MICROVALVE WITH PRESSURE EQUALIZATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application of U.S. Ser. No. 09/148,026, filed Sep. 3, 1998 pending, which application is incorporated by reference in its entirety herein as if fully put forth below.

BACKGROUND

It has been very difficult to provide a microvalve that can process fluids having high pressures such as those pressures used in refrigeration valves. The very small size of microvalves, such as those formed using typical semiconductor fabrication machinery, methods, and supplies, limits the amount of pressure that microvalves can handle. The small components of a microvalve are easy to move or deflect, and comparatively large forces are needed to maintain valves in a desired position or to move a valve to a new position.

Components within a microvalve can stick or rub against stationary portions because of the small clearances within microvalves and because of fluid flow buffeting portions of the microvalves. Further, differential pressures (such as those between or created by the difference in pressure between the inlet and the outlet of the microvalve) can easily push movable portions into undesired positions. Differential pressure can push movable portions against stationary portions of the microvalve, causing the movable portions to stick. Differential pressure can push movable portions opened or closed, causing great difficulties in regulating flow through the microvalve. These problems continue to arise in microvalves today, especially microvalves capable of handling high pressures.

What has been needed is a microvalve that opens and closes easily with little or no "stiction" and with little resistance from the fluid being controlled despite the fluid being at high pressure, that is easily regulated and responds in linear fashion to a driving force, and that has a long lifetime.

Further, brittle adhesives have been used in high pressure microvalves to adhere the microvalve to other equipment. The brittle adhesives can crack and break well before other components of the microvalve have failed. Consequently, there is a need for a microvalve that does not require a brittle adhesive.

SUMMARY OF THE INVENTION

The invention provides a micromechanical flow valve for controlling the flow of a liquid or gas. The microvalve can be configured to control the flow of fluids having a pressure of less than 1 bar to in excess of 300 bar.

The microvalve is designed to have equal pressures on all faces of the slider that controls flow through the microvalve, so that energy supplied to move the slider is not wasted on overcoming resistance to slider movement caused by fluid pressure. The microvalve comprises a body having an inlet, an outlet, and a channel within the body that is in fluid communication with the inlet and the outlet. A slider that controls fluid flow also resides within the body and is moved by an actuator that is part of or is attached to the body. The slider has a channel through it from a first face to a second face that allows fluid from the inlet to communicate with a pressure-equalizing contour beneath the slider. Fluid in this pressure-equalizing contour has the same pressure as the fluid in the inlet, and consequently the pressure on the first face of the slider is equal to the pressure on the second face of the slider.

Further, the other faces of the slider are in fluid communication with one another, so that all remaining faces experience the same pressure regardless of whether the valve is partially or fully opened or closed. Because pressures are balanced on all faces of the slider, the energy supplied by the actuator is used only to move the slider and not also to overcome a pressure force on the slider.

The microvalve preferably has an actuator formed from tapered ribs that are joined to the displaceable member by a tie-rod that forms part of the actuator. A second tie-rod is attached to the material of the second layer and also to the displaceable member, forming a fulcrum or flexure on which the displaceable member pivots. Preferably, both tie-rods are attached to the same side of the displaceable member to prevent the tie-rods from assuming an "S" shape when the displaceable member is moved.

In one preferred embodiment, the microvalve is configured as a flow control valve for high pressure applications as are found in automobile automatic transmissions or anti-lock braking systems. The flow opening is sized to provide the desired flow range or pressure drop, so the ports, channel, and/or slider have a shape and configuration provide the flow area range needed for the desired flow rate range.

In another preferred embodiment, the microvalve is configured as a refrigerant microvalve by providing a flow rate at which the expansion or cooling of a refrigerant fluid is controlled. The size of the flow opening is controlled so that there is a sufficiently high pressure drop as the fluid flows through the microvalve to provide the desired extent of cooling. The size of the flow opening can be controlled by positioning the displaceable member so that most of the inlet port is blocked, leaving a small strip of the inlet port open for fluid flow. The fluid may or may not change phase, so that liquid passing through the microvalve may either remain as a liquid or may partially or fully evaporate to form a gas.

The invention also provides a method of making a microvalve. An inlet, outlet, and fluid passage are formed within a housing, and a lever arm having a slider capable of blocking at least a portion of the fluid passage is also formed within the housing along with an actuator to move the lever arm. A deep fluid pressure-equalizing contour is positioned within the housing beneath the slider, so that fluid entering the inlet and pressing against the slider from above also enters the deep fluid pressure-equalizing contour beneath the slider and presses against the slider from below, thereby equalizing the forces on the slider in the z direction.

The invention also provides a method of using the pressure of a fluid to provide a microvalve that is capable of operating at high pressure. By providing a deep fluid pressure-equalizing contour positioned beneath at least a portion of the slider as described above, forces on the slider are equalized in the z direction, and little force is needed to shut or open the microvalve.

Among other factors, the invention is based on the technical finding that a microvalve that incorporates a slider and has deep pressure-equalizing contours above and below the slider as well as a channel through the slider to allow fluid from the inlet to fill the pressure-equalizing contour below the slider has pressures balanced in all three directions –x, y, and z-, making the valve easier to control and to regulate than previous designs such as micromachined seat valves.