incredibly rugged and reliable, as well as very reproducible from column to column (*Figure 5*).

FIGURE 5: Scanning electron microscope (SEM) photograph of HALO particles



This SEM photograph of HALO particles illustrates two important attributes of this unique column packing. First, the incredibly narrow particle size distribution is apparent. Second, this SEM photo shows some of the HALO particles "sliced in half" so that the solid core and the porous outer layer, the "halo" of the particles, is evident.

FIGURE 6: Stability testing of a HALO UHPLC column



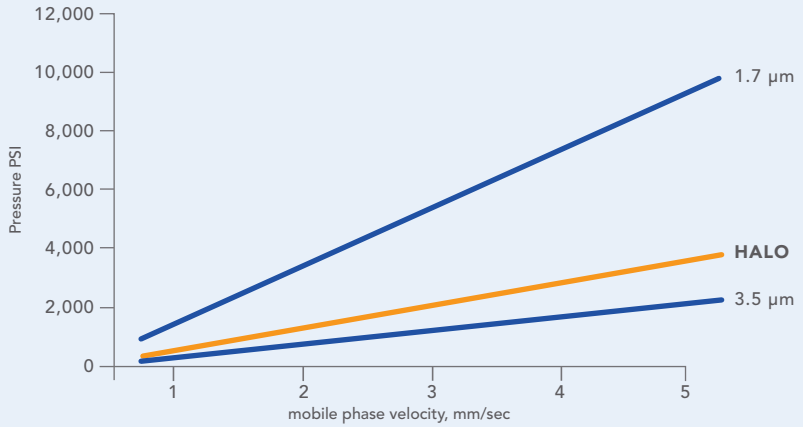
A HALO column was run under high flow conditions to test bed stability. After 500 sample injections and over 40,000 column volumes, there was no evidence of any change to the packing bed.

Also of importance, the extremely narrow particle size distribution permits the use of 2 µm porosity inlet frits on the HALO columns. This is the same inlet frit porosity typically found on columns packed with 5 µm particles. The result is a column capable of delivering incredibly high sample throughput, much higher than 3 µm packed columns, but with the ease of use and durability of a column packed with 5 µm particles (*Figure 6*). Who says you can't have both high speed and ruggedness? HALO delivers both.

HALO® UHPLC columns do not require ultra-high pressure

Fused-Core® particle technology produces hyper-fast columns that can be used on both UHPLC and conventional HPLC systems. Figure 7 provides a comparison of system back pressure for the HALO column versus other fast HPLC columns. Columns packed with stationary phases smaller than 2 µm often require pressures in excess of what is achievable with typical HPLC instrumentation. A very real bonus that comes with using a HALO column is that expensive ultra-high pressure instrumentation does not have to be purchased and new laboratory protocols do not have to be developed. HALO columns can turn almost any HPLC system into a high speed workhorse for your lab.

FIGURE 7: Comparison of column back pressure



Most HPLC systems have operating pressure limits of 6,000 psi (400 bar) or less. As the column packing particle size decreases, the column back pressure increases rapidly. To use columns packed with sub-2 µm size particles at their optimum flow rate, pressure that exceeds 6,000 psi is often encountered.This necessitates purchasing very expensive "ultra-pressure" equipment to achieve optimum performance. HALO columns, even though they do generate slightly higher back pressure than columns packed with 3.5 µm particles, can be used with both UHPLC and conventional HPLC equipment.

The science behind HALO

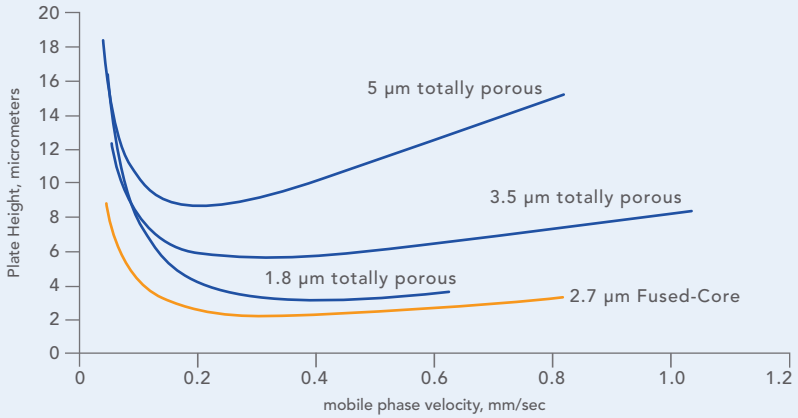
The well known van Deemter equation identifies the three main sources of band broadening.

$$H = A + B/\mu + C\mu$$

The value of the A term, eddy diffusion, reflects the multiple flow paths through a column. Packing particle size, particle size distribution, and the uniformity of the packed bed all determine the value of A. Because of the high density and extremely narrow size distribution of Fused-Core particles, HPLC columns can be packed with well ordered beds that have A term values significantly smaller than what is typically seen with columns packed with totally porous particles. This is one of the reasons that HALO columns deliver column plate numbers that are much higher than what would normally be expected from their particle size.

The C term of the van Deemter equation, the coefficient of mass transfer, reflects the time it takes for analyte to diffuse in and out of the stationary phase. The C term is directly related to mobile phase velocity because higher velocity interferes with the equilibrium between the analyte, mobile phase and stationary phase. The longer the path an analyte has to travel within the pores of the stationary phase support particles, the more detrimental the effect of mobile phase velocity will be on column efficiency.

FIGURE 8: Comparison of van Deemter plots



Van Deemter plots are a convenient way to compare the efficiency of HPLC columns. In this comparison we see that HALO columns are more efficient than columns packed with totally porous particles and that they can be run at higher mobile phase linear velocity and still maintain their resolving power.

