DISCUSSION OF THE INVENTION

[0129] The use of partial liquid boiling in microchannels or minichannels is a useful tool to control other unit operations. Microchannels are preferred and provide superior results over minichannels and even greater superiority over conventionally sized channels. The partial boiling microchannels or minichannels may be adjacent to one unit operation process channel. Alternatively, one boiling mini- or micro-channel may serve two, three, four, or more process channels. The process channel may be a microchannel (D_h<2 mm, where Dh is the hydraulic diameter) or a mini-channel (D_h from 2 to 10 mm). The heat flux for a phase change such as boiling is much higher than that for a single phase heat transfer fluid. As such, the rate of heat generation can be much higher in the process channels and thus the overall productivity of the integrated system is held high.

[0130] Coolant channels of the present invention are substantially longer than channels of comparative size that have been considered for partial boiling applications in the prior art. Conventionally, longer channels would have been considered inappropriate for partial boiling applications because they would be considered a technical risk due to high pressure drops and problems with dry out. Surprisingly, we have obtained excellent results by the use of partial boiling in long microchannels—including high capacity, high flow, acceptable pressure drop, and stability without a tendency to dry out. Additionally, devices in which the ratio of manifold volume to process channel volume is small, better utilize apparatus volume.

[0131] In one aspect, the invention provides a process of removing heat from an exothermic process, comprising: conducting an exothermic process in a process channel; removing heat from the exothermic process in the process channel to an adjacent minichannel or adjacent microchannel; and passing a coolant fluid through the adjacent minichannel or adjacent microchannel that undergoes partial boiling for a length of at least 15 cm as it passes through the adjacent minichannel or adjacent microchannel. In this aspect, the adjacent minichannel or adjacent microchannel comprises an interior wall surface that is a surface on a channel wall that separates the adjacent minichannel or adjacent microchannel from the process channel; and the average shear stress of the fluid at the wall in the adjacent minichannel or adjacent microchannel for a length of at least 1 cm, either measured or calculated, is at least 1 Pascals (Pa) .

[0132] In another aspect, the invention provides a process of cooling an exothermic process, comprising: conducting an exothermic process in a process channel; providing cooling to the exothermic process in the process channel by transferring heat to an adjacent microchannel having a channel length of at least 15 cm; passing a coolant fluid at a flow velocity of at least 0.1 m/s through the adjacent microchannel that undergoes partial boiling as it passes through the adjacent microchannel; wherein the adjacent microchannel comprises an interior wall surface that is a surface on a channel wall that separates the adjacent microchannel from the process channel; and wherein the surface's temperature during the process is no more than 5° C. above the coolant fluid's boiling temperature at conditions present within the microchannel.

[0133] In various embodiments, the invention may have one or more of the following characteristics: a wall stress at least 1 Pa, 10 Pa, 50 Pa., or at least 100 Pa; partial boiling length over at least 15 cm, over entire length of adjacent cooling channel; laminar flow; the process channel mini or micro; bubble diameters in partially boiling fluid are smaller than the gap of the adjacent minichannel or adjacent microchannel (preferably the bubbles diameters do not exceed 90%, more preferably 75%, 50%, 20% of the channel height); hydraulic diameter of 5 mm in the adjacent channel; the temperature in the adjacent minichannel or adjacent microchannel varies by no more than 5C, 3 C, 1C as measured by thermocouples disposed at regions in the channel where partial boiling is occurring; coolant entering the adjacent channel is a single phase fluid; the coolant at least IC, more pref at least 3C, 5C, 10C less than the boiling temp at the conditions in the channel; length of partial boiling at least 25 cm, 50 cm, 100 cm; adjacent minichannel or adjacent microchannel is a microchannel; the surface is 1.5 C or less above the boiling temperature at the point at which boiling is initiated, and the adjacent microchannel has a hydraulic diameter of 50 to 700 μm; adjacent microchannel is a smooth microchannel having a gap of I mm or less and wherein the average heat flux is at least 2, preferably 5, more prefereably at least 10 W/cm^2 of surface; flow rate is at least 5 mL/min per coolant microchannel, channel length is at least 25 cm, and wall surface temperature is 5 C or less above the boiling temp at channel conditions; pressure oscillation in the microchannel is 5% or less of the baseline pressure, as measured by a pressure gauge; adding a surfactant to the coolant fluid; pressure drop in the microchannel is less than 0.3 psig/2.5 cm for a flux of at least 2 W/cm^2; coolant microchannels are at least 30 cm (pref at least 45 cm, 60 cm) with stable partial boiling such that pressure drop fluctuations are no more than 5%, 3% or 1%, as measured by a pressure gauge at the channel outlet; FT reaction with partial boiling cooling and methane selectivity <15%, <12%, <10%, <8%, <5% accomplished by controlling temp well so that selectivity is low; horizontal flow of a partial boiling fluid in a microchannel, which is conventionally considered more challenging than vertical flow; horizontal cooling channels stacked vertically, cross flow partial boiling, or counter, or co-, or diagonal flow; flow segregation in submanifolds prior to entering microchannels; no change in heat transfer performance in partial boiling channels if coolant flow is stopped for more than 20 hours during operation; no change in heat transfer performance in partial boiling channels if main process flow in the exothermic channel is stopped for more than 2 hours during operation; any exothermic reaction, including the Fischer-Tropsch reactions, with change in boiling side temperature <3C, <1 C from inlet to outlet of heat transfer channel; heat transfer coefficient in first single phase heat transfer section of the cooling microchannel is <80%, <50%, <25%, or <10% of the heat transfer coefficent in the second section of the cooling microchannel where partial boiling is occurring; partial boiling microchannels coupled with an exothermic unit operation where the heat flux or load in the first part of the process channel is substantially different than the heat flux or load in the second part of the process channel; and/or partial boiling at elevated pressures, >100 psig, >300 psig, >500 psig.

[0134] Apparatus features of this invention include: Aspect ratio of the coolant channel has a width to height