essence, the inventive flow characteristics described in this invention are created when at least one wall of a microchannel has at least two angled features along the width of the microchannel, independent of whether the features are physically connected or not. Further, the inventive process is advantaged when substantially similar connected or disconnected features are repeated with modest or minimal variation in the oblique angle for at least 15 features in a row.

[0126] Preferably, the aspect ratio of the feature run width (the internal wall to wall distance in a recess; for a rectangular feature this is straightforward, for a cylindrical feature it would be the diameter, for a feature that narrows as a function of depth it is the maximum wall-to-wall distance; for a variable feature it is the average, maximum wall-to-wall distance) to channel gap (typically the minimum distance between surface features or the minimum distance between a surface feature and an opposing microchannel wall) is on the order of 0.25 to 10, where the run width of the surface feature is preferably at least 25% of the channel gap up to 10 times the channel gap. More preferably, the aspect ratio is between 0.5 and 1 to create sufficient flow disturbances. If the features are too narrow, the bulk flow glances over the top and receives minimal perturbations. If the surface feature run width is too wide, then the bulk flow will easily expand to fill the new channel gap and will receive minimal flow perturbations. Flow perturbations are defined as flow velocity vectors that do not follow the traditional laminar parabolic profile and have a perpendicular or transverse velocity vectors. It may also be preferable for the run width of the active surface feature to be less than the main channel gap when used in catalytic reactors where it is desirable to fill and drain the active surface features and retain the solution catalyst thereon. The capillary forces exerted by the fluid in the active surface feature will act to retain the fluid when draining such that it may be dried and calcined in place. If the main channel gap is less than the run width of the active surface feature it may act to pull the fluid out of the active surface feature during draining. For some catalytic reactor examples, such as those where the catalyst is deposited by reactive means such as electroless plating, this subsequent draining of the features while draining the channels may not be a problem.

[0127] Also surprisingly, the features when added to a flow stream with a Reynolds number greater than 2200 outperform a flat channel also operated in a turbulent regime. Specifically, a laminar flow with surface features (Re<2200) or a turbulent flow with surface features (Re>2200) gives improved mixing quality and or heat transfer over a flat channel with equal Reynolds number but in the turbulent regime. The surface features add a net radial or transverse component of velocity that is stronger than the radial or transverse component of velocity found from random eddies in a conventional turbulent flow channel. In fact, the design of the surface features may be made such that the relative ratio of transverse to perpendicular velocity may be tailored depending on the application. For those applications requiring good lateral mixing, including chemical reactions, an accentuation of perpendicular velocity vectors is particulary advantageous as this is the primary means of bringing fresh reactants to the surface for reaction.

[0128] Preferably, the aspect ratio of the feature depth (the internal recess or groove or surface feature depth as defined between the floor of the groove and the bulk flow channel gap or opening) to the channel gap (the minimum distance between microchannel walls at a location near (such as within 1 cm) the surface feature) is 0.25 to 10, where the feature depth of the surface feature is preferably at least 25% of the channel gap up to 10 times the channel gap. More preferably, the aspect ratio is between 0.5 and 3 to create sufficient flow disturbances. If the features are too shallow, the bulk flow glances over the top and receives minimal perturbations. If the surface feature depth is too deep, then the bulk flow will not easily flow convectively into the deep features and the fraction of bulk flow that enters the active surface features will be small.

[0129] In some embodiments with surface features in more than one wall, the features on one wall are in the same (or similar) pattern as found on a second wall, but rotated about the centerline of the main channel mean bulk flow direction (or length). In other embodiments with features on opposite walls, the features in one wall are approximately mirror images of the features on the opposite wall. In other embodiments with surface features in more than one wall, the features on one wall are the same (or similar) pattern as found on a second wall, but rotated about an axis which is orthogonal to the main channel mean bulk flow direction (in other words the features are flipped 180 degrees relative to the main channel mean bulk flow direction and rotated about the centerline of the main channel mean bulk flow). The features on opposing or adjacent walls may or may not be aligned directly with one another, but are preferably repeated continuously along the wall for some length. In alternate embodiments, surface features may be found on three or more surfaces of the microchannel. For the case of microchannel geometries with three or fewer sides, such as triangular, oval, elliptical, circular, and the like, the surface features may cover at least 20% up to 100% of the perimeter of the microchannel.

[0130] Each surface feature leg may be at an oblique angle relative to the bulk flow direction. The feature span length or span or opening is defined normal to the feature orientation. As an example, one surface feature is a diagonal depression at a 45 degree angle relative to a plane orthogonal to the mean direction of bulk flow in the main channel with a 0.38 mm opening or span or feature span length and a feature run length of 5.59 mm. The run length describes the distance from one end to the other end of the feature in the longest direction, whereas the span or feature span length is in the shortest direction (that is not depth). The feature depth is the distance from the main channel. For features with a non-uniform width (span), the span is the average span averaged over the run length.

[0131] In some preferred embodiments, three or more patterned sheets (at least 2 with through patterns—such as holes or slots) are stacked on top of each other. Two or more of the patterns may be identical, or three or more of the patterned surfaces may be distinct. Stacked patterns with varying geometries may create an advantageous flow regime, whereby the fluid approaches plug flow and does so in a fairly short distance. The distance to establish the flow regime may be less than 100 feature span lengths, or more preferably less than 50 feature span lengths, and more preferably still less than 20 feature span lengths. The surface feature may be at an oblique angle relative to the bulk flow direction. The feature span length or span is defined normal to the feature orientation. The run length describes the