# 論文 / 著書情報
# Article / Book Information

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# 論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）


An electrostatic chuck (ESC) is a clamping tool utilizing the advantages of electrostatic force. However, generally the usage is limited to handling of flat-surfaced objects as the force drops significantly for surfaces with asperity. In this thesis, an idea of ESC with electrodes in the shape of hairy micro-structure is proposed. Such incorporation of mechanical compliance to the ESC is expected to improve the application area to handling of objects with rough surfaces. Two electrode configurations with distinct characteristic, namely monopolar and bipolar are proposed.

Chapter 1 'Introduction' outlines the background of the ESC including the discussion of electrostatic force for clamping applications in general. To extend the application of ESC, an incorporation of mechanical compliance to the structure is proposed. Some other approaches made by various researchers are discussed and their limitation is mentioned and compared. In this chapter, the problem statement, motivation, as well as the purpose of the whole study is presented.

Chapter 2 'Theoretical basis of compliant ESC' lays out the theoretical basis of the proposed compliant ESC. An in-depth review of electrostatic as well as electrostatic force is given, with an introduction of force curve for both monopolar and bipolar compliant ESC. By modeling the pillar as a tip with a spring, we may discuss the ESC and the force exerted on the object by considering only the $F_e$, electrostatic force, and $F_k$, elastic force. The $F_e$ of monopolar ESC is approximated by a parallel-plate capacitor model whereas that of bipolar is calculated by using COMSOL, a commercial finite element software.

Chapter 3 'Fabrication of monopolar compliant ESC' describes the fabrication process and performance evaluation of monopolar compliant ESC. Two approaches are undertaken, namely using fiber and using microfabrication technique. Using fiber of 70μm diameter, a bundled fibers ESC prototype consisting of 200 fibers is developed. Furthermore, using fiber sample with diameter of 250μm, another ESC prototype is developed by arranging 10 fibers carefully aided by a jig. Finally, by microfabrication technique, a neater prototype of a layer consisting of 50 micropillars is fabricated. Subsequently the performance of the three developed prototype is experimentally obtained and analyzed. The generated force curve is compared with that of theoretical one and general qualitative match are obtained. The bundled fibers ESC is found to have the largest force drop due to the friction between closely packed fibers which increases stiffness. To compare arranged fibers ESC and microfabrication-based ESC, two performance parameters, namely force drop and force density, are used. Force density is obtained by dividing the experimental maximum force by the effective area of micropillars' contact. The obtained force density values with applied voltage of 600V are 58.88 and 398N/m$^2$ for arranged fibers and microfabrication-based ESC, respectively. Finally, for each prototype, pick-up demonstration of flat-surfaced aluminium pipe and sheet is performed to show the feasibility of the proposed concept.

Chapter 4 'Fabrication of bipolar compliant ESC' describes the fabrication process and performance evaluation of bipolar compliant ESC. Using the same layer of ESC developed by microfabrication, two of them are assembled as the bipolar ESC prototype. Experimental force curve is obtained and compared with that obtained by COMSOL. A discrepancy between them, in the form of force shift and maximum force drop, are observed. The possible sources of the discrepancy are suggested, namely: pillars' deflection, charge density on the surface, and irregularity of tips' alignment; and qualitatively discussed. The obtained force density with applied voltage of +/- 600V is 0.3N/m$^2$. Subsequently, a pick-up demonstration of flat-surfaced papers is also performed to show the feasibility.

Chapter 5 'Influence of object's surface roughness' discusses how rough surfaces of the objects might possibly affect the generated force. A model of several pillars making contact with a surface of sinusoidal wave profile is used to construct the theoretical force curves. The curves for both monopolar and bipolar ESC qualitatively suggest the importance of pillar's compliance to handle rough surfaces. Experiment for force measurement of monopolar ESC with respect to rough surfaces of various depth amplitude values is also conducted which yields results that match to the theoretical curve. Additionally, for bipolar ESC, a demonstration to pick up objects with random surface roughness is shown.

Chapter 6 'Design consideration for force improvement' mentions some ideas for force improvement which can be incorporated in the future work, including the use of fringe field for monopolar ESC and the slanted design for bipolar ESC that alters the charge distribution and hence increase the force.

Finally, Chapter 7 'Conclusion and future works' wraps up the whole thesis, discusses the achieved purposes set at the beginning, and lists up possible future works.


備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。