embodiments at least 30%, and in some embodiments 20 to about 100% of the gap distance between opposing microchannel surfaces. In some embodiments, the depth of surface features are more than 100% of the gap distance and may be as large as 500% of the gap. Another inventive feature of some preferred embodiments, is the aspect ratio of the surface feature run width to channel gap.

[0054] Useful applications of the invention include but are not limited to: heterogeneously catalyzed reactions (such as where solid catalysts are disposed on a microchannel wall); homogeneously catalyzed reactions; homogeneous uncatalyzed reactions; distillation; emulsion formation; advanced heat transfer; mixing; gas liquid reactions; adsorption, absorption and other gas-liquid or liquid-liquid separations. The invention may also be useful for other applications that are facilitated by the collision of a molecule with an active wall. As an example, a sensor or detector surface may be preferentially disposed within an active surface feature, such that more of the bulk solutes may collide and thus activate the active surface. This may be particularly useful for a dilute agent in a fluid. This invention may also be useful for the destruction of waste molecules, dilute or concentrated, in a fluid when flowing past an active conversion or separation agent on a surface as disposed in an active surface feature. The invention may also be useful for an enzymatic reaction or a bioreactor, again where it is preferable for a reacting molecule to collide with a catalyst whether bio based such as an enzyme or more conventional heterogeneous catalyst. The invention may be further enhanced if a catalyst is tethered or attached to the surface, but also in part extends above the surface so as to create more surface area. The extended surface or tethered catalyst or tethered active agent such as a sorbent or other surface that interacts chemically or phsyically with a solute molecule may extend a small fraction of the total depth of surface feature above the wall (<10%) or it may extend a substantial fraction of the total depth of surface feature above the wall (10% to 100%). In some inventive processes, the extended surfaces or tethers may extend into the bulk flow path. The tethers may be rigid or unmoving with the shear of the fluid in the surface features or the bulk flow path, or the tethers may be moving with the shear of the fluid. In the case of non-rigid tethers, this secondary movement may create additional spatial or temporal gradients in the fluid flow field or the movement of the tethers themselves. This latter may be further advantageous for further reducing mass transport limitations between the fluid molecules and the active agents disposed on either the active surface feature walls or the tethered extensions attached thereon.

[0055] The invention also includes methods for catalytic chemical conversion (for example, homogeneous ethylene formation or heterogeneous steam methane reforming), such method comprising flowing a reactant fluid composition into a microchannel, wherein a catalyst is present in the microchannel or may be alternatively co-fed with the reactant, and reacting the reactant fluid composition into a desired product (or products) in the microchannel. The invention also includes methods of conducting unit operations using any of the apparatus described herein.

[0056] The invention includes the prebonded stack of sheets, as well as the bonded device. By bonding, this means joining by any means including: diffusion bonding, brazing, welding, gluing, reactive bonding, and other methods. The bonded device may or may not include a coating (such as a catalyst coating) over the patterned regions and/or within the recesses of a patterned region. The invention further includes chemical processes conducted in any of the apparatus described herein.

[0057] In a further aspect, the invention provides a method of chemical processing, comprising: passing a fluid into any of the apparatus described herein. The invention includes apparatus and methods that utilize surface features that enhance mixing. The invention may also be described in terms of mixing fluids as they flow through a microchannel (for example, any of the mixing types in the Examples).

Glossary of Terms Used

[0058] A "surface feature" is a projection from, or a recess into, a microchannel wall that modify flow within the microchannel. If the area at the top of the features is the same or exceeds the area at the base of the feature, then the feature may be considered recessed. If the area at the base of the feature exceeds the area at the top of the feature, then it may be considered protruded (except for CRFs discussed below). The surface features have a depth, a width, and a length for non-circular surface features. Surface features may include circles, oblong shapes, squares, rectangles, checks, chevrons, zig-zags, and the like, recessed into the wall of a main channel. The surface features may contain sub features where the major walls of the first recessed features further contain smaller features that may take the form of notches, waves, indents, holes, burrs, checks, scallops, and the like. Some nonlimiting examples of surface feature perimeters are illustrated in FIG. **1***d*.

[0059] A "cavity" is a partial or full feature in a wall or sheet that may be an active surface feature, slots, holes, irregular or regular shapes, or other volume where fluid flow is either diffusive or advective or both in the features.

[0060] "Compact recessed features" are recesses in a main channel. Compact recessed features (CRFs) have no flow exit other than the main channel. Each CRF has one or more closed perimeters at the interface with the main gap, the surface enclosed by each perimeter being everywhere orthogonal to the bulk flow direction in the main channel, and the total area enclosed by all of the recessed feature perimeters at the interface with the main channel makes up more than 50% of the wall area for a given wall in the main channel. CRFs have no continuous flow path from one feature to the next without re-entering the main channel. Protrusions are not recessed features or CRFs.

[0061] Two features are "similar features" or "like features" if at least 50% (preferably at least 80%) of the perimeter of one feature (the perimeter being the interface between the surface feature and the main channel) can be superimposed within the perimeter of the other feature by translation along the length in the direction of bulk flow in the main channel, with less than 20 degrees (or, more preferably, without) rotation of either feature perimeter, and at least 50% (preferably at least 80%) of the perimeter of the other feature can be superimposed within the perimeter of the one feature by translation along the length in the direction of bulk flow in the main channel, with less than 20 degrees (or, more preferably, without) rotation of either feature perimeter. If the perimeter defining the interface between the surface feature and the main channel is not flat,