FUSED-CORE TECHNOLOGY

Fused-Core technology was developed by Jack Kirkland. Dr. Kirkland is widely regarded as one of the "founders" of HPLC and is well recognized for his research and contribution to the understanding of chromatography. He's authored over 150 major research publications and 6 textbooks. Dr. Kirkland holds over 30 patents and has received several prestigious awards within the field of chromatography.

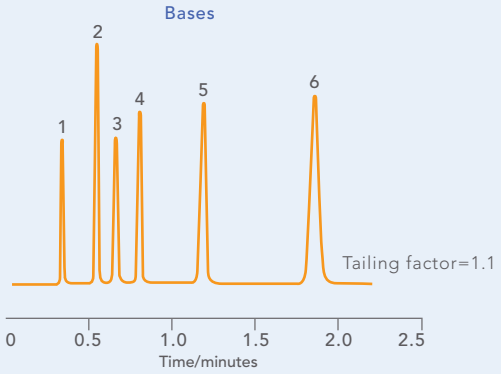
The path a solute has to travel within the pores of a stationary phase support particle can be reduced by using smaller size particles and this is typically the strategy that is used by column manufacturers when making UHPLC columns. Smaller particles have shorter diffusion path lengths and, therefore, are less affected by increases in mobile phase velocity. HALO particles, by virtue of their 0.5 µm porous shell, have reduced the diffusional mass transfer path by one third compared to 3 µm particles. As the molecular size of the solute increases, its diffusion rate slows, making this effect even greater. The result is a column that can achieve faster separations and higher sample throughput.

> *"Columns packed with the shell HALO particles exhibit most impressive performance and prove most advantageous for the analysis of low and moderate weight compounds."*
>
> Journal of Chromatography A, May 2007

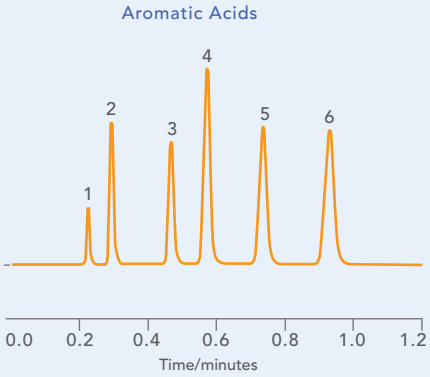
HALO is base-deactivated for excellent peak shape

HALO stationary phases are made using ultra-pure reagents and "Type B" silica. The peak shapes for bases and acids are excellent on HALO columns because metal contamination has been virtually eliminated and interference from silanol groups has been minimized (*Figure 9*). Because of the elimination of "secondary retention" of solutes from metal contamination or silanol interaction, column-to column reproducibility is also excellent.

FIGURE 9. Separations of bases and acids on HALO



Column: HALO C8, 4.6 x 50 mm
Mobile Phase: 75% Methanol, 25% 25mM potassium phosphate, pH 7.0
Flow Rate: 1.5 ml/min
Temperature: ambient (24 degrees Celsius)
Pressure: 3,000 psi, 205 bar
Sample:
1. Uracil
2. Butyl paraben
3. Propranolol
4. Naphthalene
5. Acenaphthene
6. Amitriptyline



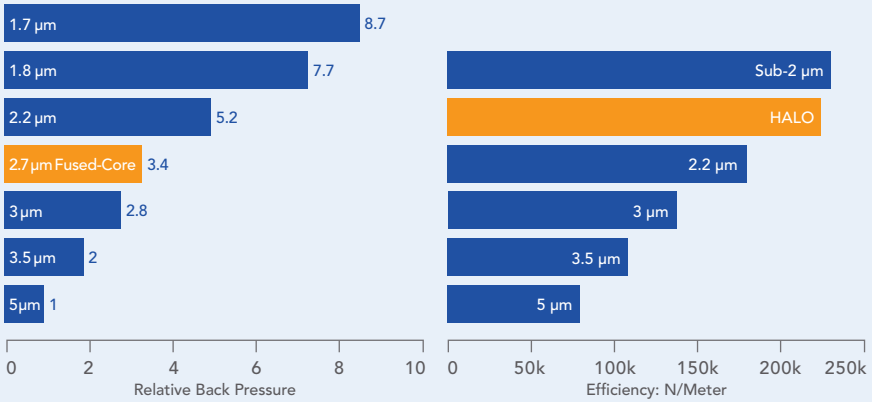
Column: HALO C8, 4.6 x 50 mm
Mobile Phase: 55% Methanol, 45% 25mM sodium phosphate, pH 2.5
Flow Rate: 2.2 ml/min
Temperature: ambient (24 degrees Celsius)
Pressure: 5,200 psi, 360 bar

Sample:
1. Uracil
2. Phthalic Acid
3. 2-Fluorbenzoic Acid
4. 3-Nitrobenzoic Acid
5. 3-Fluorbenzoic Acid
6. m-Toluic Acid

Peak tailing due to trace metals or silanol groups is essentially non-existent on HALO stationary phases. The examples here show the excellent peak shape that can be achieved for either bases or acids when using a HALO column. The conditions used for the bases were chosen to encourage any potential silanol interference. Note the excellent peak shape for amitriptyline under these conditions.

> *"This fast HPLC technology is comparable with ultrahigh-pressure liquid chromatography (UHPLC) in terms of chromatographic performance but demands neither expensive ultra-high-pressure instrumentation nor new laboratory protocols."*
>
> Analytical Chemistry, August 2007

FIGURE 10: HALO UHPLC columns operate at conventional HPLC pressure



HALO columns packed with Fused-Core particles provide over 80% of the efficiency (theoretical plates, N) and 90% of the resolving power of sub-2-µm columns, but require less than half the back pressure. This lower pressure permits HALO columns to be used with conventional 400 bar-limit HPLC equipment and achieve speed and resolution very similar to UHPLC.

