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(54) **CASCADED HYDRODYNAMIC FOCUSING IN MICROFLUIDIC CHANNELS**

(76) Inventors: **Horst Haussecker**, Palo Alto, CA (US); **Narayan Sundararajan**, San Francisco, CA (US)

Correspondence Address:
MARSHALL, GERSTEIN & BORUN LLP
6300 SEARS TOWER
233 S. WACKER DRIVE
CHICAGO, IL 60606 (US)

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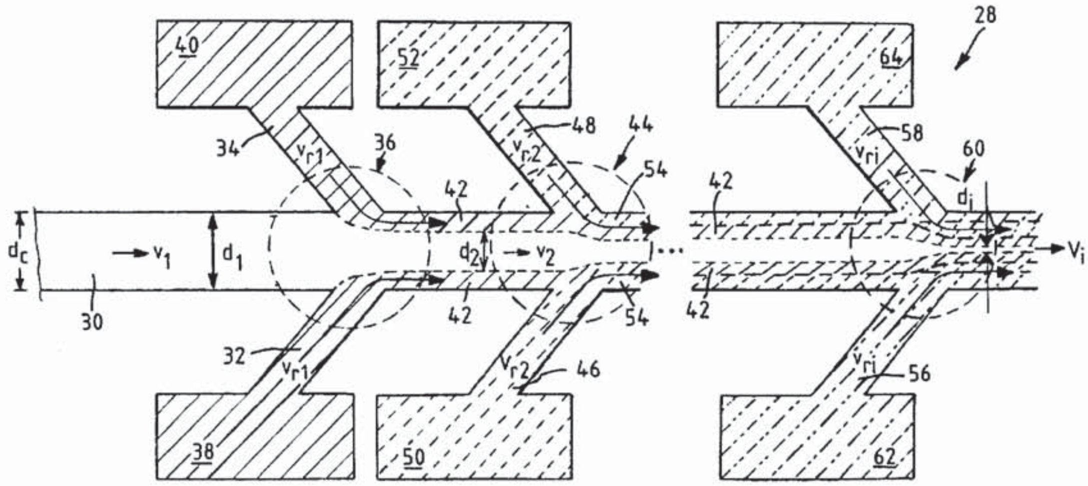
(57) **ABSTRACT**

Disclosed herein is an apparatus that includes a body structure having a plurality of microfluidic channels fabricated therein, the plurality of microfluidic channels comprising a center channel and focusing channels in fluid communication with the center channel via a plurality of cascaded junctions. Also disclosed herein is a method that includes the step of providing a body structure having a plurality of microfluidic channels fabricated therein, the plurality of microfluidic channels comprising a center channel and focusing channels in fluid communication with the center channel via a plurality of cascaded junctions. The method also includes the steps of providing a flow of the sample fluid within the center channel, providing flows of sheath fluid in the focusing channels, and controlling or focusing the flow of the sample fluid by adjusting the rate at which the sheath fluid flows through the focusing channels and cascaded junctions, and into the center channel. The disclosed apparatus and method can be useful to control or to focus a flow of a sample fluid in a microfluidic process are disclosed. Additionally, the apparatus and method can be useful to detect molecules of interest in a microfluidic process.



