論文の内容の要旨

論文題目　Microstructuring on Thermoplastic Substrate Using Submerged Laser Heating
（液中レーザ加熱によるマイクロ立体構造の加工法）

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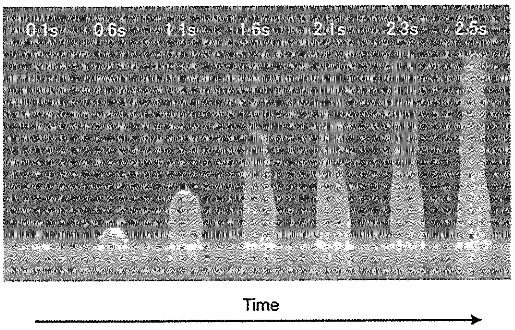

Fig.1 Freeze-frame pictures of the structure-forming process induced by a 5W laser power for 2.5s.

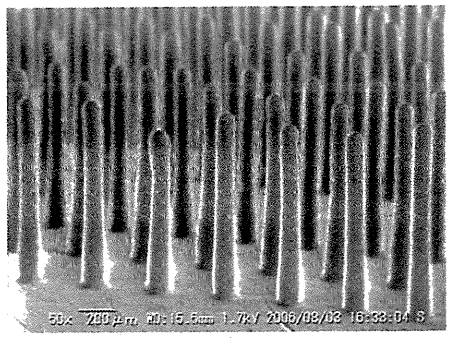

Fig.2 Micropillars with high aspect ratio and high reproducibility.

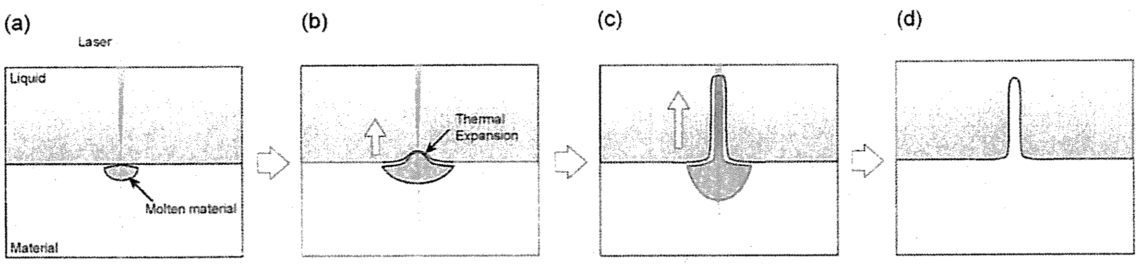

Fig.3 Flow diagram of the micropillar forming process.

This research describes a microstructuring technique on thermoplastic substrates with submerged laser heating. With this technique, convex microstructures with high aspect ratio can be fabricated in a short time (as shown in Fig.1). The micropillars fabricated with a similar irradiation time are shown in Fig.2. By using a tightly focused laser beam onto a solid-liquid interface, molten material can be solidified on the outer layer immediately by the surrounding liquid, while the center still pushes upward in a molten state. A flow diagram of the micropillar-forming process is in Fig.3. The mechanism of this fabrication technique is investigated by several experiments.

By irradiating laser on paraffin substrates at different focus positions and fabricating micropillar arrays with different space intervals, the effect of expansion (or explosion) force on the pillar-forming process can be confirmed. This experiment result suggests that the laser-induced thermal expansion inside the body drives the melted material to grow upward. The presumed direction of the internal thermal stress is illustrated in Fig.4. Paraffin substrates with various

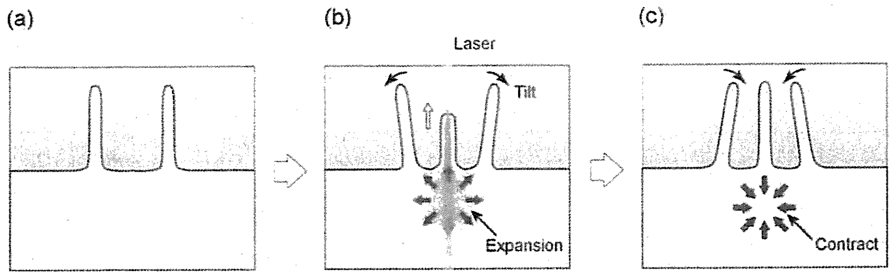

Fig.4 The effect of the expansion force induced by the laser.

thicknesses, colors, and viscosities are used as the workpieces for processing. The melt flow inside the micropillar during laser irradiation is observed in real-time and the result is discussed with a comparison toward polymer extrusion (fountain flow). Furthermore, the growing direction of melts is also investigated while the incident laser beam is perpendicular to the buoyancy and gravity.

With different irradiation parameters, the fabrication of dot-, line-shaped and oblique structures are available (see Fig.5). The structure can be stacked by scanning the same area. The SEM image of the fabricated wall-shaped microstructures with various layers stacking is shown in Fig.5(c).

