Measurable Characterization of the Slight Force Transducer used in Nano indentation Tools

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Abstract

Quantitative description of the mechanical possessions of resources in micro nano scale using depth-sensing depression method demands high performance of nanoindentation instruments in use. In this paper, the efforts to standardize the capacitive control transducer of a profitable tool are obtainable, where the quasi-static characteristic of the force transducer has sustained calibrated by a whole compensation balance with a resolution of 1 nN. To examine the dynamic response of the transducer, an electrostatic MEMS (Micro-Electro-Mechanical System) based on nano-force transfer standard with nano-Newton resolution and a bandwidth up to 6 kHz have remained employed. Primary novel results designate that the power transducer below correction needs a detailed force indecision less than 300 nN in the calibration range of 1 mN; the transient period at contact opinions totals to 10 seconds; 3 the overshoot of engagement is pre-load dependent.

Keywords : *Nanometrology; Nanoindentation Instrument; Nano-Force Transducer; Microelectromechanical Systems; Nano-Force Calibration*

I. INTRODUCTION

Nanoindentation testing, also mentioned to as complexity detecting instrumented indentation testing, verifies to be one of the maximum significant procedures for responsible the mechanical possessions of minor volumes of materials, including ultra-thin films/coatings, nanoparticles, nano-wires/tubes, etc. In the earlier decades, actual examination and understanding approaches for the instrumented indentation technique (IIT), particularly in the arena of elasto plastic material testing, have remained well established and unvarying. Conferring to the organization of, nanoindentation testing is definite as having maximum indentation depths less than 200 nm, which develops much extra challenging when the resources below test end to be easier.

Under the condition that the indenter tip in procedure has been well calibrated, the dimension correctness of characteristic nanoindentation instruments depends, in general on

1) The improbability of the zero point of contact,
2) Systematic measurement errors of the force generation system and
3) Of the depth sensing system, and
4) Drift of the instrument.

Obviously, in the case of hard resources below test, the latter two issues will play a additional significant part in error analysis, subsequently the effective indentation depth below a specified test force tends to be quite small. For weak resources, the maximum testing force below a given depression complexity will be relatively small, therefore, the previous two mistake sources become the formative issues within the indecision budget of dimension. Additionally, it’s valuable to reference that measurable determination of the tip area purpose of indenters using the way of position resources needs also exact calibration of the indentation force and complexity of an indentation tool.

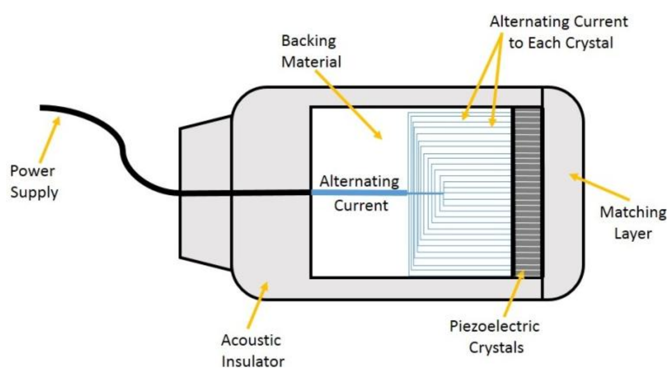

Fig 1 Transducer Basics

To date, noticeable standardization of the complexity detecting scheme of indentation tools has remained well examined, where a capable laser

Interferometer was employed for in-situ purpose of the complexity sensing competence of a nanoindentation instrument and its displacement point. As for in-situ description of the force transducer of a nanoindentation device, though, less successful consequences must remained reported, due to the lack of a capable nano-force detecting device, which could be functional to in-situ examine not only the quasi-static but also the dynamic characteristics of nanoindentation tools.