HALO® RP-AMIDE

- Alternate, complementary selectivity to C18 and C8 bonded phases
- Particularly recommended for samples containing acidic and basic compounds
- Compatible with highly aqueous mobile phases to facilitate the retention and separation of polar compounds
- Enhanced bonded-phase stability for durable, long-lived performance plus minimum bleed for LC/MS applications
- Base-deactivated for good peak shape when separating basic compounds

HALO UHPLC columns are available packed with a polar-embedded phase that offers a powerful alternate selectivity to HALO C18 and C8. HALO RP-Amide columns provide enhanced selectivity for samples containing acidic and basic compounds and are an excellent choice when a C18 or C8 phase fails to provide an adequate separation. The HALO RP-Amide columns are also particularly well suited for the separation of highly water soluble compounds that require high aqueous mobile phases, since the polar amide group ensures that the stationary phase is fully "wettable", even when using 100% aqueous mobile phases.

HALO RP-Amide should not be confused with other amide embedded phases that exhibit weak hydrolytic stability. Proprietary bonding chemistry is used in the production of the HALO RP-Amide phase to achieve excellent stability and long column life. The extremely low bleed characteristics of the HALO RP-Amide phase make it particularly well suited for LC/MS applications.

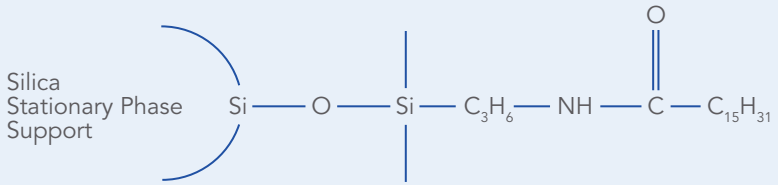
As with the HALO C18 and C8 phases, ultra-pure reagents, "Type B" silica, dense bonding technology and exhaustive endcapping generate a base-deactivated stationary phase that provides excellent peak shape for polar compounds.

Mechanism of separation

Separations on HALO RP-Amide columns are influenced by both hydrophobic interaction with the alkyl chain and hydrogen bonding with the embedded amide group. (*See Figure 11 for structure of the RP-Amide bonded phase.*) Analytes with hydrogen bond donor characteristics can be expected to be more retained on the HALO RP-Amide phase. An example of this can be seen in Figure 12 where 2-chlorophenol, 3-ethylphenol and butyl paraben are more strongly retained on the HALO RP-Amide than the HALO C18. In general, acids will be retained more, bases will be retained slightly less and neutral analytes will have approximately the same retention on the HALO RP-Amide as they will on the HALO C18.

This different selectivity provided by the HALO RP-Amide makes it a very useful alternative phase to a C18 phase. Compounds that are poorly separated on a C18 phase may be well separated on the HALO RP-Amide. Figure 13 is a good example. Here, 2-nitroaniline, 4-bromoacetanilide and 2, 2'-biphenol co-elute on a C18 phase, but are baseline separated on the HALO RP-Amide.

FIGURE 11: Structure of bonded phase of HALO RP-Amide

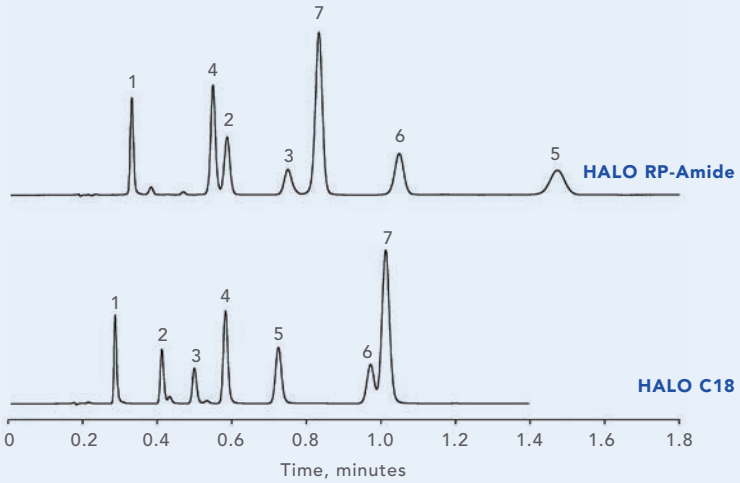


A stable amide group embedded in an 18-carbon chain is the bonded phase used for the HALO RP-Amide phase.

FIGURE 12 : HALO RP-Amide offers an alternate selectivity to C18

Conditions:
Columns: 4.6 x 50 mm
Mobile Phase: 50/50 ACN/ 20 mM potassium phosphate buffer (pH = 7.0)
Flowrate: 2.0 ml/min
Pressure: ~175 bar

Sample: 1µL of solution containing:
1. benzyl alcohol
2. 2-chlorophenol
3. 3-ethylphenol
4. benzylbenzoate
5. butyl paraben
6. 4-chloro-3-nitroanisole
7. N,N-dimethylaniline

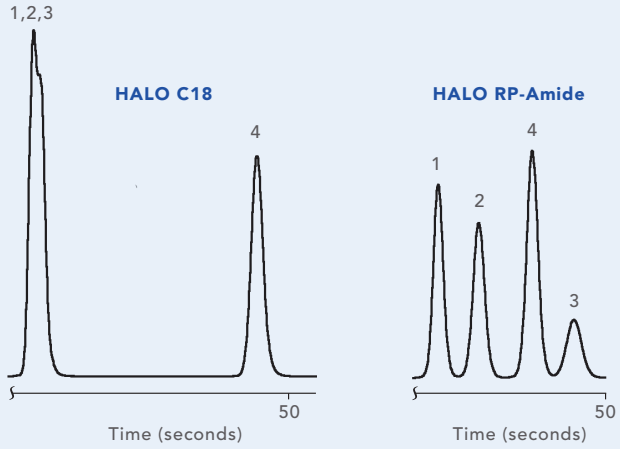


Hydrogen bond donors, like 2-chlorophenol, 3-ethylphenol, and butyl paraben are more strongly retained on the HALO RP-Amide phase than on the HALO C18 phase. Basic compounds, like N, N-dimethylaniline, are slightly less retained on the HALO RP-Amide phase. This difference in selectivity makes HALO RP-Amide an extremely useful alternate selectivity to the HALO C18 phase.

