US 20020159920A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2002/0159920 A1

Weigl (43) Pub. Date: Oct. 31, 2002

(54) MULTIPLE REDUNDANT MICROFLUIDIC STRUCTURES CROSS REFERENCE TO RELATED APPLICATIONS

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(21) Appl. No.: **10/115,374**

(22) Filed: **Apr. 3, 2002**

Related U.S. Application Data

(60) Provisional application No. 60/281,114, filed on Apr. 3, 2001.

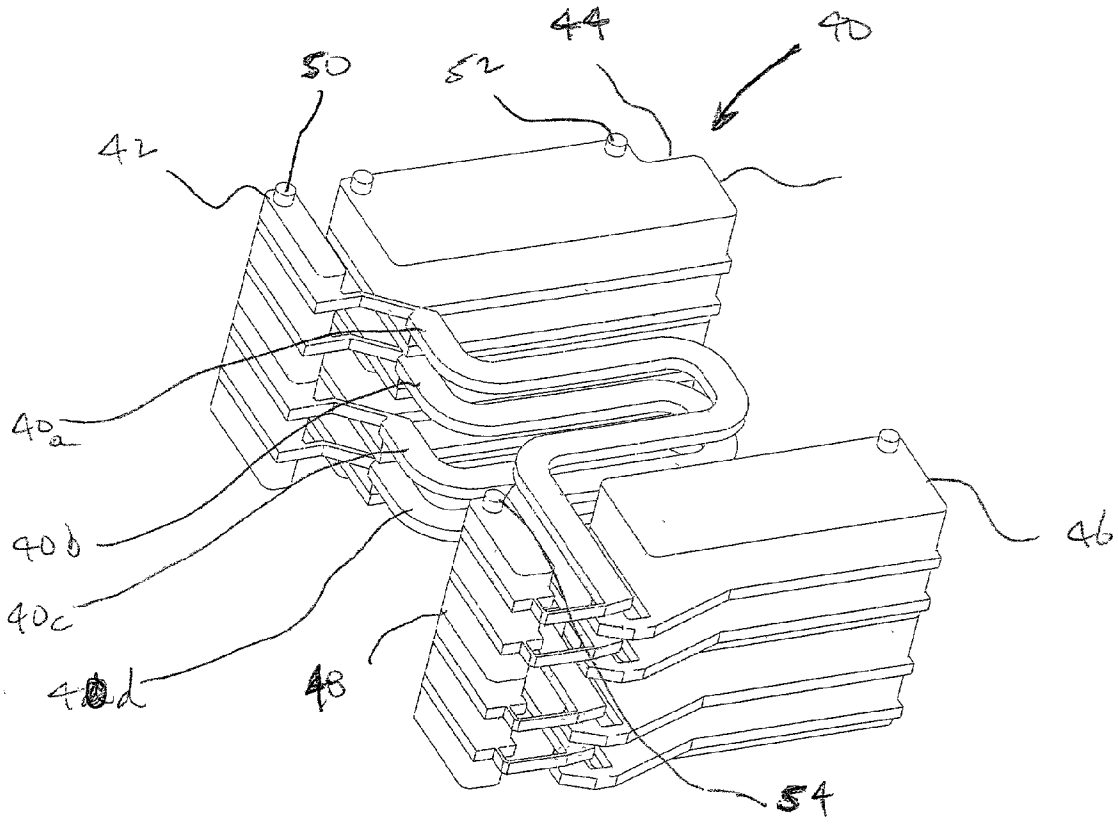
Publication Classification

(51) **Int. Cl.**[7] **B01L 3/02**

(52) **U.S. Cl.** **422/100**; 422/99; 422/101; 436/180

(57) **ABSTRACT**

A microfluidic device for performing separation functions such as dialysis. The device contains multiple redundant microfluidic structures operating in parallel to prevent failure of the device when performing critical separation operations where device failure would be harmful, while also expediting the process.