The effective processing parameters for submerged laser heating are also explained. In order to improve the reproducibility and optimize the characteristics of this processing technique, three main parameters including laser (optics), environmental temperature, and liquid properties are investigated. In this chapter, experiments are developed under various optical parameters including irradiation power, irradiation time and laser spot size. The relationship between the experiment results and the optics parameters are clarified. Moreover, the effect of temperature on the material before laser irradiation is also investigated and the result shows that reproducibility is highly influenced by the

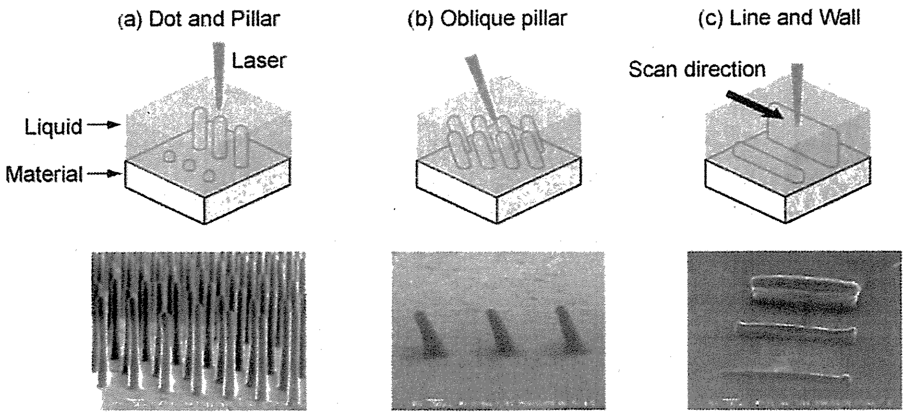

Fig.5 Conceptual diagram of the submerged laser heating technique: (a) dot and pillar, (b) oblique pillar, (c) line and wall.

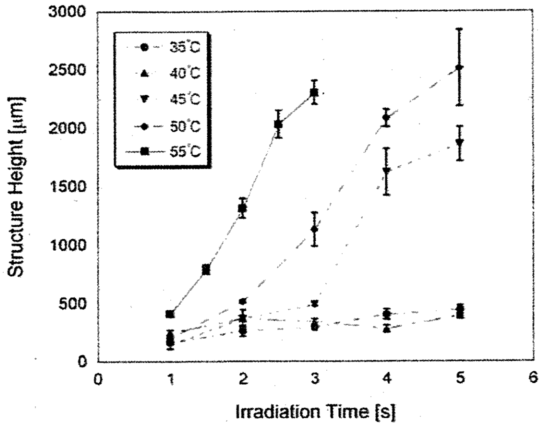

Fig.6 Height of paraffin pillars fabricated in distilled water and with a laser power of 5W with material temperature from 35 to 55℃.

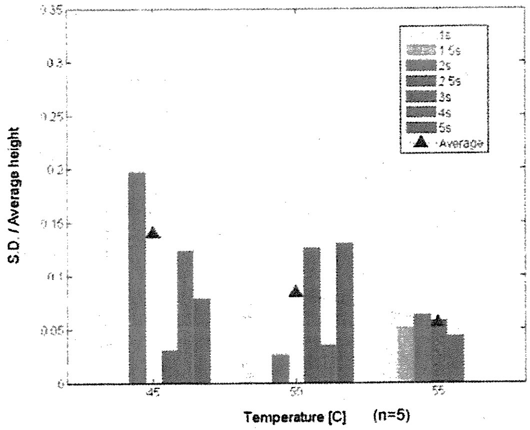

Fig.7 Height uniformity of micropillars fabricated at the material temperatures of 45, 50 and 55℃.

material temperature. The height of paraffin pillars fabricated in distilled water and with a laser power of 5W with varying material temperatures is given in Fig.6. The uniformity of these fabricated micropillars is shown in Fig.7. Furthermore, the relationship between the liquid properties and the features of the structure shapes are also investigated. For practical applications of this technique, it is necessary to be able to predict the structure shape prior to fabrication. In this research, microstructuring on materials immersed in various liquids, with different thermophysical properties, is conducted. Beyond that, the result is applied to a thermal model to analyze the dependence of this technique on the liquid properties.

Moreover, the possibility of applying this technique on other thermoplastic materials is discussed. Accordingly, aspect-ratio of the processed structures on engineering plastics is not as high as that of the processed structures on the wax materials. Finally, the three-dimensional structuring technique and some possible applications for industrial and biochemical fields are described. The examples of micropatterning are shown and the issues of three-dimensional structuring are explained. The possible applications are proposed by incorporating the structuring technique with a trial manufacture. In addition, some relevant research and techniques are surveyed for comparison.