Improving Yield for High Pin Count Wafer Probing Applications

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Abstract

Probe-to-pad contact resistance (C_{RES}) is seen to increase for die near the edge of the wafer as probe applications move to higher force x64 to x128 probe cards. As a result, far more "good" die will escape the process and end up in the trash heap due to a lack of process control capability or the general lack of process improvement in the test area. This effect is primarily attributed to the combination of low-force high pin count technology and the mechanical deflection of the prober chucktop that results.

This paper addresses the relationship between probe overtravel, planarity, C_{RES}, scrub marks, and yield for a variety of probing technologies, and suggests design improvements to ensure that all probe tips make good electrical contact with the bond pads.

Presentation Outline

Introduction

- Traditional Probe Mechanism (Stage)
- Generalized Stage Deflection
- Relationship to Production

System Modeling

- Elastic Strain, Deflection, and Stability
- Objective

Design Innovation

- Probe-Centered Z-Drive Mechanism
- EG4|200 Cross-Section
- Metrology Characterization
- Experimental Set-Up
- Design Validation

Conclusion

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Introduction

By inspecting probe marks to ensure that probe-to-pad connectivity was achieved, we discovered a relationship between C_{RES} and probe location.

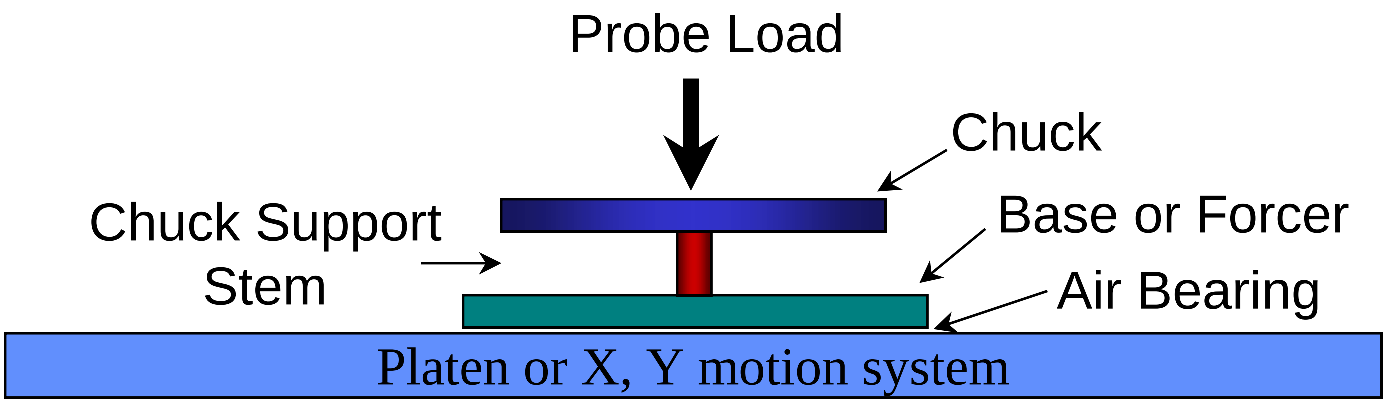
For low pin count, small array probes (low total probe force), a change in C_{RES} is not measurable over the wafer surface. For high pin count, large array probes (high probe force ~120kg), C_{RES} increases and scrub marks shorten as a function of distance from wafer center due to mechanical deflection and loss of planarity.

The mechanical model of chuck top deflection is presented, and the relationships between overtravel and compliance and planarity and yield is established with supportive test results. Prober error is differentiated from probe card error by analysis of variance methods.

Traditional Probe Mechanism (Stage)

Z-Axis drive (red) is a live post directly attached to chuck.

