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Physical properties and tactile sensory perception of microtextured molded plastics

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ABSTRACT

We developed molded plastic samples with microscale textured features, and investigated the relationship between the tactile sensory response and the physical properties of the surfaces. Samples with various pitch features, and features with various height protrusions were prepared. Changes in the tactile sensory perception of the surfaces were correlated with the magnitude of the fluctuation in the coefficients of friction that occurred as a fingerprint moved across the surface, caused by the intrusion of the features of the textured surface into the grooves of the fingerprint. This occurred when the pitch of the features on the textured surface approached that of the pattern of the fingerprint; the height of the features was not significant. A change in the tactile perception of the surfaces occurred when the pitch of the features at the surface was approximately 100 μm.

1. Introduction

Plastics are used in numerous commercial products, including automobile interior parts, and cellular phone and camera parts. Many of these products have applications whereby the user physically touches the part; therefore, the texture and tactile sensory properties of the surface are important factors, especially for high-value products. However, plastics tend to have distinctive material characteristics with respect to the visual and tactile senses, which are often regarded as inferior to other materials, such as metals, fabrics, wood, or leather by consumers. To improve these material qualities, the surfaces of plastics are often textured by etching on a millimeter scale. However, the improvement obtained by such conventional methods is often marginal.

Recently, there has been considerable interest in a variety of new functionalized surfaces with micro- or nanoscale surface structuring [1]. The micro- and nanofabrication techniques that have enabled these developments have focused on modifying the tribological [2–4], optical [5], and material properties [6] of the materials.

The purpose of this study was to develop a plastic molding with a distinguishing tactile characteristic, suitable for volume production for commercial applications. We have previously fabricated plastic moldings with microscale texturing, and investigated the effect of the surface morphology on human tactile senses using multivariate statistical analysis [7]. We found a significant change in sensation resulting from the microscale textures. Varying the texture pitch around 100 μm resulted in significant changes in the tactile properties of the material, and these sensory properties depended more strongly on the pitch than the height of the features. The frictional characteristics were investigated and correlated to tactile sensory characterizations. However, the measuring technique was simple since the characterizations were determined by human movements. Therefore, there were variations in the results, and more precise measurements conducted under constant conditions are necessary. In addition, the effect of other parameters, such as vertical displacement of the finger and deflection of the texture while being rubbed, should be examined further. In this paper, we

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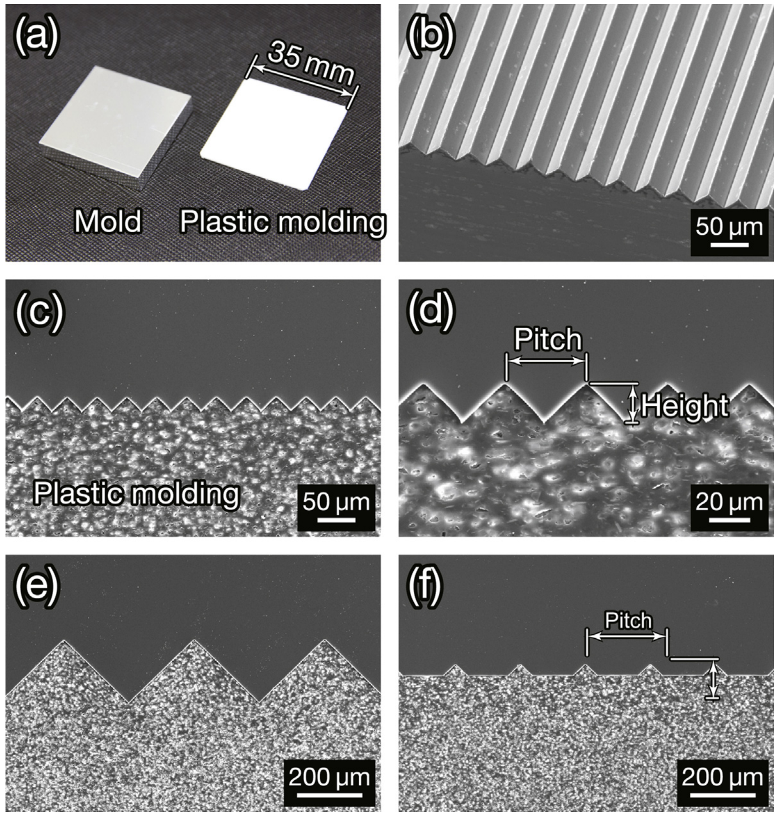

Fig. 1. (a) Aluminum mold and plastic moldings. (b) SEM image of an aluminum mold surface with grooved textures, fabricated by micromachining. The pitch was 40 μm and depth of the texture was 20 μm. (c) Cross-sectional SEM image and (d) enlarged image of a plastic molding fabricated by subsequent vacuum hot pressing. Cross-sectional SEM images of textured plastic molding surfaces with (e) a pitch of 400 μm and height of 200 μm, and (f) a pitch of 200 μm and a height of 40 μm.

describe the physical properties of textured plastic moldings and relate the tactile sensory perception of the surfaces to the material properties. We applied a texture measurement system to investigate the physical properties of the textured surface. The frictional characteristics of the actual fingers were also measured for quantitative evaluation. In addition, the interaction between the fingers and the textures was directly observed. Based on the results of these experiments, the mechanism by which the texture causes changes to the tactile sense was investigated.

2. Fabrication of textured plastic moldings

Grooved textures with pitches and depths ranging from several micrometers to several hundred micrometers were fabricated on polypropylene (PP) plastic molding surfaces by first micromachining aluminum alloy molds, and then utilizing a vacuum hot-press procedure. The micromachining of the aluminum alloy was conducted using an ultra-precision cutting machine (FANUC Corporation, ROBONANO α-0*i*B) with shuttle unit model B, and the vacuum hot press was manufactured by Imoto Machinery Co., Ltd., IMC-199A.

Fig. 1 shows an aluminum mold and a plastic sample fabricated by vacuum hot pressing. The dimensions of the aluminum mold and plastic molding were 35 mm × 35 mm × 1 mm, as shown in Fig. 1(a). A grooved texture with a pitch of 40 μm and height of 20 μm was machined on the mold surface, as shown by the scanning electron microscopy (SEM) image in Fig. 1(b). The top and bottom angles were both 90° due to the tool shape. Cross-sectional images of the PP molding shown in Fig. 1(c) and (d) indicate that the texture shape was successfully transcribed from the aluminum mold surface to the plastic. Fig. 1(e) shows a cross-sectional SEM image of the larger texture, with a pitch of 400 μm and a height of 200 μm. Fig. 1(f) shows cross-sectional images of a discontinuous texture, with flat areas between the convex structures.

Table 1 lists the surface features fabricated in this study. Fourteen textures, each with various pitches and heights, were fabricated. The minimum texture pitch was 10 μm, and the maximum pitch was 400 μm. Sample 1 had a non-textured surface. Samples 2–9 had continuous grooved textures, where the texture shape was determined by the tool shape, and the resultant texture pitch was twice the height. Samples 4 and 10–12 had various texture pitches with a constant height of 40 μm. Samples 9 and 12–14 had various texture heights with a constant pitch of 400 μm.

Table 1
Dimensions of the surface features.

Sample no.	Pitch (μm)	Height (μm)
1	Non-textured	
2	10	5
3	40	20
4	80	40
5	120	60
6	160	80
7	200	100
8	300	150
9	400	200
10	120	40
11	200	40
12	400	40
13	400	20
14	400	100