FIGURE 13: The alternate selectivity of HALO RP-Amide often provides a better separation

Conditions:
Columns: 4.6 x 50 mm
Mobile Phase: 35/65 ACN/20 mM phosphate buffer, pH = 7.0
Flowrate: 3.0 ml/min
Pressure: 310 bar
Temperature: Ambient at 26 °C

Peak Identities:
1. 2-Nitroaniline
2. 4-Bromoacetanilide
3. 2,2′-Biphenol
4. Benzylbenzoate

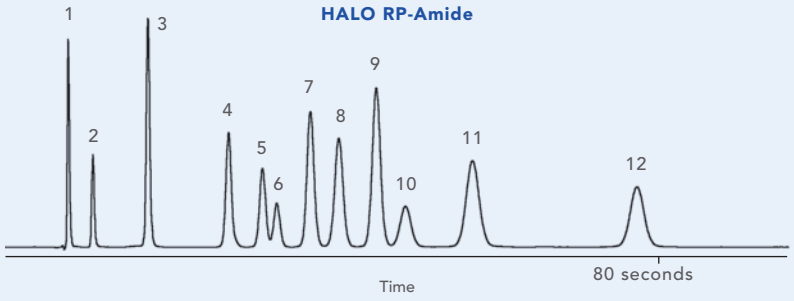


Three compounds in this sample mix do not separate on a C18 phase. Under identical mobile phase conditions, they are baseline separated on the HALO RP-Amide.

FIGURE 14 : Ultra-fast separation of a 12 component mixture on a HALO RP-Amide column

Conditions:
Columns: 4.6 x 50 mm
Mobile Phase: 35/65 ACN/20 mM phosphate buffer, pH = 7.0
Flowrate: 3.0 ml/min
Pressure: 310 bar
Temperature: Ambient at 26 ˚C

Peak Identities:
1. Uracil
2. Benzamide
3. Aniline
4. Cinnamyl Alcohol
5. Dimethylphthalate
6. Phenylacetonitrile
7. 2-Nitroaniline
8. 4-Bromoacetanilide
9. Benzylbenzoate
10. 2,2′-Biphenol
11. 4,4′-Biphenol
12. N,N-dimethylaniline



The selectivity offered by the alkyl amide phase combined with the high efficiency and high speed of the HALO Fused-Core particles facilitates the separation of these 12 compounds in under 80 seconds.

HALO® PHENYL-HEXYL

- Alternate, complementary selectivity to C18 and C8 bonded phases
- Particularly recommended for compounds containing aromatic groups
- Compatible with highly aqueous mobile phases to facilitate the retention and separation of polar compounds.
- Excellent bonded-phase stability for durable, long-lived performance plus minimum bleed for LC/MS applications
- Base-deactivated for good peak shape when separating basic compounds

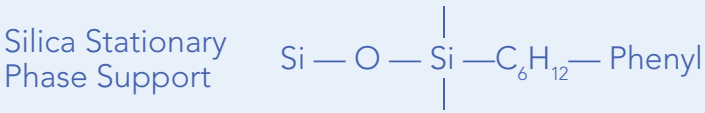
The phenyl functionality of HALO Phenyl-Hexyl provides an additional mechanism of separation that can be particularly useful when separating mixtures that contain compounds with aromatic groups. HALO Phenyl-Hexyl columns are an excellent choice to try when a C18 or C8 phase fails to provide an adequate separation. The HALO Phenyl-Hexyl columns are also particularly well suited for the separation of highly water soluble compounds that require high aqueous mobile phases, since the phenyl group provides enough polarity to the phase to keep it fully "wettable", even when using 100% aqueous mobile phases.

As with all HALO bonded phases, ultra-pure reagents, "Type B" silica, dense bonding technology, and exhaustive endcapping generate a base-deactivated stationary phase that provides excellent peak shape for polar compounds.

Mechanism of Separation

HALO Phenyl-Hexyl can retain analytes via several different mechanisms, including π–π interactions between the overlap of the delocalized electrons on the analyte and the stationary phase phenyl group, and via partitioning between the mobile phase and the hydrophobic aryl-alkyl phase. See Figure 15 for the structure of the HALO Phenyl-Hexyl bonded phase.