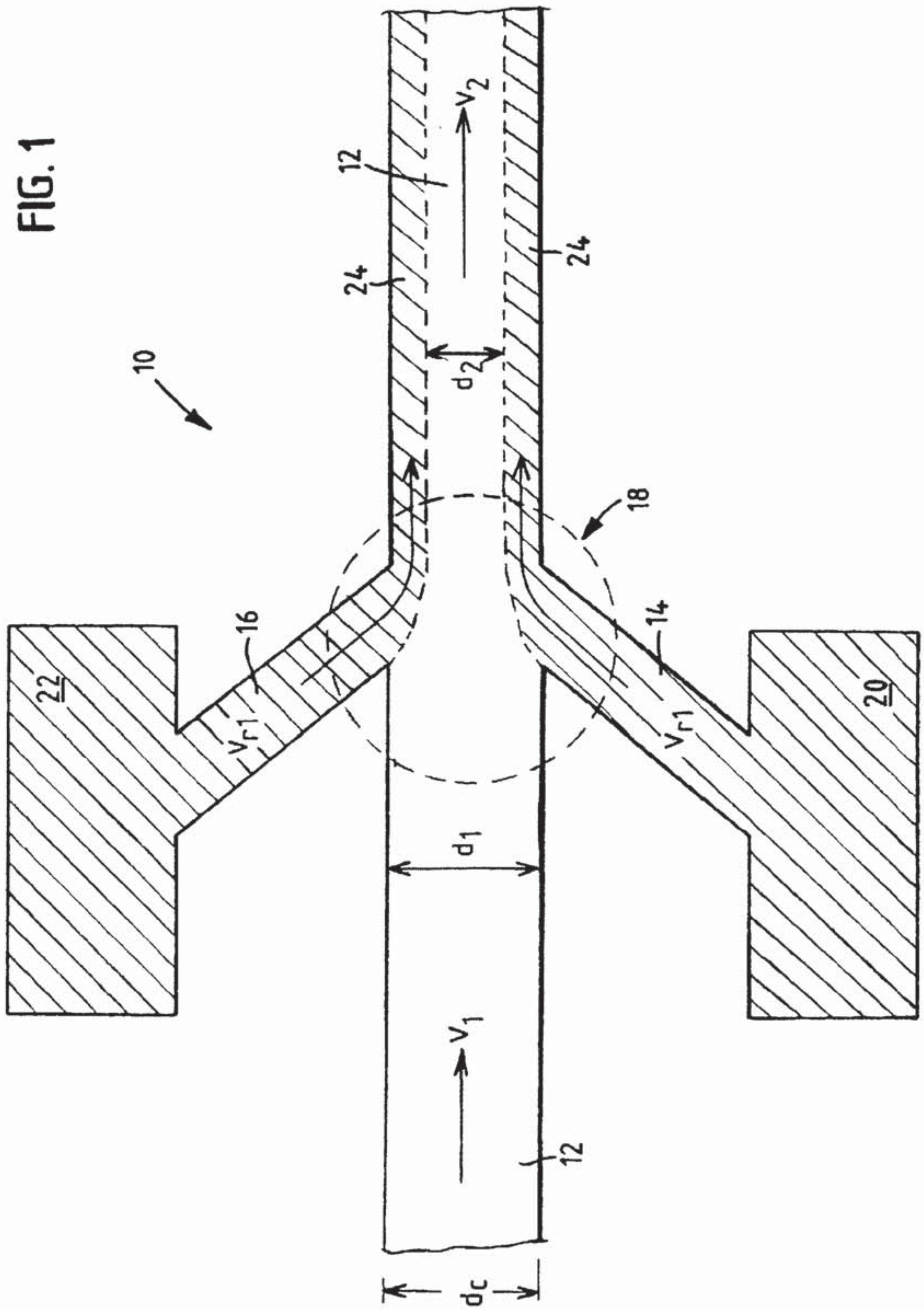


FIG. 1

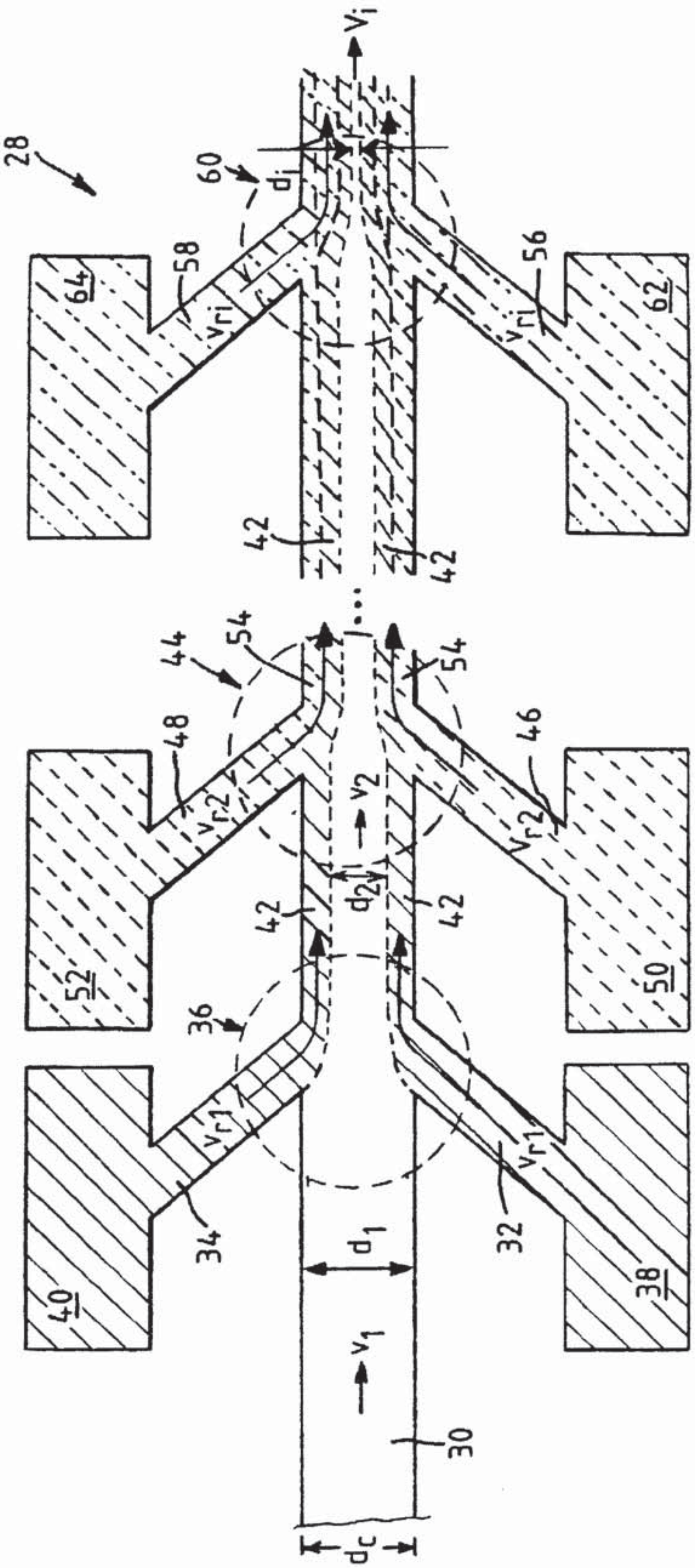

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FIG. 2

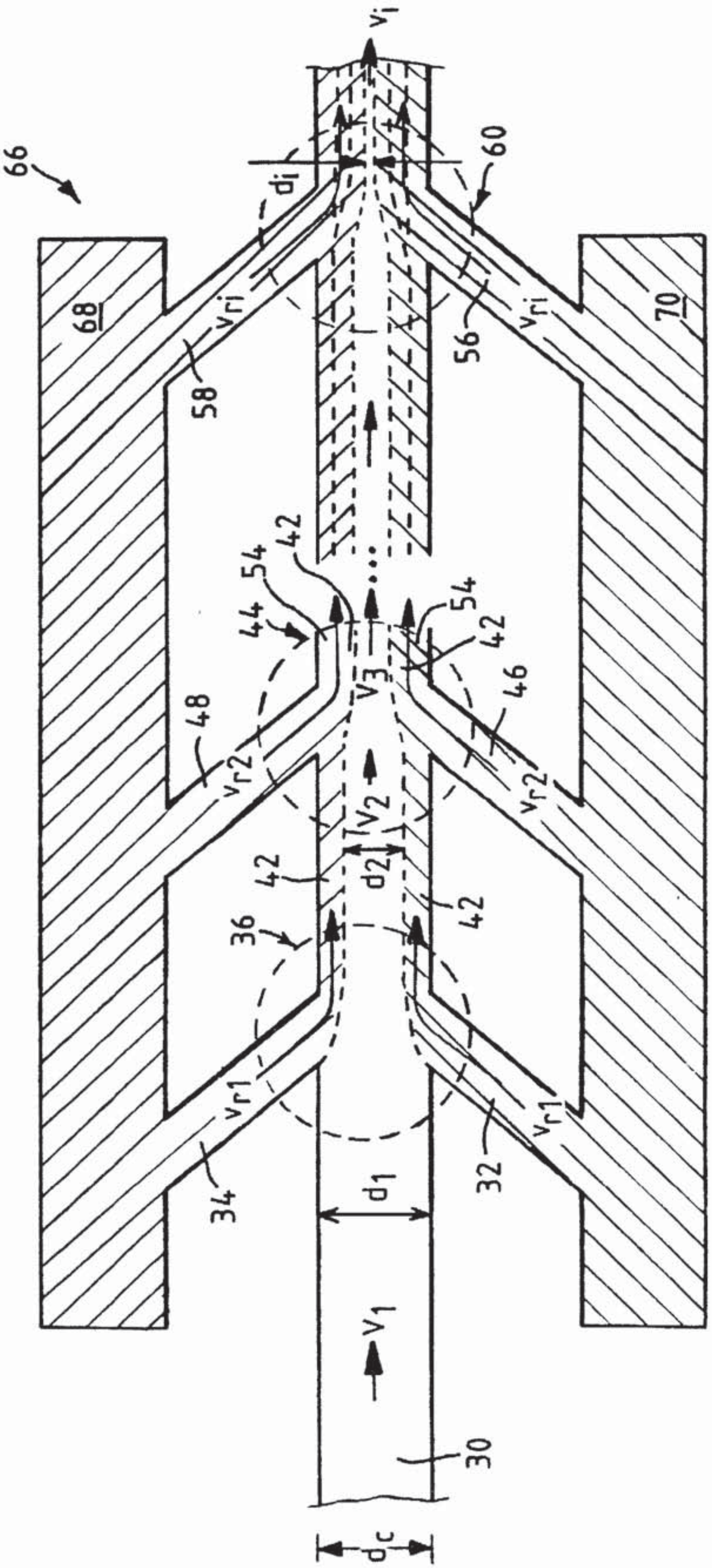
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FIG. 3

CASCADED HYDRODYNAMIC FOCUSING IN MICROFLUIDIC CHANNELS

BACKGROUND OF THE DISCLOSURE

[0001] 1. Field of the Invention

[0002] The invention generally relates to fluid transport phenomena and, more specifically, to the control of fluid flow in microfluidic systems and precise localization of particles/molecules within such fluid flows.

[0003] 2. Brief Description of Related Technology

[0004] Miniaturization of a variety of laboratory analyses and functions provides a number of benefits such as, for example, providing substantial savings in time and cost of analyses, and space requirements for the instruments performing the analyses. Such miniaturization can be embodied in microfluidic systems. These systems are useful in chemical and biological research such as, for example, DNA sequencing and immunochromatography techniques, blood analysis, and identification and synthesis of a wide range of chemical and biological species. More specifically, these systems have been used in the separation and transport of biological macromolecules, in the performance of assays (e.g., enzyme assays, immunoassays, receptor binding assays, and other assays in screening for affectors of biochemical systems).

