of the present invention include their relatively large heat and mass transfer rates, and the substantial absence of any explosive limits. Microchannel reactors can combine the benefits of good heat and mass transfer, excellent control of temperature, residence time and minimization of by-products. Pressure drops can be low, allowing high throughput and the catalyst can be fixed in a very accessible form within the channels eliminating the need for separation. Furthermore, use of microchannel reactors can achieve better temperature control, and maintain a relatively more isothermal profile, compared to conventional systems. In some embodiments, the reaction microchannel (or microchannels) contains a bulk flow path. The term "bulk flow path" refers to an open path (contiguous bulk flow region) within the reaction chamber. A contiguous bulk flow region allows rapid fluid flow through the reaction chamber without large pressure drops. In some preferred embodiments there is laminar flow in the bulk flow region. Bulk flow regions within each reaction channel preferably have a cross-sectional area of 5×10^{-8} to 1×10^{-2} m^2, more preferably 5×10^{-7} to 1×10^{-4} m^2. The bulk flow regions preferably comprise at least 5%, more preferably at least 50% and in some embodiments, 30-99% of either 1) the interior volume of the reaction chamber, or 2) a cross-section of the reaction channel.

[0077] In many preferred embodiments, the microchannel apparatus contains multiple microchannels, preferably groups of at least 5, more preferably at least 10, parallel channels that are connected in a common manifold that is integral to the device (not a subsequnetly-attached tube) where the common manifold includes a feature or features that tend to equalize flow through the channels connected to the manifold. Examples of such manifolds are described in U.S. patent application Ser. No. 10/695,400, filed Oct. 27, 2003 which is incorporated herein as if reproduced in full below. In this context, "parallel" does not necessarily mean straight, rather that the channels conform to each other. In some preferred embodiments, a microchannel device includes at least three groups of parallel microchannels wherein the channel within each group is connected to a common manifold (for example, 4 groups of microchannels and 4 manifolds) and preferably where each common manifold includes a feature or features that tend to equalize flow through the channels connected to the manifold. An aluminide coating can be formed in a group of connected microchannels by passing an aluminum-containing gas into a manifold, typically, the manifold will also be coated.

[0078] Heat exchange fluids may flow through heat transfer microchannels adjacent to process channels (preferably reaction microchannels), and can be gases or liquids and may include steam, oil, or any other known heat exchange fluids—the system can be optimized to have a phase change in the heat exchanger. In some preferred embodiments, multiple heat exchange layers are interleaved with multiple reaction microchannels. For example, at least 10 heat exchangers interleaved with at least 10 reaction microchannels and preferably there are 10 layers of heat exchange microchannel arrays interfaced with at least 10 layers of reaction microchannels. Each of these layers may contain simple, straight channels or channels within a layer may have more complex geometries.

[0079] While simple microchannels can be utilized, the invention has particular advantages for apparatus with complex microchannel geometries. In some preferred embodiments, the microchannel apparatus includes one or more of the following characteristics: at least one contiguous microchannel has a turn of at least 45°, in some embodiments at least 90°, in some embodiments a u-bend, a length of 50 cm or more, or a length of 20 cm or more along with a dimension of 2 mm or less, and in some embodiments a length of 50-500 cm; at least 2 adjacent channels, having an adjacent length of at least one cm, are connected by plural orifices along a common microchannel wall where the area of orifices amounts to 20% or less of the area of the microchannel wall in which the orifices are located and where each orifice is 2 mm^2 or smaller, in some embodiments 1 mm^2 or smaller, in some embodiments 0.6 or 0.1 mm^2 or smaller—this is a particularly challenging configuration because a coating should be applied without clogging the holes; or at least two, in some embodiments at least 5, parallel microchannels having a length of at least 1 cm, have openings to an integral manifold, where the manifold includes at least one dimension that is no more than three times the minimum dimension of the parallel microchannels (for example, if one of the parallel microchannels had a height of 1 mm (as the smallest dimension in the set of parallel microchannels), then the manifold would possess a height of no more than 3 mm). An integral manifold is part of the assembled device and is not a connecting tube. In some apparatus, a microchannel contains a u-bend which means that, during operation, flow (or at least a portion of the flow) passes in opposite directions within a device and within a continguous channel (note that a contiguous channel with a u-bend includes split flows such as a w-bend, although in some preferred embodiments all flow within a microchannel passes through the u-bend and in the opposite direction in a single microchannel).

[0080] A contiguous microchannel may have a different cross sectional area openings along the length of the contiguous microchannel. The different cross sectional areas may be formed by the stacking of different shims or laminae.

[0081] In some embodiments, the inventive apparatus (or method) includes a catalyst material. The catalyst may define at least a portion of at least one wall of a bulk flow path. In some preferred embodiments, the surface of the catalyst defines at least one wall of a bulk flow path through which the mixture passes. During operation, a reactant composition flows through the microchannel, past and in contact with the catalyst. In some preferred embodiments, a catalyst is provided as an insert that can be inserted into (or removed from) each channel in a single piece; of course the insert would need to be sized to fit within the microchannel. In some embodiments, the height and width of a microchannel defines a cross-sectional area, and this cross-sectional area comprises a porous catalyst material and an open area, where the porous catalyst material occupies 5% to 99% of the cross-sectional area and where the open area occupies 5% to 99% of the cross-sectional area. In some embodiments, the open area in the cross-sectional area occupies a contiguous area of 5×10^{-8} to 1×10^{-2} m^2. In some embodiments, a porous catalyst (not including void spaces within the catalyst) occupies at least 60%, in some embodiments at least 90%, of a cross-sectional area of a microchannel. Alternatively, catalyst can substantially fill the cross-sectional area of a microchannel (a flow through configuration). In another alternative, catalyst can be provided as a coating (such as a washcoat) of material within a microchannel