

at least 4:1. Further, the cross sectional length L is preferably in the range of 2 to 200 μm , and the cross sectional width W is preferably in the range of 0.2 to 20 μm .

[0151] The gap distance S between adjacent columns in a row is preferably selected to be as small as possible while still allowing fluid to flow between the columns without excessive resistance. In general, the gap distance S may range from 0.2 to 200 μm , and more preferably, is in the range of 2 to 20 μm . The range of 2 to 20 μm is currently preferred because it provides for substantial fluid contact with the surfaces of the columns without causing excessive resistance to the fluid flow through the chamber. The center to center spacing C between adjacent columns in a row is the sum of the cross sectional width W and gap distance S , and is preferably in the range of 2.0 to 40 μm .

[0152] The length of the extraction chamber **26**, its vertical dimension in FIG. **9**, is preferably in the range of 100 to 5000 μm , and more preferably at least 1000 μm . The width of the extraction chamber **26** is preferably in the range of 100 to 3000 μm . The fluid ports **28** and **30** each preferably have a width or diameter of at least 100 μm . It is presently preferred that the chamber **26** have a minimum length of 1000 μm to allow sufficient room for the array of columns **32** and for the fluid ports **28** and **30**. In particular, it is presently preferred to confine the array of columns **32** to the center area of the chamber **26**, leaving open space at the ends of the chamber **26** where the fluid ports **28** and **30** join the chamber. This arrangement increases uniformity of fluid flow into the chamber **26** prior to the fluid flowing between the columns **32**.

[0153] Referring again to FIG. **6**, the internal surfaces of the chamber **26**, e.g. the columns **32** and chamber walls, may be coated with a substance having a high binding affinity with the target analyte. Suitable substances include, for example, silicon, silicon derivatives such as silicon dioxide, polymers, polymer derivatives such as polyamides, nucleic acids, certain metals, polypeptides, proteins, and polysaccharides.

[0154] The silicate (SiO_2) nature of glass can attract and bind nucleic acids. Silicon, when it becomes oxidized, results in a similar surface chemistry. Non-permanent (non-covalent) attachment (adsorption) to such a surface is typically based on weak dipole, hydrogen bonding, or ionic interactions between the surface and moiety to be captured. These interactions are reversible via changes in the ionic nature of the solvent and/or surface, heat, or other physiochemical means. Many materials can be tailored to have a variety of interactions with solvents and solutes in solution. Polymers can have active surface groups that provide specific interactive forces, and they can have copolymers or dopants that provide ionic or even hydrogen binding capabilities. Some polymers can have reversible polarities or adjustable conductivity. Synthetic and some natural polypeptides and proteins have shown a similar capability to have a variety of interactions with solute molecules. Metals, such as gold, are well known to have the ability to capture DNA, and due to its electronic nature, can change the ionic interactions with solutes.

[0155] The internal surfaces of the chamber **26** may also be coated with a substance having a high binding affinity with a specifically targeted analyte, e.g., a specific sequence of RNA from a virus or a specific sequence of DNA from a bacteria. This may be accomplished by coating the internal surfaces with a specific nucleic acid sequence complementary to the target nucleic acid sequence. The surfaces may be coated during manufacture of the chip or immediately prior to use.

[0156] The microfluidic chip **20** preferably includes a heater for heating the extraction chamber **26**. The heater allows for highly efficient elution of the analyte from the chamber so that a large amount of analyte may be released into a small volume of elution fluid. The heater may also be used to facilitate capture of the analyte. One advantage of the use of a heater in a small volume microchamber is that minimal energy is required to heat the chip.

[0157] In general, the heater may comprise any suitable mechanism for heating the chamber **26**, including resistive heaters, optical heaters for directing visible or infrared light, or electromagnetic heaters. If the body of the chip **20** is fabricated from an electrically conductive material, preferably silicon, the heater may simply comprise a power source and electrodes for applying a voltage across a portion of the body forming the chamber **26**. Also, high thermal conductivity of the material allows for fast heating times, reduced power requirements, and highly uniform temperatures. This embodiment is described in greater detail below.

[0158] In the preferred embodiment, the heater comprises a resistive heating element **34** coupled to the bottom wall of the chamber **26**. As shown in FIG. **7**, the resistive heating element **34** is preferably a thin film of metal, carbon, or polysilicon that is patterned on the bottom surface of the substrate **22**. Alternatively, the heating element may comprise a laminated heater source, such as an etched foil-heating element, attached to the substrate **22**. Electrically conductive bond pads **38A** and **38B** are also patterned on substrate **22** for electrically contacting opposite ends of the heating element **34**.

[0159] The bond pads **38A** and **38B** may be connected by electrical leads to a power source for applying a voltage across the heating element **34**. Control of the power source is preferably carried out by an appropriately programmed controller, such as a computer, microprocessor, or microcontroller in the cartridge or external instrument. The controller may be programmed to take the chamber **26** through any number of predetermined time/temperature profiles by varying the amount of power supplied to the heating element **34**.

[0160] The microfluidic chip also preferably includes one or more temperature sensors in communication with the controller for measuring the temperature of the extraction chamber **26**. In general, the temperature sensor may be any suitable device for measuring temperature, such as a thermocouple, resistance thermometer, thermistor, IC temperature sensor, quartz thermometer, or the like. Alternatively, the temperature coefficient of resistance of the heating element **34** may be utilized as a means to monitor the chamber temperature and to control the heat input by measuring the resistance as indicative of temperature.

[0161] In the preferred embodiment, the temperature sensor comprises a strip **36** of electrically conductive material patterned on the substrate **22**. The strip **36** comprises a material having an electrical resistance dependent on the temperature of the material, so that the temperature of the chamber **26** may be monitored by monitoring the resistance of the strip **36**. Electrically conductive bond pads **40A** and **40B** are also patterned on substrate **22** for electrically contacting opposite ends of the sensor strip **36**.

[0162] In an alternative embodiment, the substrate **22** may also have an additional bond pad **42** patterned thereon for providing a bulk contact to the substrate **22**. The bulk contact may be used to charge the internal attachment surfaces of the chamber **26** with a voltage to attract and/or elute nucleic acid.