High functionality of an optical fiber stylus for micro metrology

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Abstract

We aim to develop a highly accurate measurement system with a low measurement force using a micro optical fiber probe. In this research, we conducted performance test of water repellent and antistatic coating on a stylus tip to prevent adhesion to the measured surface by surface forces, in addition to durability tests. As a result, when a stylus tip with a water repellent coating was used, the separation distance from the target surface was shorter by approximately 78% compared with the uncoated tip. Also, when a stylus tip with an antistatic coating was used, the adsorption and separation distances were reduced by 84% and 77% compared with the uncoated tip.

1 Introduction

Recent years have witnessed an increased demand for a method for precise measurement of the microstructures of mechanical microparts, microelectromechanical systems, micromolds, optical devices, microholes, *etc.* Therefore, we aim to develop a highly accurate measurement system with low measurement forces by using a micro optical fiber probe. In this research, we conducted performance test of water repellent and antistatic coating on a stylus tip to prevent adhesion to the measured surface by surface forces, in addition to durability tests.

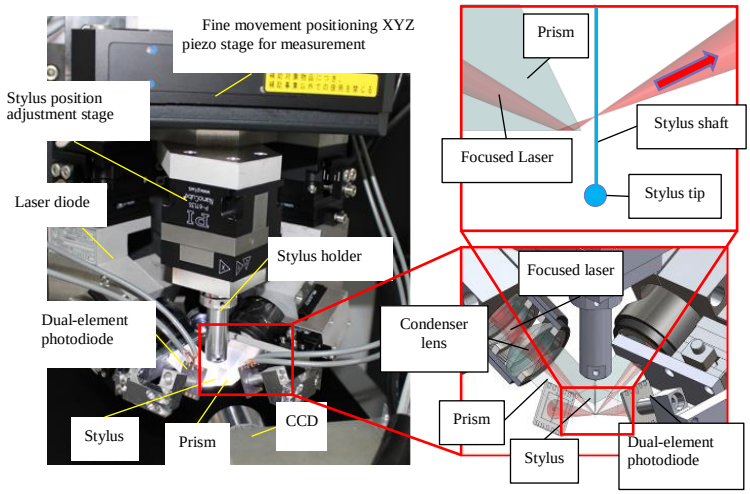
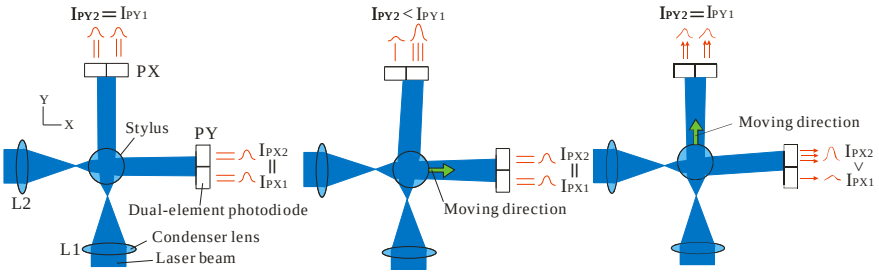


Figure 1: Overview of the measurement system



(a) Initial state (b) Displacement X (c) Displacement Y

Figure 2: Measurement principle

2 Principles of measurement

Figure 1 shows an image of the measurement system and a schematic of the laser-irradiated portion of the stylus. Figure 2 shows a cross-sectional view of Fig. 1 in the XY plane as well as the measurement principle of the optical fiber probe. A focused laser light is irradiated in the XY direction toward the shaft of the stylus. The diameter of the stylus is reduced by acid etching and the tip of it is irradiated with a CO_2 laser to generate a stylus tip [1]. The laser transmitted through the stylus shaft is received by two pairs of dual-element photodiodes installed on opposite sides with the stylus in between. Before the stylus tip comes into contact with the measured surface, the light intensities measured using each element of the dual-element photodiode are equal, as shown in Fig. 2 (a). When the stylus tip contacts the measured surface in the X direction, the stylus shaft is displaced, and the light intensities of each element of the dual-element photodiode becomes unequal, as shown in Fig. 2 (b). When the stylus shaft is displaced in the +X direction, the angle of refraction of the laser beam passing through the stylus shaft in the Y direction changes because of a shift in the irradiated section of the stylus shaft.

3 Coating performance test of stylus tip

When the stylus comes into contact with the object to be measured, it is significantly influenced by surface forces such as liquid bridging forces, van der Waals forces, electrostatic forces, etc [2, 3]. The tip adheres to the surface to be measured since the resultant force of the surface force becomes larger than gravity. This leads to an increase in measurement time and deterioration in measurement accuracy. Therefore, a water-repellent coating and antistatic coating on the stylus tip were examined to reduce the surface force.

