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CMOS 이미지 센서를 이용한 광영역 입자 계수기

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Large areal particle counting system with CMOS image sensor

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Abstract - In this paper, particle counting system using a CMOS image sensor is demonstrated. The system utilizes a linear photodetector array as a detection element. Therefore, the particles are detected by large detection region, in contrast to a single detector in conventional particle counting devices, while maintaining the sensitivity. The advantage of proposed system is that particles are detected in a relatively large area without using the particle focusing method. Also, proposed system can be easily integrated with a microfluidic chip by attaching the device underneath the bottom plate of the microfluidic chip. Detection of polystyrene microbeads has been tested at a flow rate of 4.89mm/s. For 21 measurements, proposed system showed an average count error of 7.29% and a standard deviation of 4.74%. Potentially, the proposed system can detect even smaller particles simply by utilizing a higher resolution CMOS image sensor.

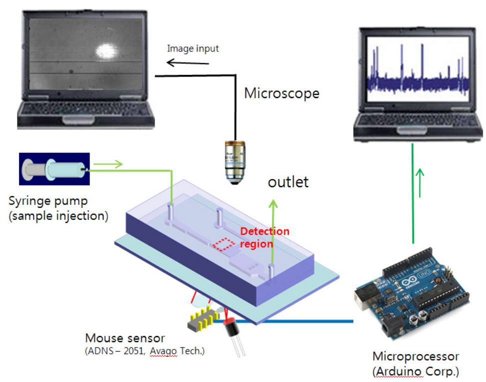
1. Introduction

Micro particle counters have been used as an important tool in micro total analysis system(μ-TAS). Counting systems are generally classified with electrical and optical sensing methods [1, 2]. Typically detection area of the sensor determines the sensitivity and probability of particle clogging. Size of the detection region needs to be small to achieve a high sensitivity, which in turn makes the system prone to particle clogging due to small aperture size. Particle focusing methods, such as hydrodynamic method [3] or dielectrophoresis (DEP) [4], are used for the particles to pass through desired detection region without channel clogging.

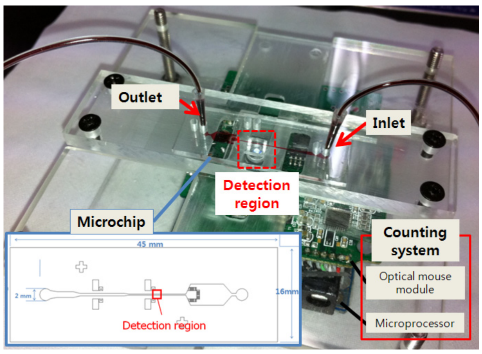
In this paper, particle counting system without particle focusing method is demonstrated using light scattering method. Linear photodetector array scans the bottom of a microchannel, where large channel width prevents the channel clogging. Also, detection sensitivity is maintained by utilizing multiple array of small detection regions.

2. System Design

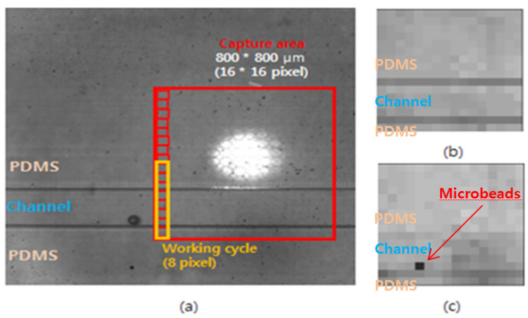
Figure 1 shows the schematic view of the experimental setup. Proposed system which consists of a CMOS image sensor and a microprocessor board (Arduino Corp.) scans the bottom of the microchannel. Performance of the system has been evaluated by observation of the particle flow in a microchannel. A single channel microfluidic chip with channel width of 200μm and height of 85μm is used. Microfluidic channel is fabricated with PDMS by molding technology, which is then bonded to a slide glass after oxygen plasma treatment. A CMOS image sensor of an optical mouse is used as photodetector array. The proposed counting system is shown in Figure 2. Laser module and lens are components of the optical mouse. Captured data from the CMOS image sensor are sent to microprocessor board. Figure 3 shows photographs of the microchannel acquired with a microscope and the CMOS image sensor. Each pixel of the image sensor has a resolution of 50x50μm^2. Therefore, four pixels are used to detect 200μm-wide microchannel. The system detects signals derived from eight pixels of the sensor, of which the data of four selected pixels covering the channel width are analyzed for bead detection. Scan rate of the system is 103 times per second.