[0005] Generally, microfluidic processes and apparatus typically employ microscopic channels through which various fluids are transported. Within these processes and apparatus, the fluids may be mixed with additional fluids, subjected to changes in temperature, pH, and ionic concentration, and separated into constituent elements. Still further, these apparatus and processes also are useful in other technologies, such as, for example, in ink-jet printing technology. The adaptability of microfluidic processes and apparatus can provide additional savings associated with the costs of the human factor of (or error in) performing the same analyses or functions such as, for example, labor costs and the costs associated with error and/or imperfection of human operations.

[0006] The ability to carry out these complex analyses and functions can be affected by the rate and efficiency with which these fluids are transported within a microfluidic system. Specifically, the rate at which the fluids flow within these systems affects the parameters upon which the results of the analyses may depend. For example, when a fluid contains molecules, the size and structure of which are to be analyzed, the system should be designed to ensure that the fluid is transporting the subject molecules in an orderly fashion through a detection device at a flowrate such that the device can perform the necessary size and structural analyses. There are a variety of features that can be incorporated into the design of microfluidic systems to ensure the desired flow is achieved. Specifically, fluid can be transported by internal or external pressure sources, such as integrated micropumps, and by use of mechanical valves to re-direct fluids. Utilization of acoustic energy, electrohydrodynamic energy, and other electrical means to effect fluid movement also have been contemplated. Each, however, suffers from certain disadvantages, most notably malfunction. Additionally, the presence of each in a microfluidic system adds to the cost of the system.

[0007] Microfluidic systems typically include multiple microfluidic channels interconnected to (and in fluid communication with) one another and to one or more fluid reservoirs. Such systems may be very simple, including only one or two channels and reservoirs, or may be quite complex, including numerous channels and reservoirs. Microfluidic channels generally have at least one internal transverse dimension that is less than about one millimeter (mm), typically ranging from about 0.1 micrometers (μm) to about 500 μm. Axial dimensions of these micro transport channels may reach to 10 centimeters (cm) or more.

[0008] Generally, a microfluidic system includes a network of microfluidic channels and reservoirs constructed on a planar substrate by etching, injection molding, embossing, or stamping. Lithographic and chemical etching processes developed by the microelectronics industry are used routinely to fabricate microfluidic apparatus on silicon and glass substrates. Similar etching processes also can be used to construct microfluidic apparatus on various polymeric substrates as well. After construction of the network of microfluidic channels and reservoirs on the planar substrate, the substrate typically is mated with one or more planar sheets that seal channel and reservoir tops and/or bottoms while providing access holes for fluid injection and extraction ports as well as electrical connections, depending upon the end use of the apparatus.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0009] For a more complete understanding of the disclosure, reference should be made to the following detailed description and accompanying drawings wherein:

[0010] **FIG. 1** schematically illustrates a partial cross-section of an enlarged microfluidic apparatus exemplifying single-step (non-cascading), hydrodynamic fluid focusing;

[0011] **FIG. 2** schematically illustrates a partial cross-section of an enlarged microfluidic apparatus exemplifying multi-step (cascading), hydrodynamic fluid focusing according to the disclosure; and,

[0012] **FIG. 3** schematically illustrates a partial cross-section of an enlarged microfluidic apparatus exemplifying multi-step (cascading), hydrodynamic fluid focusing according to the disclosure.

[0013] While the disclosed method and apparatus are susceptible of embodiments in various forms, there are illustrated in the drawing figures (and will hereafter be described) specific embodiments of the disclosure, with the understanding that the disclosure is intended to be illustrative, and is not intended to limit the invention to the specific embodiments described and illustrated herein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] As used herein, the term (or prefix) "micro" generally refers to structural elements or features of an apparatus or a component thereof having at least one fabricated dimension in a range of about 0.1 micrometer (μm) to about 500 μm. Thus, for example, an apparatus or process referred to herein as being microfluidic will include at least one structural feature having such a dimension. When used to describe a fluidic element, such as a channel, junction, or

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