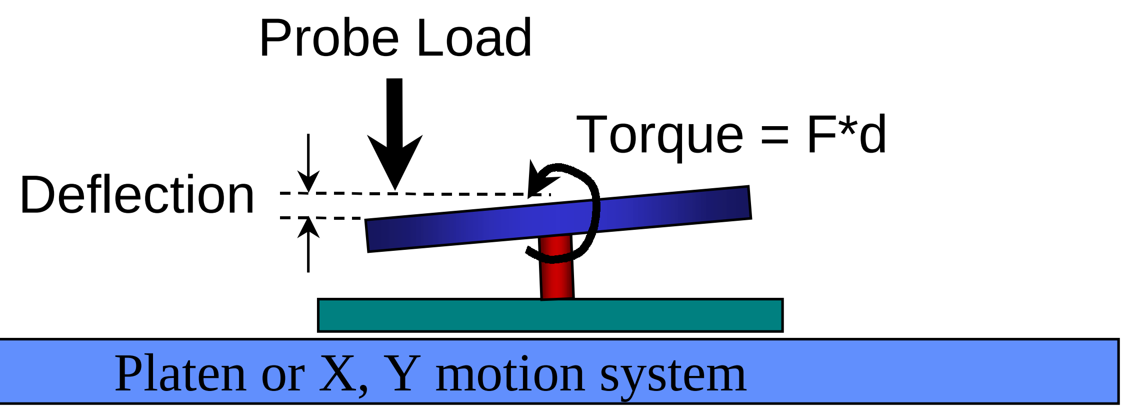
Centered probe load results in uniform deflection.



Traditional Probe Mechanism

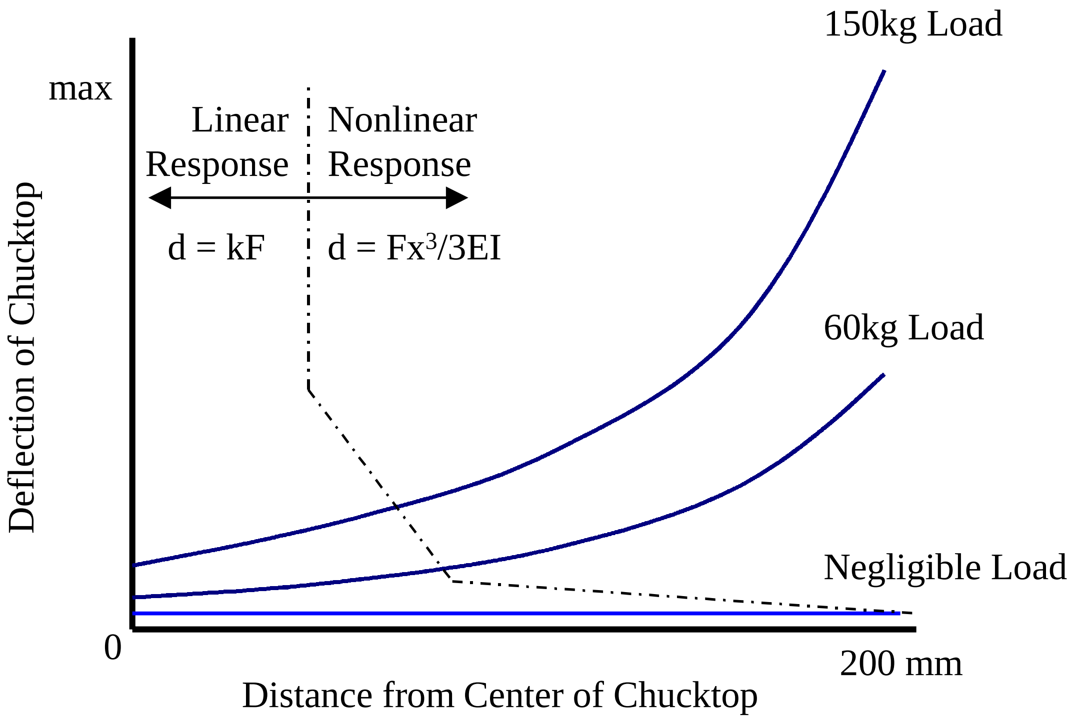
Large bending moments about z-axis' live post result when probe load is moved to chuck edge.

Edge load bends and tilts chuck and live post system -- deflection is maximum.



Generalized Stage Deflection

The deflection of the chucktop becomes nonlinear as force is applied further from probe center.



Relationship to Production

Yield → C_{RES} → Scrub Marks → Overtravel → System Deflection

In a perfect probe system, a flat array of stiff probe pins contact and penetrate vertically into the wafer with near-zero C_{RES}. In reality, each probe pin deflects to compensate for variation in z-axis tolerance. The probe pin with the least deflection may determine the outcome of the test.