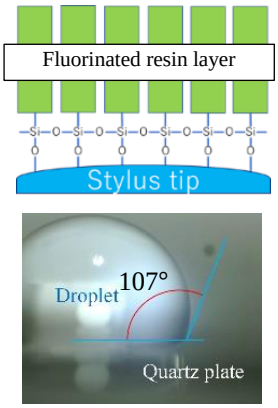


Figure 3: Structure and contact angle of the water repellent coating

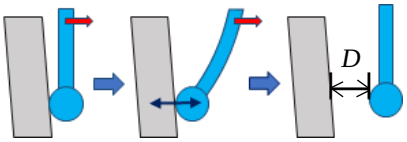


Figure 4: Experimental apparatus for measurement of surface forces

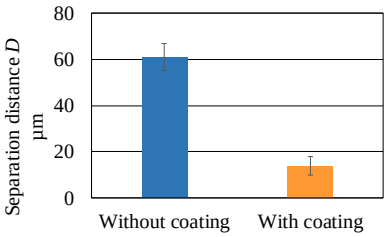


Figure 5: Average separation distance

3.1 Water repellent coating

By immersing the stylus tip into the coating agent, a fluorinated resin layer is formed on the surface of a stylus tip to improve water repellency as shown in Fig. 3. The film thickness of a fluorinated resin layer ranges from 10 nm to 20 nm. A peeling test for an optical flat wall surface and a stylus tip was performed as shown in Fig. 4 as a water repellent coating performance test. After the stylus tip comes into contact with the measured surface, the stylus tip is displaced in backward direction. Because the stylus tip is displaced while maintaining its contact with the measured surface by the surface force, the stylus shaft is deflected and the force required to separate the stylus tip from the measured surface is generated by the deflection of the stylus shaft. Therefore, the stylus tip can be separated from the measured surface when the displacement *D* of the stylus tip exceeds a certain value. The distance *D* between the stylus tip and the wall surface is defined as the separation distance. Using two styluses with and without water-repellent coating, the separation distance was measured 10 times in each case. In addition, an ionizer was used to simultaneously remove static electricity from the stylus tip to reduce the electrostatic force. The results are shown in Fig. 5. It is seen that the separation distance was reduced by about 78%. Next, an abrasion resistance test of the stylus

tip between the tip and the hole sidewall (Through-Silicon Via, TSV) on the silicon wafer was performed. In the approach, a tip was brought into contact with the side wall of the TSV hole. Furthermore, a force was applied to stylus shaft until it was deflected by 5 μm. Thereafter, pseudo-contact was reproduced by oscillating the tip in the vertical direction of the hole at an amplitude of 10 μm and a vibration frequency of 4 Hz. The contact counts were 10 000, 100 000 and 300 000 times. As a result, there is no change in separation distance even when the stylus comes into contact 300 000 times.

3.2 Antistatic coating

Au coating is formed on the surface of a stylus tip to remove the static electricity. The film thickness of au coating is 3 nm. A peeling test for a charged surface (-2 kV) and a stylus tip was performed as shown in Fig. 6. When the stylus approaches the charged surface, the stylus tip is adsorbed to the surface by static electricity. The distance between the stylus tip and the measured surface is defined as D_a as shown in Fig. 6. When the system detects the overtravel signal, the stylus tip is displaced in backward direction. As a result, the stylus tip can be separated from the measured surface when the displacement D_s of the stylus tip exceeds a certain value. The results are shown in Fig. 7. It is confirmed that the adsorption and separation distances were reduced by 84% and 77%, and the antistatic coating is effective at reducing the electrostatic force. The effect of liquid bridging force remains in the results of the adsorption and separation distances with coating. Figure 8 shows the schematic diagram of the stylus coated with a double layer of the antistatic and water repellent coating. Thus, we plan to apply the coating to the stylus in two layers in order to be able to eliminate both effects in the future. Also, we plan to conduct an abrasion resistance test of the antistatic coating in the future.

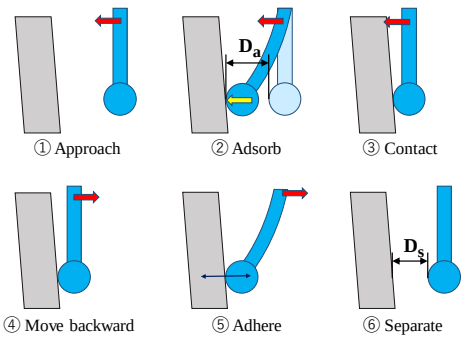


Figure 6: Experimental apparatus for measurement of electrostatic forces

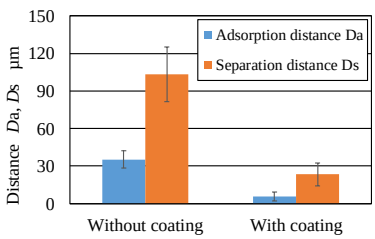


Figure 7: Average adsorption and separation distances

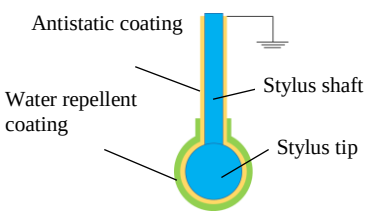


Figure 8: Schematic diagram of antistatic and water repellent coating

4 Conclusion

When a stylus tip with a water repellent coating was used, the separation distance from the target surface was shorter by approximately 78% compared with the uncoated tip. Also, when a stylus tip with an antistatic coating was used, the adsorption and separation distance were reduced by 84% and 77% compared with the uncoated tip. In the future, we plan to investigate the sphericity of the stylus tip fabricated by the CO_2 laser and the influences of coating on the sphericity of the stylus.

Acknowledgments
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References

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