II. CALIBRATED FORCE TRANSDUCER A COMMERCIAL NANOINDENTATION INSTRUMENT

The minor force transducer examined in this paper is one of the key mechanisms in a profitable nanoindentation tool. It needs remained established on the base of a characteristic three plate capacitive power activating and detecting arrangement. The membrane-like spring system, and stimulated by the capacitive force produced after the energy plates (P_1 and P_2) with the maximum movement range up to about 5 µm The unresolved recital of the electronic switch and detecting units of the transducer confirms that the supreme depression force up to 10 mN can be output, and a nominal noise floor of 30 nN for force generation can be achieved.

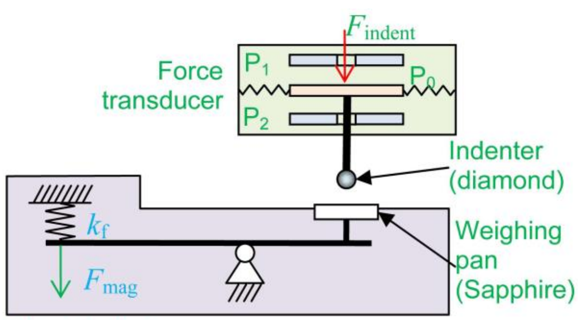

Fig 2 Schematic of the Calibration Setup

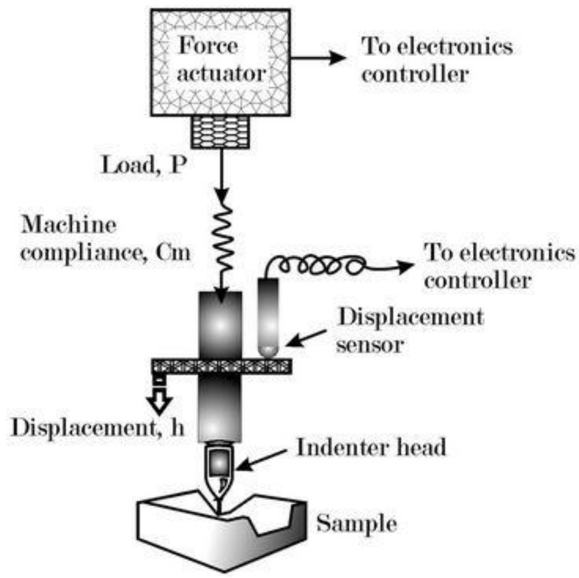

Fig 3 Nanoindentation Instrument

III. CHARACTERIZATION OF THE ACTIVE REACTION OF A FORCE TRANSDUCER IN A PROFITABLE NANOINDENTATION TOOL

The active reaction of a force transducer used in nanindentation tools plays an significant role, mainly when the resources under test have time-dependent automatic properties, e.g. viscoelastic/plastic materials counting polymers. Though the recompense stability used in the calibration arrangement has established high compassion and constancy, its slow reply time (on the order of tens of seconds) avoids itself from actuality used for the examination of the dynamic presentation of a power transducer, whose character frequency is frequently on the order of hundred Hz.

A new force detecting device, which features not only great power compassion but also comparatively broad bandwidth, is hereby extremely favored. Occupied into supposed that silicon-based micro electro- mechanical systems (MEMS) feature minor size, comfort of consignment fabrication and so low cost, competence of addition of electronics and much developed quality occurrence (associated with conservative mechanical macro-sensors/actuators). So here a MEMS force sensor was select to assume the wanted calibration tasks.

A. A MEMS-Based Nano-Force Transfer Standard

Freshly in the PTB a silicon-based nano-force transmission standard needs remained established, whose important arrangement is the highest trough of the force normal is deferred by numerous pairs of creased mechanisms with an corresponding spring constant *k*MEMS, the vertical undertaking of the MEMS highest shaft is actual restrained by a set of electrostatic comb-drives, whose transportable fingers are secure to the central shaft of the MEMS sensor. On the top of the main shaft a check platform is involved for appointment with the substances to be tested.

Perceptibly the test power restrained by this thoughtful of force standard will be F_m□ k_{MEMS}□ U_s□s_{MEMS}, where U_s is the capacitive data of the MEMS sensor, and s_{MEMS} the compassion of the in-plane movement of the MEMS main shaft.

