A technique for drift compensation of an area-varying capacitive displacement sensor for nano-metrology

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Abstract

Area-varying capacitive displacement sensors can overcome the short measurable range of widely-used gap-varying sensors. However, the output signal of the area-varying sensor may have an apparent drift. The drift in the signal is thought to be caused by several parameters, such as alignment error, thermal effect, external electric waves, etc. Since these parameters are difficult to control, so is reducing the drift. In this study, a model using two sets of electrodes in a single sample is proposed for reducing the drift while improving SNR (signal to noise ratio). The model is applied to an area variation type capacitive device to achieve drift and common noise reduction.

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Keywords: area-variation capacitive sensor; displacement sensor; drift compensation; nano-metrology; multiple-electrode

1. Introduction

A capacitive displacement sensor has many advantages, such as a simple structure, low cost, and high resolution. Hence, it has various applications. However, measurable range of the sensor is not long enough for some applications such as stepper machine for semiconductor industries. To solve this problem, some propose use of a capacitive displacement sensor called 'comb-type'.[1-5] The comb-type uses an area-variation motion that is horizontal, moves relatively, and has periodic electrodes. (Fig 1) The periodic electrodes make a periodic signal, and since the comb-type outputs a periodic signal, it is easy to obtain a high measurable range. The comb-type needs a very small gap over a wide range for high resolution; hence it is difficult to control this with conventional gap control techniques. For this reason, a new comb-type sensor using a contact method has been reported. [6, 7] The method to control the gap in the reported comb-type sensor is to adopt a lubricating thin solid layer such Diamond Like Carbon (DLC) while the two facing electrodes with thin dielectric lubricating layer upon them. Even if the gap problem is solved, the comb-type sensor has a drift problem of low frequency noise. This drift is affected by various parameters, such as thermal effect, stage coupling, random wave noise, vibration, alignment, etc.
Thus, it is hard to control; however, the drift must be reduced considerably to achieve high resolution. In this study, reducing the drift is achieved without losing signal to noise ratio (SNR) by using a dual electrode set.

2. Main

The concept of the dual set is based on the concept of a differential amplifier in electric circuits,[8] which removes common signals. If the operating conditions of two identical CLECDiS are exactly same, the signal difference from the two sensors must be zero. However, in real situations, it is difficult to make identical two sensor units and install into a system in identical conditions in various aspects. Furthermore, it is challenging to maintain the same operating conditions of two identical sensors installed on different locations of a given system. To solve this problem, we propose a variant type of CLECDiS that has small spacing between electrodes: CLECDiS with the two groups of identical electrode patterns, one electrode of one group is adjacent to the one of other group and there is a small glass pattern between them as can be seen in Fig 2. The signals obtained from this modified CLECDiS may be affected only by differences in the patterns. The signals are out-of-phase each other with common noise, and the final signal is a difference of the signals. Therefore, it may be very effective to reduce common noises.

A test sample is designed and fabricated based on the principle described above. The typical electrode patterns are 100 µm wide and the spacing between the electrodes is 10µm. The reason why to adopt these values may be the difficulties in fabrication and geometrical errors in preparing the mask for the patterns. The fabrication process has the following sequence (see Fig 3); chrome deposition on a glass wafer (thickness is 120nm) using sputter, PR patterning, a chrome layer etching, deposition of silane(SiH4) on the patterned chrome layer for adhesion layer, and a diamond-like carbon (DLC) coating on the patterned chrome (thickness is 200nm). DLC has been used as the dielectric layer for surface contact. The fabricated components of sensor (a stator and a mover plates) have the same size of 2mm by 4mm.

Fig. 1: Concept images of a comb-type and a traditional type capacitive sensor.

Fig. 2: Concepts and sample images of the dual set.
Fig 4 shows a test bench to evaluate the signals from the sample. The bench consists of stages of ©Newport and custom-made supporting structures. Data acquisition is performed by ©NI PXI using ©LabVIEW. The output signals obtained from the sensor are shown in Fig 5.

In the graphs in Fig 5 the abscissa and the ordinate represents the displacement of and the digitized value of the output voltage signals from the sensor. Fig 5(a) shows the typical signals directly obtained from the two groups of electrodes, where several impulsive noise as well as apparent drifts can be observed. In Fig 5(b) we can find that the drifts and the noises observed in the direct signals are successfully reduced by taking the difference of two signals. Standard deviations of the noise of the original signals are 2.77 and 2.74, but the deviation of the final signals may be 1.65. Fig 5(c) shows the noise level of a half period. In addition, variation of the signal is twice of the original signals. Hence, we may say that the proposed design could reduce the drifts in output signals and it may improve SNR in addition. This implies that an improved CLECoS can be developed with this proposed method in the aspects of resolution and reliability.
3. Conclusion

Based on our findings, we suggest a dual-set model for reducing drift error of CLECDiS. The signals from the sample of the model are out-of-phase with drift, and the difference of them is used. The sample is fabricated using micro machining. The device size is 2mm by 4mm with 100µm of the electrode width. The sample was tested in the bench for CLECDiS. As the result, our suggested method successfully reduces the drift error without any complex signal processing. In addition to, the method improves SNR by common noise reduction. Standard deviations of the noise of the original signals are 2.77 and 2.74, but the deviation of the difference may be 1.65. The drift and common noise can be reduced by using the suggested method in another similar area-varying capacitive sensor.

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