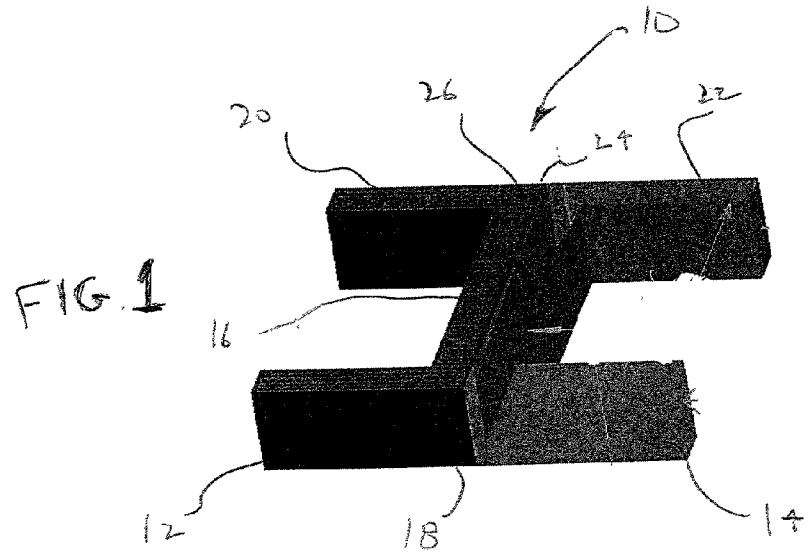


FIG. 1

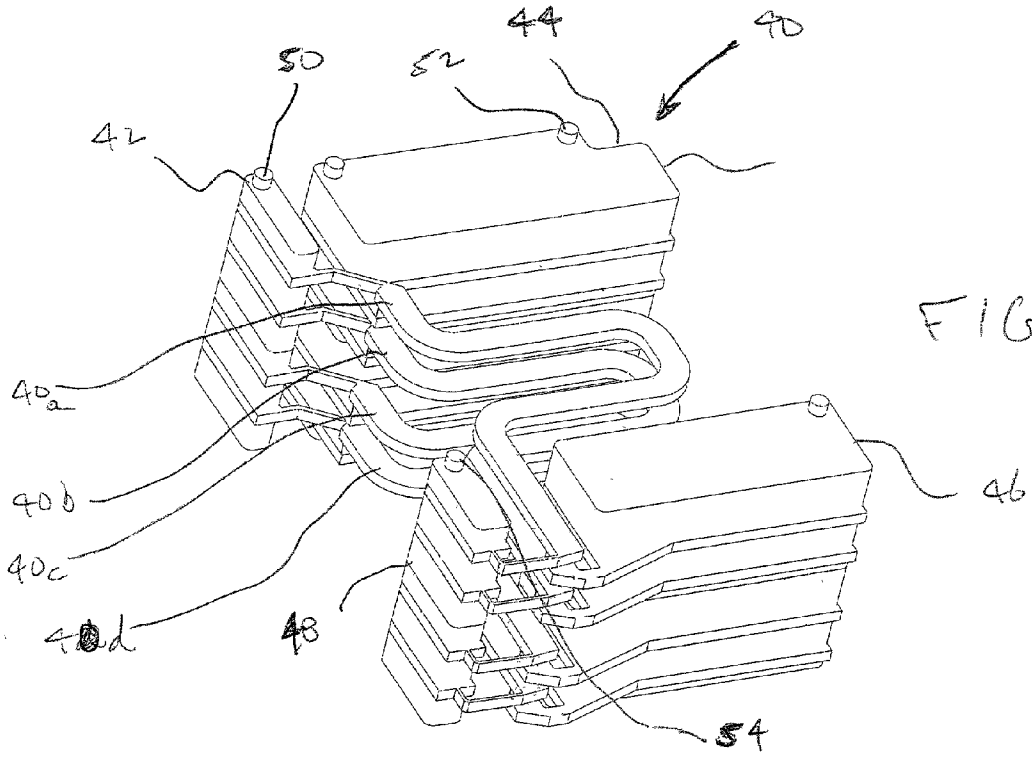


FIG. 2

MULTIPLE REDUNDANT MICROFLUIDIC STRUCTURES CROSS REFERENCE TO RELATED APPLICATIONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit from U.S. Provisional Patent Application Serial No. 60/281,114, filed Apr. 3, 2001, which application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates generally to microfluidic devices for performing analytic testing, and, in particular, to a device having multiple redundant systems to prevent total failure of the device.

[0004] 2. Description of the Related Art

[0005] Microfluidic devices have recently become popular for performing analytic testing. Using tools developed by the semiconductor industry to miniaturize electronics, it has become possible to fabricate intricate fluid systems which can be inexpensively means produced. Systems have been developed to perform a variety of analytical techniques for the acquisition of information for the medical field.

[0006] Microfluidic devices may be constructed in a multilayer laminated structure where each layer has channels and structures fabricated from a laminate material to form microscale voids or channels where fluid flow. A microscale channel is generally defined as a fluid passage which has at least one internal cross-sectional dimension that is less than 500 μm and typically between about 0.1 μm and about 500 μm. The control and pumping of fluids through these channels is affected by either external pressurized fluid forced into the laminate, or by structures located within the laminate.

[0007] U.S. Pat. No. 5,716,852 teaches a method for analyzing the presence and concentration of small particles in a flow cell using diffusion principles. This patent, the disclosure of which is incorporated herein by reference, discloses a channel cell system for detecting the presence of analyte particles in a sample stream using a laminar flow channel having at least two inlet means which provide an indicator stream and a sample stream, where the laminar flow channel has a depth sufficiently small to allow laminar flow of the streams and length sufficient to allow diffusion of particles of the analyte into the indicator stream to form a detection area, and having an outlet out of the channel to form a single mixed stream. This device, which is known at a T-Sensor, may contain an external detecting means for detecting changes in the indicator stream. This detecting means may be provided by any means known in the art, including optical means such as optical spectroscopy, or absorption spectroscopy of fluorescence.