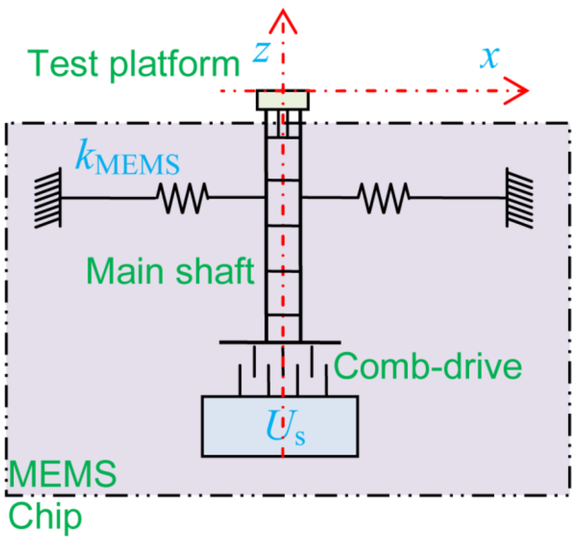

Fig 4 Schematic of a MEMS-Based (passive) nano-Force Transfer Standard

$$F_m = K_{MEMS} . U_S . S_{MEMS}$$

where U_s is the capacitive readout of the MEMS sensor, and s_{MEMS} the sensitivity of the in-plane displacement of the MEMS main shaft.

A lock-in founded capacitive movement data scheme requires been established, which allows that the in-plane movement of the MEMS main shaft can be restrained with sub nano metric determination, springy a sensitivity of the MEMS power standard down to 3 nN.

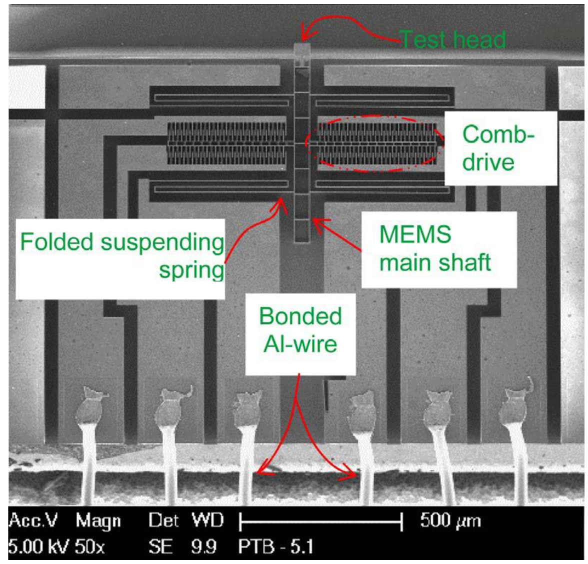

Fig 5 Photography of the MEMS Force Standard

IV. NANOINDENTATION OF POLYMERS

A amount of difficulties exist with the present request of nanoindentation methods to polymeric materials by means of both DSI and SPM schemes. In overall, capacities of E using DSI tend to upsurge with declining diffusion complexity, often mentioned to as an depression size result. This object similarly seems to be a problematic for depression of polymers using DSI26). Thus, either E(surface) > E(bulk) for a huge amount of resources, which appears improbable, or these developments result from increased reservations for shallow depth indentations that are probable due to tip imperfections close the apex and reduced signal-to-noise relations at low load and movement heights. Also, standards of E restrained for polymers using DSI are meaningfully developed than ideals measured consuming stretchable testing or dynamic mechanical analysis (DMA).

Though, such appraisals can often be deceptive, since repeated standards of E for many polymer schemes can cover a huge variety due to possible differences in microstructure, semi crystalline morphology, anisotropy, molecular weight, crosslink density, etc. Therefore, assessments of modulus standards are maximum suitable for polymer examples with identical chemistry, molecular weight, and dispensation history. To date, comparatively rare quasi-static depression studies of polymers using DSI schemes must remained published, mainly because of the insufficiencies of DSI systems and traditional examination approaches as practical to measuring polymer possessions.