<Fig. 1> Schematic view of the experimental setup



<Fig. 2> Photograph of the counting system and microchip

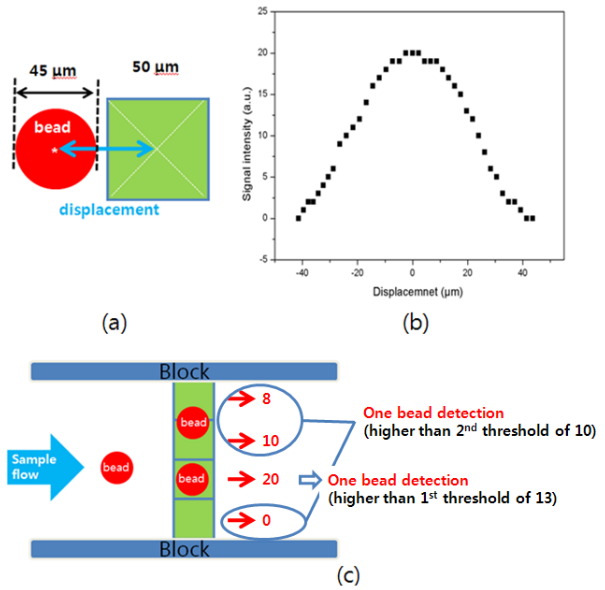


<Fig. 3> Photographs of the microchannel captured by (a) microscope, (b) Captured by proposed system without bead, (c) with bead.

3. Experimental Results

Figure 4 shows the measurement result at microbead flow rate of 0.21mm/s. The highest signal intensity was obtained when the whole surface area of the microbead was covered by the detection region. The signal intensity decreased gradually as the microbead moved away from the detection region. As the counting system consists of four photodetectors, the signal intensity depends on the number of detection regions covered by the microbead as shown in Figure 4(c). We have determined two separate intensity threshold values to distinguish between the two different cases of microbead overlap with detector region. Firstly, the system compares the signal intensity of each pixel with threshold value of 13. The first comparison determines whether a microbead is passing through a single detection region. Signal intensities of remaining pixels are then added and divided by secondary threshold value of 10, which indicates whether the microbead is passing through two detection regions. The quotient value represents the number of the microbeads passing by.

The sample solution was prepared by mixing isopropyl alcohol solution with 45µm-diameter polystyrene microbeads (Polysciences). The solution was injected with Harvard PHD 2000 microsyringe pump (Harvard Apparatus). Microbead flow rate was set to 4.89mm/s. Experimentally determined microsyringe pump pressure was 5.7µl/min.

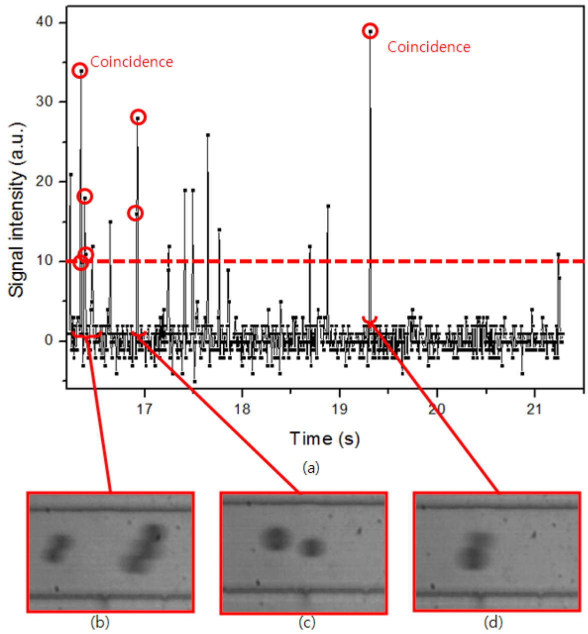


<Fig. 4> (a) Displacement of the bead and detection region, (b) Relationship between the signal intensity and bead location, (c) The principle for bead detection.

4. Results and Discussion

Figure 5(a) shows the measured signal intensity when the microbeads were passing through the detection region. Each pixel had a signal noise within ±1. As the signal intensities of 4 pixels were added, generated signal noise was within ±4. The measurement result clearly visualizes the microbead detection and counting capability irrespective of the number of microbeads passing by. Especially, the system was capable of counting the number of microbeads passing by in a close proximity from one another, as shown in Figure 5(b) and (d). Signal intensities were affected by the size of the microbeads as shown in Figure 5(c). Size of the microbeads ranged from 30µm to 56µm.

For the repeated 21 measurements, the counting system showed an average error rate of 7.29% and a standard deviation of 4.74%. Errors in microbead count can be ascribed to unstable flow rate. Signal intensity was lower than the threshold value when the microbead flow rate was lower than the optimum value. Also, microbead was counted twice when the flow rate was too low.



<Fig. 5> (a) Measured signal intensity for 45μm polystyrene microbead at flow rate of 4.75mm/s. The photograph shows the microchannel (b) at 16.2sec, (c) at 16.8sec, and (d) at 19.3sec.

5. Conclusion

We have demonstrated a particle counting system using an off-the-shelf CMOS image sensor disassembled from an optical mouse. The proposed system successfully detected microbeads in the microfluidic chip. One of the major advantages of the proposed system is that mirobeads can be detected without particle focusing method. Moreover, the system is suitable for potentially low cost, compact, portable particle counter, which can be easily assembled with any microfluidic chip. Proposed detection system can be further improved to detect even smaller particles simply by replacing the CMOS image sensor with a higher resolution version.

[Reference]

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