[0121] In some preferred embodiments, mixing is further promoted by creating multiple points throughout the channel where the flow is first split (flow divergence) and then later recombined (flow convergence) with flow in other locations. This can be achieved in the present invention by using substantially diagonal features which alternatively diverge and converge. For example, multiple chevrons or angles can be placed laterally across the channel versus one point or angle or chevron at a fixed axial location in a microchannel. Preferred patterns of divergence and convergence of these features will make use of the three principles outlined above, namely coordination of relative feature location on opposite faces, balance of the number of diverging and converging features, both in the flow direction and in the width dimension (perpendicular to the mean bulk flow and into the microchannel gap between the faces containing recessed features), and having a sufficiently small gap in the open microchannel (see gap dimensions mentioned above). In some preferred embodiments, the number of converging and diverging features is minimized and substantially similar features are repeated.

[0122] FIG. **1***c* shows some options for the overlap of surface features on opposing walls. Since the features on opposite faces are substantially trans to one another in FIG. **1***c*, the flow patterns are not expected to be as effective for mixing as for the case where the features on opposite faces are in a cis configuration.

[0123] The present invention can utilize patterned surfaces on two sides of a microchannel or only on one side of a microchannel. For example, a surface can be paired (on opposite sides of a microchannel) with a shim of similar structure with diagonal stripes (the stripes are preferably recesses) that are either: aligned, staggered or crossed with respect to the opposing surface. For some cases, pairing creates better mixing than in channels structures only on one major surface, especially as the main channel gap increases beyond 1 mm. In some preferred embodiments, the patterning consists essentially of diagonal recesses that are disposed over substantially the entire width of a microchannel surface. The patterned surface area of a wall can occupy part or the entire length of a microchannel surface; in some embodiments diagonal recesses are disposed over at least 10%, 20%, 50%, or at least 80% of the length of a microchannel surface. In some embodiments, the features comprise diagonal features (preferably recesses (including CRFs) that comprise one or more angles relative to flow direction. In some preferred embodiments, the features have two or more angles on at least one wall relative to the direction of flow. The angles may be connected or disconnected at the apex or point. The different angles across the width of at least one wall of the microchannel at at least one axial location acts to push and pull the fluid in different directions and improves lateral and transverse flow relative to the otherwise straight laminar streamlines. As the flow lateral and transverse flow is increased it preferably enters the active surface features with an increased propensity as Reynolds number increases.

[0124] In another aspect, a patterned surface comprises multiple patterns stacked on top of each other. In one example, a pattern or array of holes are placed adjacent to a heat transfer wall and a second pattern, such as a diagonal or chevron array of features stacked on top and adjacent to an open channel for flow. A sheet adjacent to an open gap has patterning through the thickness of the sheet such that flow can pass through the sheet into underlying patterning. Flow may be through advection or diffusion. As an example, a first sheet with an array of through holes can be placed over a heat transfer wall, and a second sheet with an array of diagonal through slots or chevrons disposed on the first sheet. This preferred embodiment creates more surface area for adhering a catalyst or other active agent including an adsorbent, wick, etc. In some embodiments, the pattern is repeated on at least one other wall of the microchannel. The patterns can be preferentially offset on opposing walls. The innermost patterned surfaces (those surfaces bounding a flow channel) may contain a pattern such as a diagonal array. The diagonal arrays may be oriented both with the direction of flow (cis orientation) or one side oriented with the direction of flow and the opposing side oriented against the direction of flow (trans orientation). By varying surface features on opposing walls, different flow fields and degree of vorticity are created in the fluid that travels down the center and open gap.

[0125] The gap between microchannel walls (that is, the unobstructed bulk flow path) is preferably 10 mm or less, more preferably 5 mm or less, in some embodiments in the range of 0.05 to 2 mm. The surface features may be repeating identical shapes or nonidentical. Nonidentical features change orientation and/or shape and/or size along the length of microchannel. As an example, a pattern may include a chevron (or a check shape) that is aligned with the direction of flow then aligned against the direction of flow and then aligned or pointed to one side of a microchannel and then the other. The features may be randomly placed, or may have small groupings of 2 or 5 or 10 or more of similar features before switching to a new feature. It is preferable to have similar features aligned continuously or for many features in a row on at least one wall of the main channel, where at least 10 or 20 or more similar features are in series along the length of one or more walls of the main channel. Similar features essentially maintain the overall bulk flow direction as defined as a net positive velocity vector in the x or y direction (flow between the top and bottom of a surface feature and flow from side to side of a microchannel) rather than the net velocity in either the x or y coordinate moving negative along the channel length as would be the case for a back and forth motion in the flow in the main flow channel. As a result, similar features have no or modest changes in the location where the second angle of the at least two angle active surface feature groove begins across the width of the microchannel. Chevrons at the shift in a staggered herringbone mixer are not similar. Variations in the feature span or run width may change from feature to feature, but preferably by less than 50% from feature to feature. More preferably by less than 30% and more preferably still by less than 15%. It should be further noted that a feature with discontinuous legs with at least two or more angles is still considered a feature with more than one angle. As an example, consider a simple chevron where two legs of different angles are connected at an apex at the top of the grooved feature. The apex of the grooved chevron may be blocked such that the microchannel contains two net single angle features along the width of at least one wall of the microchannel. The resulting performance for this disconnected feature set is substantially similar to the connected feature set if the distance separating the two disconnected legs is less than 20% of the width of the microchannel. In