Yield is a function of C_{RES}

- **High C_{RES} = false failures and poor yield**

C_{RES} is a function of Scrub Marks

- **Good penetration is required to achieve good electrical contact**

Scrub Mark is a function of Overtravel

- **Overtravel is required to compensate for non-planar probe surfaces**

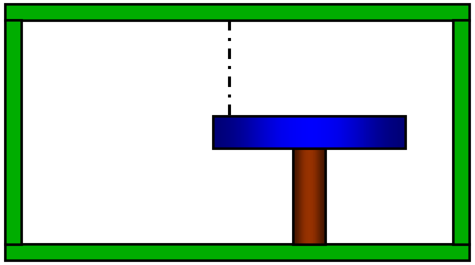
∴ Yield is a function of System Deflection

System Modeling

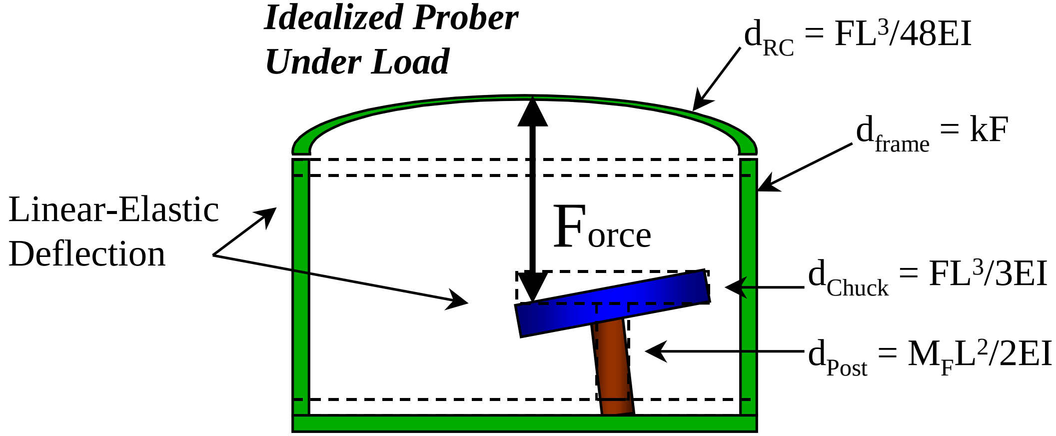
The deflection at any point on the chucktop is the sum of the individual deflections of the system

- Chucktop
- Live Post (z-axis)
- Frame
- Ring Carrier
- PCB

Idealized Prober Without Load



Idealized Prober Under Load



$$d_{System} = d_{Chuck} + d_{Post} + d_{Frame} + d_{RC} + d_{PCB}$$

Objective

Develop a model to predict the deflection of the chuck for a given probe load and array size for a radial distance from chuck center.

Why Predict Deflection?

- Increase in probe pin counts increases probe forces
- Probe mechanism exhibits non-linear deflection under high probe loads
- Many new probe technologies require less overtravel
- It is critical to model the system to accurately predict overtravel programmed (input) into the prober
- Understanding leads to design innovation & improvement