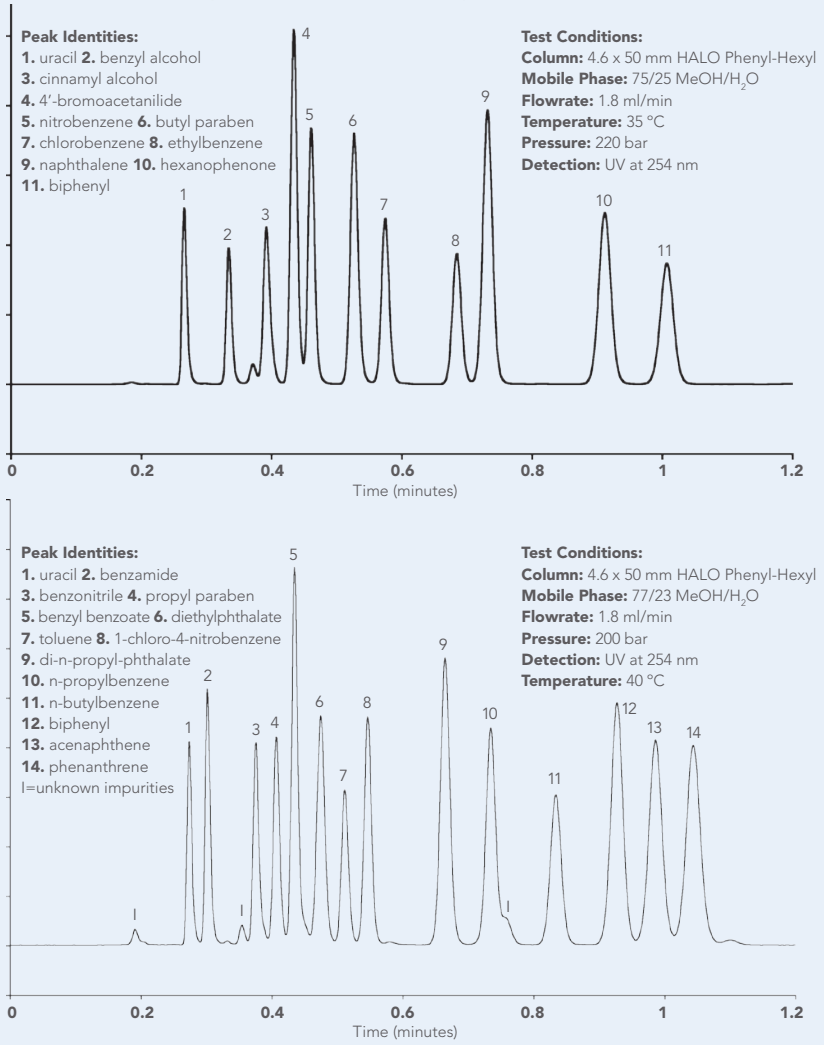
FIGURE 15: Structure of bonded phase of HALO Phenyl-Hexyl



A phenyl group is bonded to the silica surface via a hexyl chain.

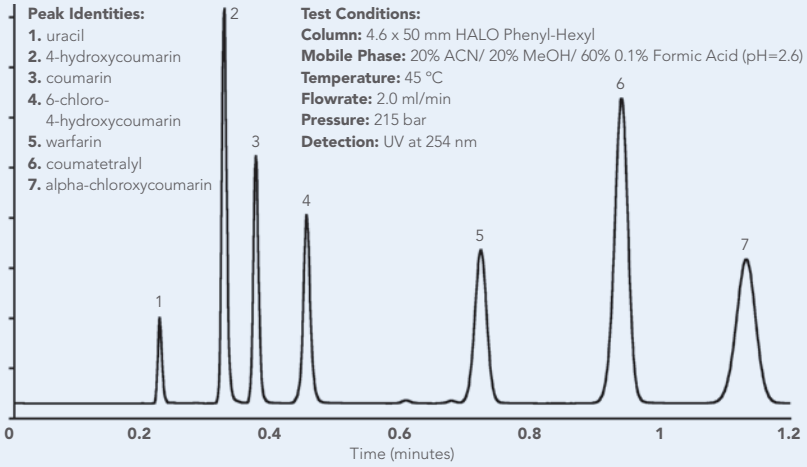
Acetonitrile tends to decrease the π–π interactions between aromatic and polarizable analytes and phenyl stationary phases, but methanol enhances those same interactions, giving both increased retention and changes in selectivity. This does not mean that acetonitrile should not be used with a phenyl bonded phase or that it might not provide an acceptable separation, but methanol is more likely to deliver the additional selectivity that is desired from a phenyl phase. Figures 16 and 17 provide examples of the type of high speed, high resolution separations possible with HALO Phenyl-Hexyl.

FIGURE 16: Fast Separation of Aromatic Compounds



These two chromatograms illustrate how HALO Phenyl-Hexyl columns can provide separation of complex mixtures in a little over a minute.

FIGURE 17: Fast Separation of Anticoagulants



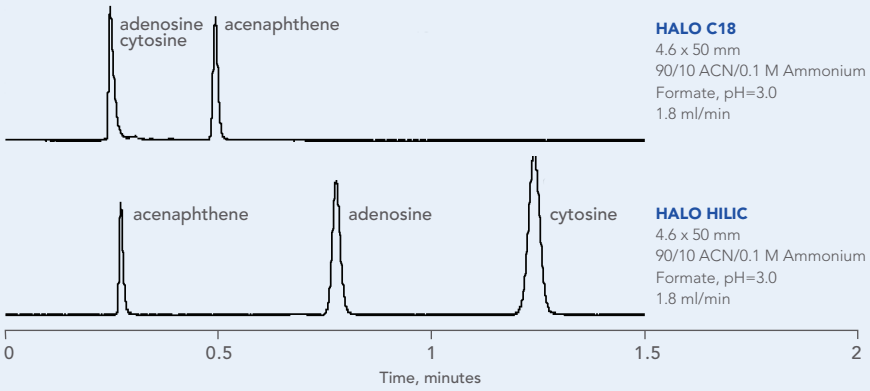
Six anticoagulants are well separated on a HALO Phenyl-Hexyl column in less than 72 seconds.

HALO® HILIC

- Separate highly polar compounds that are poorly retained on reversed-phase columns
- Complementary selectivity to reversed-phase
- Increase LC/MS sensitivity

HILIC, or hydrophilic interaction liquid chromatography, is especially suitable for separating polar compounds. HALO HILIC UHPLC columns can be particularly useful for separating acidic and basic compounds that are either not retained or poorly retained on reversed-phase columns. In addition, the complementary selectivity of HILIC may provide a better separation than that achieved by reversed-phase. Since typical mobile phases used with HILIC are composed of a large fraction of volatile organic solvent such as acetonitrile, HILIC separations can offer significant increases in sensitivity when interfaced to mass spectrometry.

FIGURE 18: Complementary selectivity of reversed-phase and hydrophilic interaction liquid chromatography (HILIC).



