can be formed in any of the walls, and/or can be formed in more than one wall of the micro-channel **115**. The grooves **135** can span an entire length of a wall, or only a portion of the wall.

FIGS. **2**A-**2**D are schematics illustrating particle suspensions flowing through a micro-channel having flat walls and another micro-channel having grooves formed in a wall. FIG. **2**A shows a microfluidic device **200** that includes a micro-channel **205** having a rectangular cross-section. The walls of the micro-channel **205** do not include grooves such as those described with respect to the microfluidic device **100**, i.e., surfaces of the walls are flat. A particle suspension **220** including particles **225** suspended in a fluid is flowing through the micro-channel **205**. In contrast, FIG. **2**B shows a similar suspension flowing through the microfluidic device **100**.

As the fluid flows past a herringbone pattern formed by arranging grooves **135** in a column in the micro-channel **115**, the grooves **135** in the path of the fluid disrupt fluid flow. In some embodiments, depending upon flow velocity and the dimensions of the grooves, specifically, for example, a size of the grooves and an angle between the two arms of a groove, the disruption in the fluid flow leads to a generation of microvortices in the fluid. The microvortices are generated because the grooves induce fluid flow in a direction that is transverse to a principal direction of fluid flow, i.e., the axial direction. In some embodiments, although microvortices are not generated, the grooves **135**, **140** induce sufficient disruption to alter the flow path of portions of the fluid to increase wall-particle interactions.

In an absence of the grooves, as shown in FIG. **2**C, the particles **225** suspended in the fluid travel through the flat micro-channel **205** in a substantially linear fashion such that only those particles **225** near the edges of the flow field (e.g., immediately adjacent to the walls of the micro-channel **205**) are likely to interact with the micro-channel **205** walls. In contrast, as shown in FIG. **2**D, flowpaths of the particles **225** traveling past the herringbone patterns experience can be disrupted by the microvortices in the fluid, increasing the number of particle-micro-channel wall interactions. The microvortices are affected by the structural features of each groove **445** formed in the upper wall **130** of the microfluidic device **100**. Exemplary dimensions of a groove **445** are described with reference to FIG. **3**.

FIGS. **3**A and **3**B illustrate a groove **135** faulted on an upper wall **130** of a micro-channel **115**. As shown in FIG. **3**A, a symmetric groove **135** includes two arms, each spanning a length between a first end **150** and the apex **145** (l_1), and a second end **155** and the apex **145** (l_2). In the illustrated embodiments, the angle α between the two arms is 90°. In some embodiments, the angle α between the arms ranges between 10° and 170°. FIG. **3**B is a view of the micro-channel **115** including the groove **135** formed in the upper surface **115**. As shown in FIG. **3**B, the width of the groove is w, the height of the side walls **120** and **125** of the micro-channel **115** is h_c and the height of the groove **135** formed on the upper wall **115** is h_g. In some embodiments, l_1 and l_2, each range between 250 μm-400 μm h_g ranges between 3 μm and 70 μm, h_c is 100 μm. For example, when h_c is 100 μm, h_g is 25 μm.

FIG. **3**C illustrates an asymmetric groove **140** including two arms, each spanning a length between a first end **170** and an apex **165** (l_3), and a second end **175** and the apex (l_4), respectively. In the illustrated embodiment, the angle β between the two arms is 90°, and can range between 10° and 170°. In some implementations, the groove **140** can be manufactured such that a ratio between l_3 and l_4 is 0.5. For example, l_3 is 141 μm and l_4 is 282 μm. The groove **140** has a thickness of 35 μm. An effect of the height of the groove, h_g, on particle capture is described with reference to FIG. **15**.

A herringbone pattern can be created by fanning a column of herringbones in which each groove is positioned adjacent to another groove. Further, all grooves in the column can face the same direction. In some embodiments, a distance between each groove is 50 μm. Alternatively, the grooves can be positioned at any distance from each other. A column can include any number of grooves, for example, ten grooves. The herringbone pattern can further include multiple columns of grooves formed serially from an inlet to the outlet. In some embodiments, two adjacent columns of grooves can be separated by 100 μm. In other words, a first groove of the second column can be positioned 100 μm away from a last groove of the first column. This pattern can be repeated from an inlet to the micro-channel **115** to the outlet.

In some embodiments, grooves or groups of grooves in a column can be laterally offset from each other. For example, as can be see in FIG. **2**B, the column of grooves in microfluidic device **100** includes a first set of grooves with apexes set to the right (facing downstream) of the channel centerline and a second set of grooves with apexes set to the left of the channel centerline. Such offsets are thought to further increase wall-particle interactions.

The dimensions shown in FIGS. **3**A-**3**C are exemplary. In general, the choice of groove heights can depend on factors including channel dimensions, particle properties including size, density, and the like, and particle suspension flow rates. Although deeper grooves offer more disruption, other factors can impose limits on groove heights. For example, up to a certain limit, the groove height can be increased in proportion with the channel height. The channel height, and consequently the groove height, can depend upon the particle to micro-channel **115** surface contact area. An increase in channel dimensions can cause a decrease in particle-micro-channel **115** interactions as surface contact area available for the particles to interact decreases relative to the cross-sectional flow area. Also, a lower limit on the channel height, and consequently the groove height, can be imposed to prevent clogging. In some implementations, a ratio between groove height and channel height can be less than one, for example, in a range between 0.1 to 0.6. In some implementations, the ratio can be equal to one (e.g., the groove height can be equal to the channel height), or can be greater than one (e.g., the groove height, for example, 60 μm, can be greater than the channel height, for example, 50 μm). Further, the shape of the groove can be different from a "V" shape, for example, "U" shape, "L" shape, and the like.

The micro-channel **115** can be formed in the upper substrate **105**, for example, using soft lithography techniques. In some implementations, negative photoresist (SU-8, MicroChem, Newton, Mass., USA) can be photolithographically patterned on silicon wafers to create masters with two-layer features. The masters thus formed can include SU-8 features that form the basis for the features of the micro-channel **115**, for example, channel cross-section, channel size, and the like. The heights of SU-8 features (ranging from 3 μm-100 μm) on the masters can be measured with a surface profilometer such as a Dektak ST System Profilometer, commercially available from Veeco Instruments Inc., Plainview N.Y. The masters can then be used as molds on which PDMS pre-polymer can be poured and allowed to cure in a conventional oven at 65° C. for 24 hours. The upper substrate **105**, including the micro-channel **115**, is formed when the poured PDMS pre-polymer is cured. The cured upper substrate **110** can be removed from the molds and bonded to the lower substrate **105**, for example using oxygen plasma treatment, to form the microfluidic