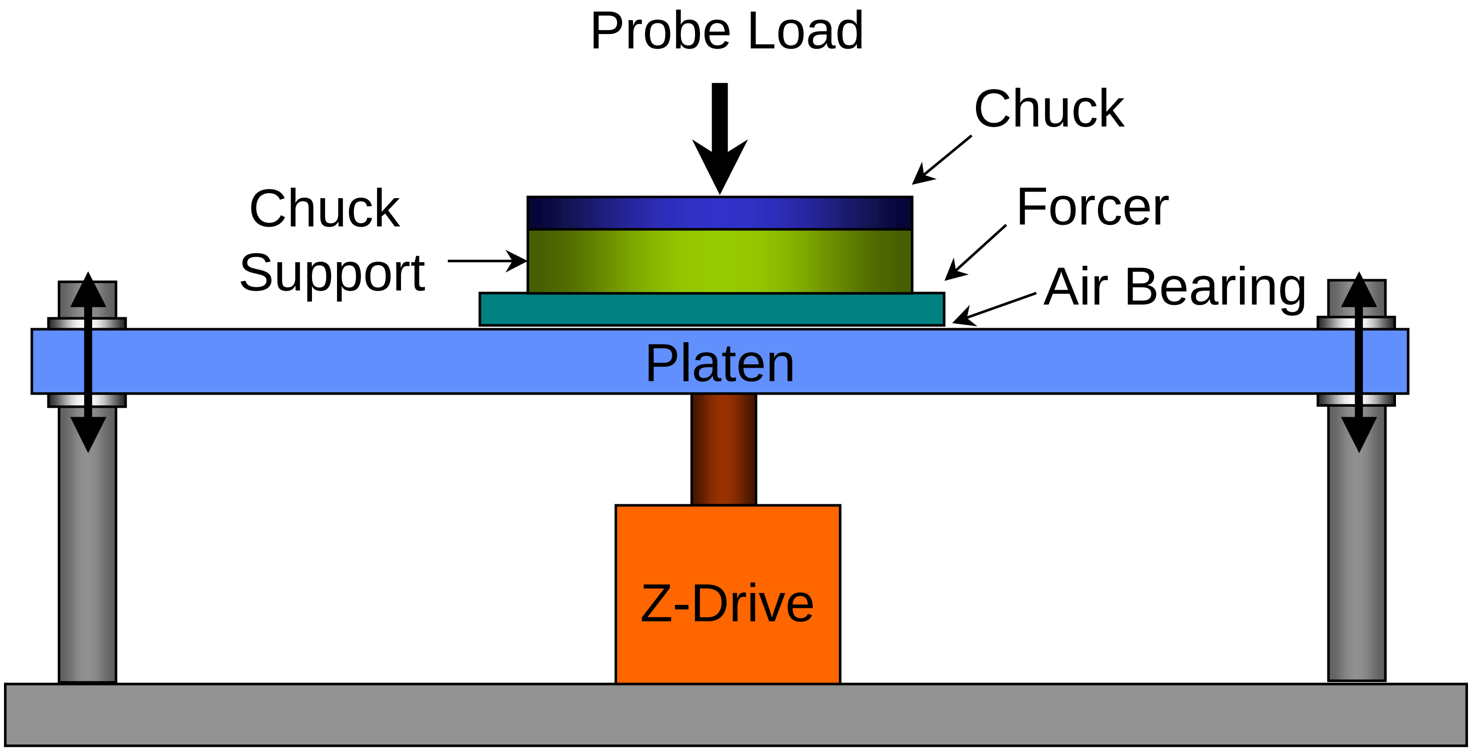
Design Innovation

Low-force high pin count probes were developed, in part, due to a perception that robotic systems (probers) are incapable of holding micron-accuracy tolerances while applying probe forces up to 150kg.

While ring carrier and probe card stiffness are important factors they are, often, easier to address since they are static and not usually constrained by weight and, to an extent, by size. The chuck and related motion systems are limited in height and weight by the physical dimensions of the prober.