Retention mechanism

Retention in HILIC appears to be a combination of hydrophilic interaction, ion-exchange and some reversed-phase retention. The aqueous layer which forms on the polar surface of HILIC particles promotes interaction with polar solutes. Retention in HILIC as a function of the mobile phase is just opposite from that in

reversed-phase. The strongest mobile phase has a high percentage of water and the weakest has a high percentage of organic solvent. For gradient separations, the initial mobile phase has a high percentage of organic solvent and the gradient is formed by increasing percentage of the aqueous component. The greatest retention for basic and acidic analytes is found when using more than 70% organic (e.g., acetonitrile) in acidic mobile phases. Since high organic concentrations are used in the mobile phases, HILIC is especially favorable for separations using mass spectrometry (MS) detection.

Due to the highly polar mobile phases used in HILIC, both acidic and basic compounds often exhibit highly symmetrical peak shapes, frequently superior to those obtained in reversed-phase. In addition, sample loading effects often are more favorable for HILIC. When optimized, HALO HILIC columns show efficiency that is competitive with results obtained with reversed-phase. Although increased column operating temperatures can improve efficiency and peak shape in reversed-phase chromatography, temperatures above 60 °C generally are not recommended with HILIC.

Mobile phase solvents

Acetonitrile is commonly used as the weak mobile phase component in HILIC separations. With this solvent, 95% is typically the upper limit and 60% the lower limit for adequate retention. At least 5% of the mobile phase should be a highly polar solvent such as water or methanol. If buffers are used, water is preferred for improved buffer solubility. As in reversed-phase, the organic solvent type can be varied to change retention and separation selectivity. Solvent strength (from weakest to strongest) for HILIC generally is tetrahydrofuran < acetone < acetonitrile < isopropanol < ethanol < methanol < water.

When using a gradient to scout for optimum mobile phase conditions, 90 - 95% acetonitrile is suggested as the initial solvent composition and 50 - 60% acetonitrile as the ending composition. The resulting elution characteristics can be used to estimate the appropriate mobile phase composition for isocratic elution in much the same way as for reversed-phase. To further increase retention in HILIC, replacing some of the water in the mobile phase with another polar solvent such as methanol or isopropanol is sometimes effective.

Mobile phase buffers

For optimum column efficiency and reproducibility, buffers in the range of 10 - 20 mM concentration or additives in the 0.5% range can be used in the mobile phase. Phosphate buffers are not recommended because of their poor solubility in highly organic mobile phases and incompatibility with MS detection. Additives such as formic acid, trifluoroacetic acid and phosphoric acid at concentrations up to about 1% can be used in the mobile phase. Volatile ammonium formate/formic acid buffers up to a final concentration of about 20 mM and pH 3 are especially effective for separating both basic and acidic compounds when interfacing the liquid chromatograph to a mass spectrometer. Acetonitrile/formate mobile phases seem to be a good starting point for many separations of both basic and acidic compounds. Ammonium acetate at pH ~5 has also been used at concentrations of 5 - 20 mM, but is generally less effective for separating stronger basic and acidic compounds. Buffers or additives above pH 6 usually are not recommended because they may enhance the slow dissolution of the silica support.

Sample conditions

As with reversed-phase, the solvent used to inject the sample is an important consideration with HILIC. The sample solvent should, as closely as possible, resemble the strength and type of the mobile phase. The sample solvent can contain a higher amount of organic than the mobile phase, but if it contains a higher amount of polar solvent (e.g., water), peak shape will be compromised, especially with early-eluting compounds. If for some reason it is not possible to inject the sample dissolved in the mobile phase, a mixture of 75:25 (v/v) acetonitrile/methanol is sometimes useful as the sample solvent.

Very strong solvents, such as dimethylformamide or dimethylsulfoxide, will usually result in poor peak shapes and are not recommended. These solvents will generally have to be diluted with a weaker solvent, such as acetonitrile, before satisfactory peak shape can be obtained.

HALO® Specifications

Stationary Phase Support

- Ultra-pure, "Type B" silica
- 1.7 µm solid core particle with a 0.5 µm porous silica layer fused to the surface
- 150 m^2/gram surface area
- 90 Å pore size

Bonded Phase

- C18: Octadecyldimethylsilane, 3.5 µmoles/m^2
- C8: Octyldimethylsilane, 3.7 µmoles/m^2
- RP-Amide: Alkylamide, 3.0 micromoles/m^2
- Phenyl-Hexyl, 3.0 micromoles/m^2
- Densely bonded phase
- Maximized endcapping
- pH Range: 2 to 9

Maximum Pressure: 9,000 psi, 600 Bar

HALO® Ordering Information

Description (mm)	C18	C8	RP-Amide	Phenyl-Hexyl	HILIC
2.1 x 20	92812-202	92812-208	92812-207	92812-206	92812-201
2.1 x 30	92812-302	92812-308	92812-307	92812-306	92812-301
2.1 x 50	92812-402	92812-408	92812-407	92812-406	92812-401
2.1 x 75	92812-502	92812-508	92812-507	92812-506	92812-501
2.1 x 100	92812-602	92812-608	92812-607	92812-606	92812-601
2.1 x 150	92812-702	92812-708	92812-707	92812-706	92812-701
3.0 x 30	92813-302	92813-308	92813-307	92813-306	92813-301
3.0 x 50	92813-402	92813-408	92813-407	92813-406	92813-401
3.0 x 75	92813-502	92813-508	92813-507	92813-506	92813-501
3.0 x 100	92813-602	92813-608	92813-607	92813-606	92813-601
3.0 x 150	92813-702	92813-708	92813-707	92813-706	92813-701
4.6 x 30	92814-302	92814-308	92814-307	92814-306	92814-301
4.6 x 50	92814-402	92814-408	92814-407	92814-406	92814-401
4.6 x 75	92814-502	92814-508	92814-507	92814-506	92814-501
4.6 x 100	92814-602	92814-608	92814-607	92814-606	92814-601
4.6 x 150	92814-702	92814-708	92814-707	92814-706	92814-701
1.0 mm and Capillary					
1.0 x 50	92811-402				
1.0 x 100	92811-602				
1.0 x 150	92811-702				
0.300 x 50	98216-402	98216-408			
0.300 x 150	98216-702	98216-708			
0.200 x 50	98217-402	98217-408			
0.200 x 150	98217-702	98217-708			
0.100 x 50	98218-402	98218-408			
0.100 x 150	98218-702	98218-708			
0.075 x 50	98219-402	98219-408			
0.075 x 150	98219-702	98219-708			

For additional configurations and phases, please call.

