Part I: Reading (50%)

Reading Passage 1

Sensors and Actuators: B. Chemical, Vol. 114, Issue 1, March 30, 2006, pp. 9-18.

A microstructured silicon membrane with entrapped hydrogels for environmentally sensitive fluid gating

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Abstract

In this paper, we report on the fabrication and characterization of a new hydrogel-based microvalve. The basic structure is a silicon membrane having an array of orifices with an internal structure designed to anchor the hydrogel while allowing it to gate the flow across the membrane. Each orifice (140 μm diameter) has a central post suspended by four tethers on each side of the membrane. A stimuli-sensitive hydrogel is polymerized inside each orifice. In the swollen state, the hydrogel completely occupies the void space of the orifice, completely blocking pressure-driven fluid flow. In the shrunken state, the hydrogel contracts around the post, allowing fluid to flow through an opened annular gap. Fabrication of the microstructured silicon membrane requires only two masking steps and involves a combination of deep trench and KOH etch. Two different hydrogels, based on *N* -isopropylacrylamide (temperature-sensitive) and phenylboronic acid (pH and glucose-sensitive) were trapped and tested in this microvalve. The measured response times were 10 s (temperature), 4 min (pH), and 10 min (glucose). The maximum pressure drop the microvalve can sustain before breakage of the hydrogel is 21 kPa and 16 kPa for temperature-sensitive and (pH/glucose)-sensitive hydrogels, respectively.

Conclusions and outlook

We have demonstrated the fabrication of double-sided, tethered structures in silicon membranes. These structures, when loaded with hydrogel, function as a microvalve that can gate fluid flow in response to external stimuli such us temperature, pH, and glucose concentration. The response time for the temperature-sensitive microvalve is of order 10 s, while the pH- and glucose-sensitive microvalves response times are of order 4 min and 10 min, respectively. While these response times are significantly improved compared to previously studied microfabricated systems, even faster response times might be achieved by further miniaturization. Another possible improvement would be to provide focused polymerization inside the orifices, perhaps using photoinitiation. This alteration may eliminate the need to peel or scrape off excess hydrogel from the surface, which is both inconvenient and inelegant.

The environmentally sensitive microvalve presented here can be used to implement autonomous systems. For example, it can be integrated within a microreaction chamber having catalysts, enzymes or cells. Reaction or metabolization processes take place in the chamber resulting in a change in certain chemical concentration (e.g. pH or glucose). Once the desired concentration is reached the microvalve orifices open and let the product out. As product is pumped out new reactants or medium enters the chamber. At this point, the chemical concentrations return to the original values and the flow through the microvalve stops, thus initiating a new reaction cycle. Such a system would work without need of additional control electronics.

Reading comprehension and vocabulary questions

1. When was this article published?

2. How many people wrote this article?

3. What is the product that was investigated in this study?

4. What is the basic structure of the product that was investigated in this study?

5. Compare the difference between hydrogel in the swollen state and in the shrunken state.

6. What is the shape of an orifice (square, rectangle, triangle, round, or oval)? Why do you think so?

7. How many masking steps are required to fabricate the microstructured silicon membrane?

8. What is the maximum pressure drop that the microvalve can sustain before the breakage oof the (pH/glucose)-sensitive hydrogels?

9. How did the authors think about the response times that they achieved? Was it better or worse than previous research?

10. What are two ways which the authors suggested to make the response times faster?

11. In your own words, explain why the authors said that the microvalve presented in this paper can work in a system that does not need additional control electronics.

12. In the abstract, there is the following sentence: "Each orifice (140 μm diameter) has a central post suspended by four tethers on each side of the membrane." What is the meaning of the word "suspended." Replace it with another English word that will keep the same meaning of the sentence.

13. Here is another sentence from the abstract: "The maximum pressure drop the microvalve can sustain before breakage of the hydrogel is 21 kPa and 16 kPa for temperature-sensitive and (pH/glucose)-sensitive hydrogels, respectively." What is the meaning of the word "sustain." Replace it with another English word that will keep the same meaning of the sentence.

14. In the conclusion, there is a sentence: "We have demonstrated the fabrication of double-sided, tethered structures in silicon membranes." What is the meaning of the word "demonstrate"? Replace it with another English word that will keep the same meaning of the sentence.

15. Here is another sentence from the conclusion: "This alteration may eliminate the need to peel or scrape off excess hydrogel from the surface, which is both inconvenient and inelegant." What is the meaning of the word "alteration"? Replace it with another English word that will keep the same meaning of the sentence.

16. What is the meaning of the word "excess" in the previous sentence? Replace it with another English word.

Reading Passage 2

Sensors and Actuators: A. Physical, Vol. 127, Issue 1: February 28, 2006, pp. 31-36.

Room temperature wafer level glass/glass bonding

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Abstract

The findings of this study report the bonding of glass/glass wafers by using the surface activated bonding (SAB) method at room temperature (RT) without heating. In order to bond, the glass wafers were activated by a sequential plasma activation process, in which the wafers were cleaned with reactive ion etching (RIE) oxygen radio frequency (rf) plasma and nitrogen radical microwave (MW) plasma one after another and then contacted under hand-applied pressure followed by cold rolling under 20 kg load in atmospheric air. High bonding strength for glass/glass was achieved. Paramount influence of N_2 radical MW plasma on the adhesion enhancement of silicon/silicon bonding motivated the investigation of the N_2 radical MW plasma relationship with the bonding strength of glass/glass. A considerable influence of N_2 pressure on the bonding strength was not observed except in N_2 gas pressure of 30 Pa, which might be due to the debonding between glue and fixture used for tensile pulling test. No significant effect of OH density of glass wafers on the bonding strength was found below 400 °C. The result was evident from 400 °C and it was about twofold higher at 600 °C than that of RT to 400 °C. This result indicated that the sequential process bonding mechanism was consisting of long bridges of hydrogen bonding by water molecules. Significant environmental influence on the bonding strength was found and which could be correlated with OH molecules of glass wafers.

Questions

17. What do the authors mean by "room temperature" in this article?

18. What was the bonding method used in this study?

19. What is the meaning of the word "paramount"?

20. What is the meaning of the word "enhance"?

21. What is the meaning of the word "considerable"?

Part II Writing test (50 points)

Directions: Write an essay that includes at least three paragraphs.

In the first paragraph, you will explain Microelectromechanics (MEMS) as a general field of study. What is MEMS?

In the second paragraph, you will explain your research interests in MEMs. What would you like to learn at Tsinghua after you have enrolled in the system? Why are you interested in those topics?

In the third paragraph, explain what you think are necessary qualities of a successful graduate student in MEMS. What kind of knowledge does a person need (for example, math, physics, chemistry, different fields of engineering, etc.)? What characteristics should that person have?

The focus of this exam is on your ability to write well in English, your organization, and your language. You can use the space below to draft your answers. Please write your essay on the exam booklet.

This is the end of the test.
Thank you for your cooperation. Good luck!