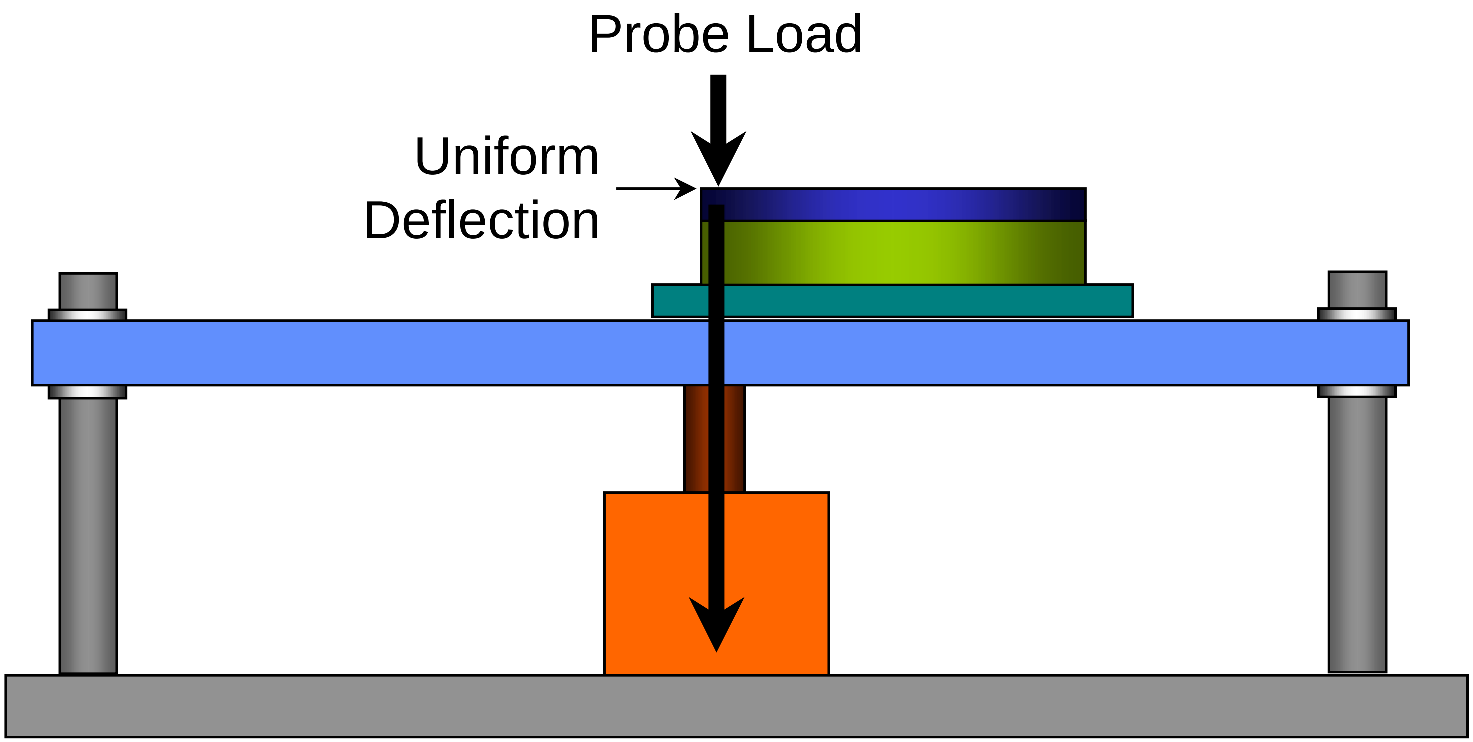
Recent metrology-based advancements to minimize chuck deflection are presented with supportive test results. This development effort supports process improvements related to improving yield for high pin count, high probe force, wafer probing applications in back-end semiconductor manufacturing processes.