To place an order contact:

MAC-MOD Analytical, Inc.
103 Commons Court | P.O. Box 587 | Chadds Ford, PA 19317-9927
Phone: 800-441-7508 | Fax: 610-358-5993
Website: www.mac-mod.com | Email: info@mac-mod.com

HALO® Fused-Core particle technology has been thoroughly investigated by the scientific community

Fused-Core particle technology is, indeed, new technology that has revolutionized ultra-performance liquid chromatography, a.k.a. UHPLC. However, this technology has been carefully studied by recognized experts in the field of chromatography and their work has been published in peer reviewed publications. Listed below is just a partial list of publications by respected scientists from both industry and academia that report on the characteristics, performance, and application of UHPLC columns packed with Fused-Core particles. Together, these publications provide a thorough understanding of Fused-Core technology and verify its benefit of providing ultra-fast high resolution separations.

"Critical comparison of performances of superficially porous particles and sub-2 µm particles under optimized ultra-high pressure conditions" | ***Journal of Chromatography A, Volume 1216, Issue 21, 22 May 2009, Pages 4597-4605*** | Yu Zhang, Xiaoli Wang, Partha Mukherjee, Patrik Petersson

"Comparison of fused-core and conventional particle size columns by LC–MS/MS and UV: Application to pharmacokinetic study" | ***Journal of Pharmaceutical and Biomedical Analysis, Volume 50, Issue 3, 15 October 2009, Pages 491-500*** | Wei Song, Deepthi Pabbisetty, Elizabeth A. Groeber, Rick C. Steenwyk, Douglas M. Fast

"Fused-Core Particles: A Practical Alternative to Sub-2 Micron Particles" | ***Journal of Chromatographic Science, Vol. 46, November/December 2008, pp 883-886.*** John J. Salisbury

"Fused-core particle technology as an alternative to sub-2-µm particles to achieve high separation efficiency with low backpressure." | ***Journal of Separation Science, Published Online: Nov 14 2007 (p 3104-3109)*** | Jennifer M. Cunliffe, Todd D. Maloney

"Fused-Core Silica Column High-Performance Liquid Chromatography/Tandem Mass Spectrometric Determination of Rimonabant in Mouse Plasma" | ***Anal. Chem.; (Article); 2007; 79(15); 5668-5673*** | Hsieh, Y.; Duncan, C. J. G.; Brisson, J.-M.

"Fused Core Particles for HPLC Columns" | ***American Laboratory, April 2007, pp 18-21*** | Joseph J. Kirkland, Timothy J. Langlois, and Joseph J. DeStefano

"Comparison between the efficiencies of columns packed with fully and partially porous C18-bonded silica materials" | ***Journal of Chromatography A, Volume 1157, Issues 1-2, 20 July 2007, Pages 289-303*** | Fabrice Gritti, Alberto Cavazzini, Nicola Marchetti, Georges Guiochon

"Evaluation of the properties of a superficially porous silica stationary phase in hydrophilic interaction chromatography" | ***Journal of Chromatography A, Volume 1193, Issues 1-2, 6 June 2008, Pages 85-91*** | David V. McCalley

"Comprehensive two-dimensional liquid chromatography separations of pharmaceutical samples using dual Fused-Core columns in the 2nd dimension" | ***Journal of Chromatography A, Volume 1216, Issue 9, 27 February 2009, Pages 1338-1345*** | Anthony J. Alexander, Lianjia Ma

"A high-throughput LC–MS/MS method for the quantitation of posaconazole in human plasma: Implementing fused core silica liquid chromatography" | ***Journal of Pharmaceutical and Biomedical Analysis, Volume 50, Issue 1, 15 August 2009, Pages 46-52*** | Jennifer M. Cunliffe, Carl F. Noren, Roger N. Hayes, Robert P. Clement, Jim X. Shen

"Fast, comprehensive two-dimensional liquid chromatography" | ***Journal of Chromatography A, Volume 1168, Issues 1-2, 19 October 2007, Pages 3-43*** | Dwight R. Stoll, Xiaoping Li, Xiaoli Wang, Peter W. Carr, Sarah E.G. Porter, Sarah C. Rutan

"Gradient elution separation and peak capacity of columns packed with porous shell particles" | ***Journal of Chromatography A, Volume 1163, Issues 1-2, 7 September 2007, Pages 203-211*** | Nicola Marchetti, Alberto Cavazzini, Fabrice Gritti, Georges Guiochon

"Shell and small particles; Evaluation of new column technology" | ***Journal of Pharmaceutical and Biomedical Analysis, Volume 49, Issue 1, 15 January 2009, Pages 64-71*** Szabolcs Fekete, Jenö Fekete, Katalin Ganzler

"Unusual behavior of the height equivalent to a theoretical plate of a new poroshell stationary phase at high temperatures" | ***Journal of Chromatography A, Volume 1169, Issues 1-2, 26 October 2007, Pages 125-138*** | Fabrice Gritti, Georges Guiochon

"Modeling of the Mass-Transfer Kinetics in Chromatographic Columns Packed with Shell and Pellicular Particles" | ***Anal. Chem.; (Article); 2007; 79(12); 4648-4656*** Kaczmarski, K.; Guiochon, G.