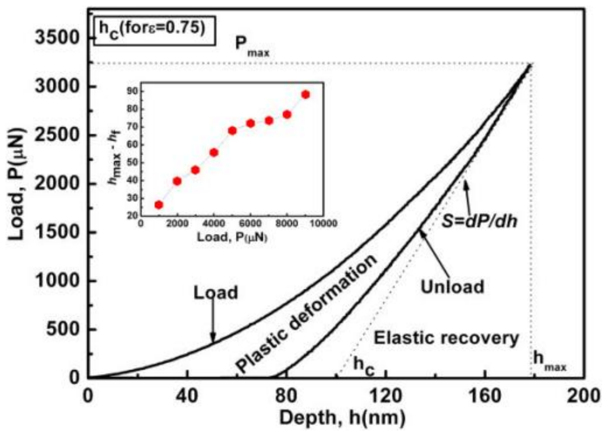

Fig 6 Typical Load Depth Curved

Also, viscoelastic creep through unloading can intensely disturb the grade of the unloading bend, important to undesirable morals of S in dangerous ases. This sneak result needs remained shown finished modeling to be related to a sustained growth in the communication radius throughout the early portion of the unloading cycle30. Because of this affect, control law fits will commonly not be appropriate to appropriate the reception response of polymers. In fact, nonlinear power law turns frequently will not spread a convergent solution.

Though, around profitable DSI scheme software will produce a response built on the standards of the appropriate parameters for the Nth repetition, where N is the whole amount of repetitions permitted by the appropriate routine. Perhaps in realizing this problem, some researchers have returned to responsible S using a linear estimate to the upper portion of the unloading curve31), which accepts that the interaction area residues continuous for the early receiving of the substantial. Though, this preparation makes a requirement of S on the amount of opinions used in the linear fit.

Furthermore, it ignores the reason of the deviance from power law performance, specifically viscoelastic creep. In our new studies, a benzocyclobutene (BCB) polymer designated in aspect was dejected with a DSI scheme using a Berkovich indenter tip. Load frame and tip shape corrections had been resolute using traditional DSI approaches, as conferred earlier.

Moreover, blind reconstruction was used to generate a material-independent tip form area function. Eleven load-penetration bends were achieved with extreme tons of among 43 µN and 944 µN. Numerous dissimilar appropriate procedures were used to fit the receiving curves. Control law fits using commercially obtainable numbers software also did not converge. Power law fits using the profitable DSI scheme software also did not converge for any of the data sets, but standards for S, hc, and E were output built on the standards of the appropriate parameters for the last iteration. The subsequent curve turns are shown laterally with turns based on lined fits to logarithmic information, neither of which remained good representations of the unloading curves.

V. CONCLUSION

In this paper, our determinations to quantitatively standardize the minor power transducer of a profitable nanoindentation tool are described. A altered recompense stability has remained exploited to describe the quasi-static concert of the nano indenters capacitive transducer and a self-developed MEMS power transmission standard has been working to examine the dynamic reply of the transducer in the low power variety. Initial experimental consequences confirm that the minor power transducer below test possesses acceptable quasistatic concert for depression forces extending from 30 µN to 1 mN. Initial moving description of the minor force transducer using a MEMS force normal has exposed that a comparatively long passing period is wanted for the transducer below test to find the zero-contact point, preload-dependent weighty overshoot can seem through the engagement process, which necessity be occupied into thought, once substances below test are actual weak. In adding, owed to the high compassion of the MEMS power normal, the "snap-in" phenomenon among the diamond indenter tip and the silicon surface of the MEMS device needs remained noticed, where the highest attractive power amounts to 50 nN. The used MEMS power transmission normal prototype in this paper has not yet been traceably standardized, including its in-plane movement scale and spring continuous, which must be our following work in the close future.

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