Probe-Centered Z-Drive Mechanism

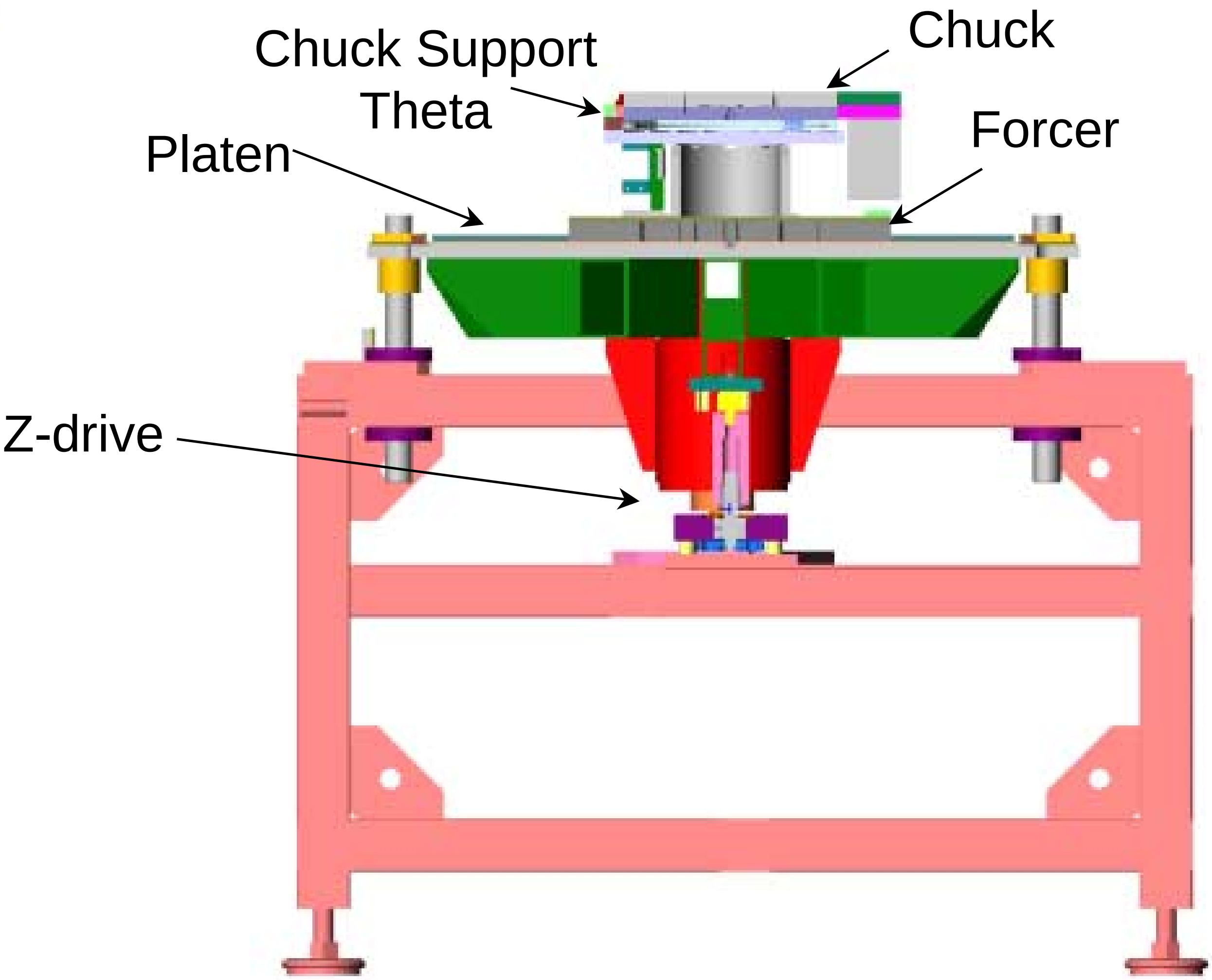


Probe-Centered Z-Drive Mechanism

Edge load does not tilt chuck or system.



EG4|200 Cross-Section



Metrology Characterization

Elimination of “Live Post” via probe-centered z-axis drive innovation uses metrology of Forcer and Platen to simplify chucktop construction while improving system deflection.

System Modeling

- **Linear-Elastic Deflection**
- **Beam Deflection Models**

Probe Mechanics

- **Planarity Measurements**
- **Overtravel Calculation**
- **Scrub Mark Images (Feedback)**
- **Contact Resistance (Feedback)**
- **Yield Correlation**

Experimental Set-Up

Test Setup to Measure Deflection

Experimental Data

Deflection Under Load

- Data presented at workshop

Contact Resistance, C_{RES}

- Data presented at workshop

Probe Mark Images

- Data presented at workshop

Design Validation

For high pin count, large array probes (high probe force ~120kg), the change in C_{RES} is negligible over the wafer surface using the probe-centered z-axis mechanism. With nominal overtravel, all probe tips make good electrical contact with the bond pads because the chucktop remains planar to the probe card.

Slope Deflection Across a Known Array Size

- Summary of deflection results measured on EG4|200 prober
- Data presented at workshop

Z-Stage Comparison

- Comparative analysis (deflection vs force) between conventional and new stage mechanisms
- Data presented at workshop

Conclusion

Understanding the system deflection model led to innovation and improvement in probe mechanism design.

Probe-Centered z-axis drive

- Off-Axis overtravel model simplified to $d_{System} = \Sigma kF$
- Uniform deflection across wafer
- Improved probe-to-pad C_{RES} across wafer

Future Work

While the benefit of probing low-yield wafers with greater than x32 arrays remains speculative, probing high-yield wafers with x64 or even x128 arrays is advantageous. In addition, decreasing bond pad size and pitch is driving improvements in probe technology to smaller probe pins and highly integrated probe arrays. These smaller probe pins produce less spring force per mil of overtravel. Consequently, understanding the bond-pad-to-probe-pin system is key to successful probing. More can be done to improve the prober system.