This paper presents a droplet optical diffraction grating array which is realized using multiphase microfluidic droplets. The tunable diffraction gratings based on a T-junction droplet generator was suitable for dynamic and reversible control. Results show the diffraction pattern of one-dimensional and two-dimensional droplet array which has potential application in biomaterials or cell analysis.

KEYWORDS
droplets, diffraction gratings, optofluidics, micro-photonic-fluidic-systems(MPFS)

INTRODUCTION

Optical diffraction gratings are typically fabricated by using solid materials such as glass, quartz, polymers or metals. For specific applications, which may require optics that can be modified structurally in real time, the classical optical components are re-innovated using various optofluidic components such as liquid waveguide, liquid lens, liquid prism and liquid beam splitter. They are intrinsically well suited for dynamic and reversible control over optical properties [1].

This paper reports a tunable diffraction gratings based on a microfluidic platform, which consists of a T-junction droplet generator, one-dimension and two-dimension droplet array formed by dynamic self-assembly. The droplet optical diffraction grating array is formed with high stability and has potential applications in biomaterials or cell analysis.

DESIGN AND FABRICATION

Figure 1 shows the design of the microfluidic chip. PBS buffer droplets are generated in immersion oil using T-junction geometries.

A one-dimension gratings along the microchannel is formed using droplet flow stream(Figure 2(b)). In a much wider chamber, the droplet flow stream is self-assembled into a hexagonal pattern array and a two-dimension grating array is formed(Figure 2(c)). A laser
light source (632.8 nm) is placed above the chip orthogonally such that the incident laser light passes through the microfluidic chip and the diffraction pattern is observed by a microscope. The microfluidic chip is fabricated by polydimethylsiloxane (PDMS) material using soft-lithography process. The structured PDMS slab is bonded to the other bare PDMS slab using plasma bonding.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Figures 2(a–c) show the formation of the PBS buffer droplets at the T-junction. The size of the droplet can be controlled over a broad range based on a simple scaling relation [2].

Figure 2(d) shows the formation of the one-dimension grating array, when the droplets are travelling along the channel. The pitch of the grating is decided by the droplets’ size and the flow rate. Figure 2(e) shows the formation of the two-dimension grating array. As the droplets are accumulating in the chamber, the volume fraction is increasingly higher, the droplets are in contact with each other and interact by the shape-restoring elastic forces. These interactions lead to self-assembly of the droplets into a uniformly ordered two-dimensional array.

Figure 3 shows that the period of the diffraction pattern Δy (i.e. the displacement between two consecutive maxima) is inversely proportional to the length of grating pitch d (i.e. the length of the interval between two droplets). The result shows that Δy ranges from 4.03 μm to 2.03 μm as d value ranges from 21.1 μm to 47.3 μm. The experimental results are agreed with the theoretical calculation results.

Figure 4 shows the diffraction pattern of one-dimension grating with four different grating pitches. The vertical line pattern is generated from the 1-D droplet array. On the other hand, the circular diffraction pattern is generated from a single round droplet. It can be concluded that smaller grating pitch will result in a larger period. It is easier to observe a clear diffraction pattern of a smaller droplet since the size of the droplet is closer to the incident light wavelength.
Figure 5 illustrates the diffraction pattern of the two-dimension droplet array. The diffraction pattern corresponds to the hexagonal structure of the droplet array. An analysis of the diffraction pattern can detect the change of the array orientation or the existence of any defect in the array such as droplets with different concentrations of buffers or encapsulated with biomaterials/cell [3].

CONCLUSIONS

In conclusion, a droplet optical diffraction grating array using multiphase microfluidic is designed, fabricated and demonstrated. The tunable diffraction gratings provide real-time tunability and wide diffraction pattern. The droplet optical grating array has wide applications in biology, biochemical and biomaterials detection and measurements.

REFERENCES