"Equation for Peak Capacity Estimation in Two-Dimensional Liquid Chromatography" | ***Analytical Chemistry 2009, 81, 845-850*** | Xiaopine Li, Dwight R. Stoll, and Peter W. Carr

"Characterization of new types of stationary phases for fast liquid chromatographic applications" | ***Journal of Pharmaceutical and Biomedical Analysis, Volume 50, Issue 5, 5 December 2009, Pages 703-709*** | Szabolcs Fekete, Jenö Fekete and Katalin Ganzler

"Comparison study of porous, fused-core, and monolithic silica-based C18 HPLC columns for Celestoderm-V Ointment® analysis" | ***Journal of Pharmaceutical and Biomedical Analysis, Volume 50, Issue 5, 5 December 2009, Pages 815-822*** | Jinjian Zheng, Dolly Patel, Qinglin Tang, Robert J. Markovich, Abu M. Rustum

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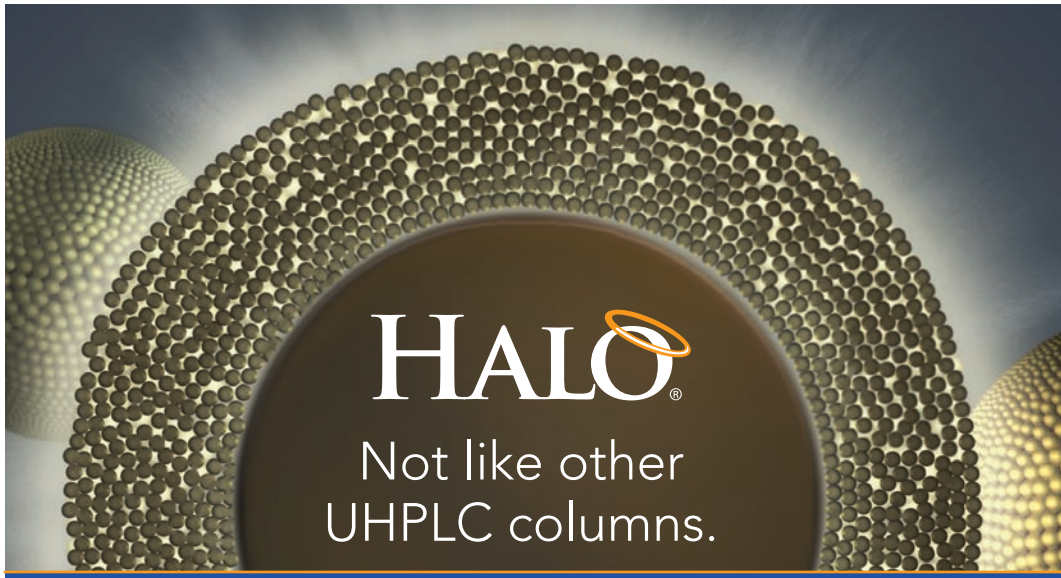
"High peak capacity separations of peptides in reversed-phase gradient elution liquid chromatography on columns packed with porous shell particles" | ***Journal of Chromatography A, Volume 1176, Issues 1-2, 28 December 2007, Pages 206-216*** | Nicola Marchetti, Georges Guiochon

"Approaches to comprehensive multidimensional liquid chromatography systems" | ***Journal of Chromatography A, 1216 (2009) 1363-1371*** | Jacob N. Fairchild, Krisztian Harvath, Georges Guiochon

"Development of some stationary phases for reversed-phase HPLC" | ***Journal of Chromatography A, Volume 1060, Issues 1-2, 10 December 2004, Pages 9-21*** | J.J. Kirkland

"Atypical silica-based column packings for high-performance liquid chromatography" | ***Journal of Chromatography A, Volume 965, Issues 1-2, 2 August 2002, Pages 25-34*** | J. J. Kirkland, F. A. Truszkowski, R. D. Ricker

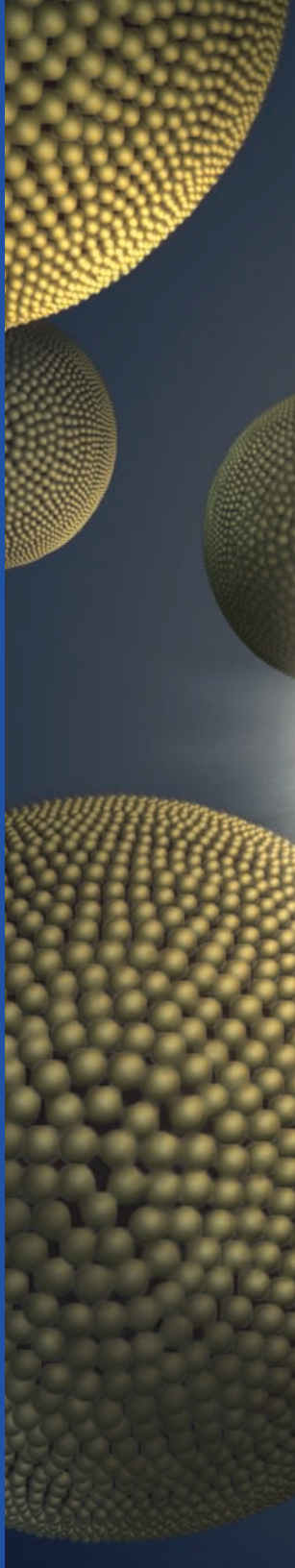
"Superficially porous silica microspheres for fast high-performance liquid chromatography of macromolecules" ***Journal of Chromatography A, Volume 890, Issue 1, 18 August 2000, Pages 3-13*** | J. J. Kirkland, F. A. Truszkowski, C. H. DilksJr., G. S. Engel



HALO UHPLC columns made with Fused-Core® particle technology are hyper-fast and super-rugged. Their low back pressure allows them to be used with conventional HPLC equipment as well as ultra-high pressure systems.

HALO columns can turn almost any HPLC into a high speed workhorse for your laboratory.

LC506



MAC-MOD Analytical, Inc.
103 Commons Court | P.O. Box 587 | Chadds Ford, PA 19317-9927
Phone: 800-441-7508 | Fax: 610-358-5993
Website: www.mac-mod.com | Email: info@mac-mod.com