[0008] U.S. Pat. No. 5,932,100, which patent is also incorporated herein by reference, teaches another method for analyzing particles within microfluidic channels using diffusion principles. A mixture of particles suspended in a sample stream enters an extraction channel from one upper arm of a structure, which comprises microchannels in the shape of an "H". An extraction stream (a dilution stream) enters from the lower arm on the same side of the extraction channel and due to the size of the microfluidic extraction channel, the flow is laminar and the streams do not mix. The sample stream exits as a by-product stream at the upper arm at the end of the extraction channel, while the extraction stream exits as a product stream at the lower arm. While the streams are in parallel laminar flow is in the extraction channel, particles having a greater diffusion coefficient (smaller particles such as albumin, sugars, and small ions) have time to diffuse into the extraction stream, while the larger particles (blood cells) remain in the sample stream. Particles in the exiting extraction stream (now called the product stream) may be analyzed without interference from the larger particles. This microfluidic structure, commonly known as an "H-Filter," can be used for extracting desired particles from a sample stream containing those particles.

[0009] When dealing with microfluidic devices, which contain channels the size of a human hair, there is a possibility that one of the channels within the device may become clogged. This can be a serious problem if the device is performing a critical function, such as dialysis. Thus, in these type of devices, it is imperative that there is a backup system within the device so that a failure is not damaging to the patient, or even life threatening.

SUMMARY OF THE INVENTION

[0010] It is therefore an object of the present invention to provide a microfluidic device which has redundant microfluidic structures within the device to prevent failure of the device.

[0011] It is a further object of the present invention to provide a microfluidic structure in which processing is done in parallel using multiple structures to insure completion of the process.

