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.

[0059] The heat exchange fluid can be the reaction stream, either before it has passed through the catalyst contaning zone or after it has passed through the catalyst containing zone.

[0060] While simple microchannels can be utilized, the invention has 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 0.6 $mm^2$ or smaller, in some embodiments 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).

[0061] In preferred 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 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 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. The catalyst can be a coating (such as a washcoat) of material within a microchannel reaction channel or channels. The use of a flow-by catalyst configuration can create an advantageous capacity/pressure drop relationship. In a flow-by catalyst configuration, fluid preferably flows in a gap adjacent to a porous insert or past a wall coating of catalyst that contacts the microchannel wall (preferably the microchannel wall in direct thermal contact with a heat exchanger (preferably a microchannel heat exchanger), and in some embodiments a coolant or heating stream contacts the opposite side of the wall that contacts the catalyst).

[0062] Other Substrates

[0063] In preferred embodiments, the inventive apparatus, catalysts or methods contain or use an aluminide coating on an interior microchannel. In preferred embodiments, the invention includes an aluminide layer, an alumina layer and a catalyst material coated onto an interior microchannel wall. However, in some embodiments, the invention includes a catalyst (or method of making a catalyst) in which an aluminide layer is formed on a substrate (catalyst support) other than a microchannel wall. Thus, in some embodiments, the invention includes a substrate, an aluminide coating over the substrate, and a catalyst material over the aluminide (preferably with an intervening alumina layer)—the substrate may have a conventional form such as pellets or rings; in some embodiments the substrate is not an expanded metal sheet. As in the case of microchannel walls, preferred catalyst supports are preferably formed of a Ni-, Co-, or Fe-based superalloy.

[0064] In some preferred embodiments, the catalyst comprises a metal, ceramic or composite substrate having a layer or layers of a catalyst material or materials deposited thereon. Preferably, the substrate is thermally conductive. A preferred substrate is a finned substrate that is characterized by the presence of fins (such as square-wave type fins) on the substrate's surface. These fins may, for example, take the form of fins etched in the wall of an integrated reactor or a finned insert (such as a flat metal plate with one grooved surface) that can be inserted into a combustion chamber of a microreactor. In some cases, the reactor can be refurbished by replacing an insert. One method of fabrication within a microchannel comprises the use of a slitting saw, partial etching using a photochemical process, or a laser EDM. This type of support provides numerous advantages including: high heat flux with short heat transfer distances, high surface area, and low pressure drop. Preferably, the support has a height (including fins) of less than 5 mm and preferably less than 2 mm and a fin-to-fin separation of 1000 $\mu$m or less, and in some embodiments, a fin-to-fin separation of 150 to 500 $\mu$m. Alternatively, the catalyst may take any conventional form such as a powder or pellet.

[0065] Metal Aluminide Layer

[0066] In some embodiments of the invention, at least a portion of at least one interior wall of a microchannel apparatus (preferably a microreactor) is coated with a layer of a metal aluminide (preferably nickel aluminide (NiAl)). It has been surprisingly discovered that an alumina wall coating formed by oxidizing a metal aluminide (NiAl in the examples) coating provides superior corrosion resistance as compared to either thermally grown oxide layer (grown from the substrate without forming an aluminide) or a solution deposited alumina layer. It is believed that exceptionally uniform and dense coatings result from solid state reaction of aluminum deposited at the surface from the gas phase and nickel diffusing out from the substrate towards the surface. In addition, nickel may be plated onto a metal that is not rich in nickel, such as stainless steel, to create a reactive surface for the aluminidization process. Nickel aluminide could also be deposited by supplying both Al and Ni precursors in the vapor phase concurrently or as a