present invention, a "surface feature section" is where the flow does not substantially relax to a laminar parabolic flow profile between two features. In some preferred embodiments of the present invention, at least 50%, more preferably at least 70%, and still more preferably at least 90% of the mass entering the channel enters at least one active surface feature in a surface feature section.

[0030] For unit operations, including homogeneous chemical reactions and heat exchangers, interaction of the bulk flow species with the active surface feature wall is also advantageous to transfer heat to an adjacent heat transfer chamber. Unlike the prior art micromixers, it is desirable to move the bulk stream near and past the wall and not necessarily completely and uniformly mix the bulk flow stream. An active surface feature wall that moves more fresh fluid near and past the active surface will be preferential over a design that primarily mixes the bulk stream.

[0031] For these applications, performance is enhanced with higher Reynolds numbers as opposed to disadvantaged at higher Reynolds numbers because the high momentum streams are moved into a repeating rotating flow pattern that winds the bulk flow past the active surface features and does not substantially stop the flow rotation and try to turn it back in an opposing direction. Once the flow has started to turn in a fixed direction within the active surface features, it continues in the same direction thus demonstrating a high vorticity such that the fluid is replenished against the active surface feature walls. As the momentum is increased at higher Reynolds numbers, the relative vorticity or angular force to spin the fluid also increases and thus the number of contacts or collisions with or near the active surface feature walls is also increased. For these cases, however, vorticity alone is not the only element. Patterns that merely spin the fluid in the bulk flow path, such as that created by a single angular diagonal feature groove across the width of a microchannel wall do not do a good job of pulling the center flow stream into the active surface features. In the present invention, the geometry of the active surface feature wall pattern may be designed to enhance "contact" (as defined to a molecule breaking the plane of the active surface feature groove and entering into the recessed and angled groove) with active surface features. The preferable active surface features have more than one angle across the width of at least one wall of the microchannel. "At least one angle" means that there is a change in slope—the feature is not a straight line but contains a bend; the feature is preferably contiguous such as a chevron or zig-zag; but in some embodiments a surface feature having "at least one angle" could be discontinuous if the elements of the feature are aligned so that, except for a gap, the recesses or protrusions would connect—an example is a chevron with a missing apex.

[0032] For the prior art examples, the relative time spent within the surface features for a typical molecule was less than about 10%, while for a typical molecule in the present invention the time spent within the surface features for a typical molecule is preferably greater than about 15%, more preferably greater than 20%, and more preferably still greater than about 30% of the average residence time spent in the channel is spent in the active surface features. The time that a molecule spends within an active surface feature is defined by the time that the molecules spend after breaking the plane of the surface features and have moved out of the bulk flow path. The "bulk flow path" is esentially continuous from inlet to outlet, where the active surface features typically start and stop along the length of the flow path.

[0033] For the invention, the performance enhancement of the active surface features relative to a corresponding featureless or flat or smooth wall is typically improved as the residence time is decreased. The featureless wall is defined by a microchannel that has a gap not inclusive of the depth of the recessed features and having the same width and length. As the Reynolds number increases the importance of inertial forces increases. For higher inertia or momentum streams, maintaining the momentum in a single primary direction rather than reversing or changing directions makes it easier to keep the stream turning. As the stream keeps turning, it keeps moving more and more flow or molecules into the active surface features where they may interact with the walls that exchange either heat or mass or both.

[0034] In one aspect, the invention provides microchannel apparatus, comprising: a microchannel comprising surface features; at least a segment of the microchannel characterized by a feature entrance length of more than 10; wherein the segment is at least 1 cm long; wherein the segment comprises plural similar, repeating surface features; and wherein the similar, repeating surface features comprise at least 1 angle in each similar surface feature. Preferably, the majority of a circumference of the microchannel is populated by surface features; for example, opposing surfaces of a rectangular microchannel.

[0035] In another aspect, the invention provides microchannel apparatus, comprising: a microchannel defined by at least 3 microchannel walls; at least a segment of the microchannel characterized by a feature entrance length number of more than 10; wherein the segment is at least 1 cm long; wherein the segment comprises plural similar, repeating surface features; and wherein the similar, repeating surface features comprise at least 1 angle in each similar surface feature.

[0036] In a further aspect, the invention provides microchannel apparatus, comprising:

[0037] a microchannel comprising a microchannel wall comprising surface features; wherein the surface features comprise sub-patterning that increases the surface area of the microchannel wall; and further comprising a catalyst composition disposed on at least of the surface features that comprise sub-patterning.

[0038] In another aspect, the invention provides microchannel apparatus, comprising:

a microchannel comprising a microchannel wall comprising more than 15 similar, repeating surface features. The similar, repeating surface features comprise at least 1 angle in each similar surface feature.

[0039] Any of the inventive aspects may be further characterized by any of the features described herein. For example, in preferred embodiments, the microchannel has two, major opposing walls comprising surface features in which the surface feature depth:channel gap is greater than 0.3. In preferred embodiments, microchannels are operated in parallel and are connected via a manifold. The distribution