[0012] It is a still further object of the present invention to provide a device which will expedite the processing of a sample fluid.

[0013] These and other objects of the present invention will be more readily apparent from the description and drawings that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** is a perspective drawing of an H-Filter which is used in the present invention; and

[0015] **FIG. 2** is a perspective drawing of an array of H-Filters for use in the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] **FIG. 1** shows a flow schematic for an H-Filter® microfluidic device, which is described in detail in U.S. Pat. No. 5,932,100. An H-Filter structure, generally designated at **10**, is formed by a sample input channel **12** and a receiver or extractor solution channel **14** which connect to a diffusion channel **16** at a first end **18**. A sample outlet channel **20** and a waste channel **22** both connect at a second end **24** of diffusion channel **16**. In operation, a sample stream such as blood is loaded into input channel **12**, while an acceptor solution, such as a dialysis solution, is loaded into channel **14**. The two fluids meet at first end **18** of diffusion channel

16 and then flow together laminarly within channel **16**. A contact line **26** is formed between the two fluids and is referred to as the diffusion interface. Smaller components within the sample stream diffuse across interface **26** into the acceptor solution. When the laminar stream reaches end **24** of diffusion channel **16**, the flow is split, with the sample flowing into outlet channel **20** and the extractor solution flowing into waste channel **22**. Channel **20** now contains a blood sample with the undesired urea particles removed, while channel **22** contains the acceptor solution containing the undesired particles. Thus H-Filter **10** can be used as a compact and simple dialysis device.

[**0017**] **FIG. 2** demonstrates another structure, which allows an H-Filter to efficiently and safely act as a dialysis device. H-Filter structure, generally indicated at **40**, contains a plurality of H-Filter structures **40***a*, **40***b*, **40***c*, **40***d*. Each H-Filter contains a sample input chamber **42**, an extractor solution chamber **44**, a waste outlet chamber **46**, and processed a sample outlet **48**. As H-Filters **40***a*, **40***b*, **40***c*, **40***d* are arranged in parallel, when a sample fluid is loaded into channels **42** through an inlet **50**, and a receiver solution loaded into chamber **44** through an inlet **52**, all of H-Filters **40***a*, **40***b*, **40***c*, **40***d* operate simultaneously and independent of each other. When all of the sample has been processed, the cleaned sample can be retrieved through an outlet **54** of chamber **48**.

[**0018**] There are several advantages to the H-Filter shown in **FIG. 2**. First, it is safer to use than the standard H-Filter for critical procedures, as the redundancy of the structure allows processing even if one of the filters would clog. In addition, the use of multiple structures makes it possible to reduce processing time for the procedure. Although four H-Filters are shown in this embodiment, this number may be increased to further reduce processing time.

[**0019**] While the present invention has been shown and described in terms of a preferred embodiment thereof, it will be understood that this invention is not limited to this particular embodiment and that changes and modifications may be made without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A microfluidic device, comprising:

an inlet;

an outlet;

a fluid flowing through said inlet; and

multiple microfluidic structures connecting said inlet and said outlet such that a portion of said fluid flows through said first microfluidic structure, and another portion of said fluid flows through said second microfluidic structure.

2. A microfluidic device, comprising:

an inlet;

an outlet;

a fluid flowing through said inlet; and

a plurality of microfluidic structures connecting said inlet and said outlet such that portions of said fluid is split up such that it flow through most or all of said microfluidic structures.

3. The device of claim 1 wherein said microfluidic structures are essentially identical.

4. The device of claim 1 wherein said microfluidic structures comprise H-Filters.

5. The device of claim 1, also comprising a second inlet connected to said first and second microfluidic structure.

6. The device of claim 5, also comprising a second outlet connected to said first and second microfluidic structure.

7. The device of claim 2, wherein said microfluidic structures are essentially identical.

8. The device of claim 2, wherein said microfluidic structures comprise H-Filters.

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