On Probe Card Cleaning:

The Interplay of Materials Science and Tribology

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INTRODUCTION

Probe Card Cleaning

The critical step in the wafer testing process that helps minimize false negative tests by maintaining contact resistance. Here, we present an overview of the relationship between tribology and materials science. The integration of these two fields is essential for addressing advanced probe card cleaning requirements, efficiency, material durability, and wear characteristics.

- Tribology deals with the study of friction, wear, and lubrication of interacting surfaces in relative motion.
- Materials science is concerned with the design, characterization, and application of materials with tailored properties.

Increasingly rigid demands for extreme temperature wafer probing of high-density arrays require advanced understanding of these key disciplines to improve cleaning material efficacy.

In this discussion, we explore the general properties and metrics that are involved in the design and development of high performing, polymer composites to ultimately produce the ideal probe cleaning media: one that recovers contact resistance, reduces alignment failures, and improves overall cost of ownership while maximizing probe card lifetime.

TRIBOLOGY THEORY

What is Tribology?

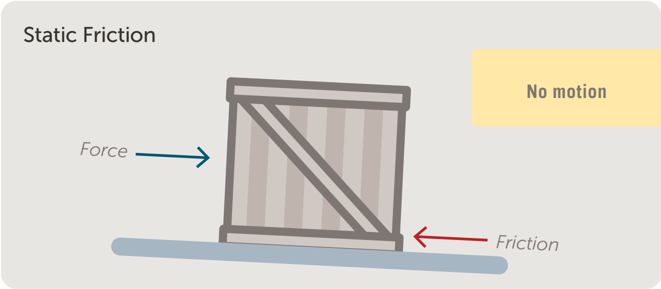
- Derived from the Greek work "tribos" meaning rubbing or to rub.
- Interdisciplinary field that includes mechanical engineering, materials science, and chemical engineering.

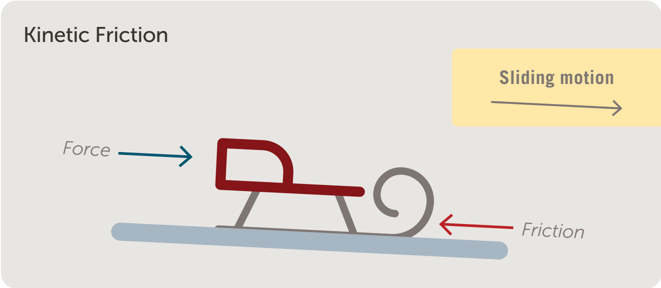
The Laws of Friction

1. The maximum static frictional force (limiting friction) is directly proportional to the normal force.
2. Friction acts in a direction opposite to the direction of motion.
3. Frictional force is independent of the area of contact surfaces.
4. Frictional force depends on the nature of the surfaces in contact.
5. Kinetic Friction is independent of the sliding velocity.

The Coefficient of Friction

The unitless measure of the amount of interaction between two surfaces.





Static	Two surfaces in contact but not moving
Kinetic	Two surfaces sliding over one another

MATERIALS SCIENCE THEORY AND APPLICATIONS

Mechanical Property Characterization

- Material properties are critical for selecting appropriate materials for specific applications.
- Common testing methods such as tensile, compressive, or indentation tests are used to characterize material properties.
- Mechanical testing involves measuring the material response to an applied force or displacement.

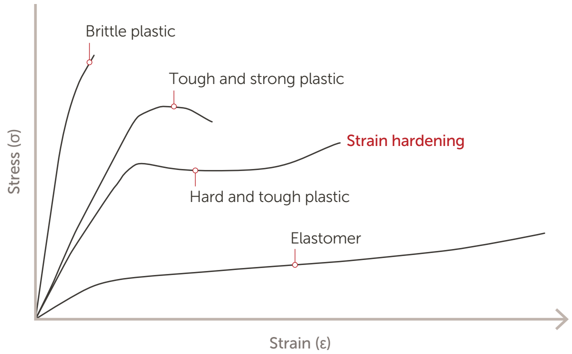
Material Properties from Mechanical Testing

- Tensile testing can be used to determine key material properties such as Young's modulus, tensile strength, strain at break, yield point, and toughness.

Cleaning Material Applications

- Common probe card cleaning materials are made from a hard abrasive material dispersed in a polymer matrix.
- Mechanical properties of both components synergize with the tribological properties to determine the ultimate cleaning performance.

Various Stress vs. Strain Profiles



STRIBECK CURVES: METHODOLOGY AND RESULTS

Methodology

- Pins are pressed into the sample disc with a defined normal force.
- The measuring system rotates at a given speed from which sliding speed is calculated.
- To maintain speed, a certain torque is required.
- Frictional force and friction factor can then be calculated.

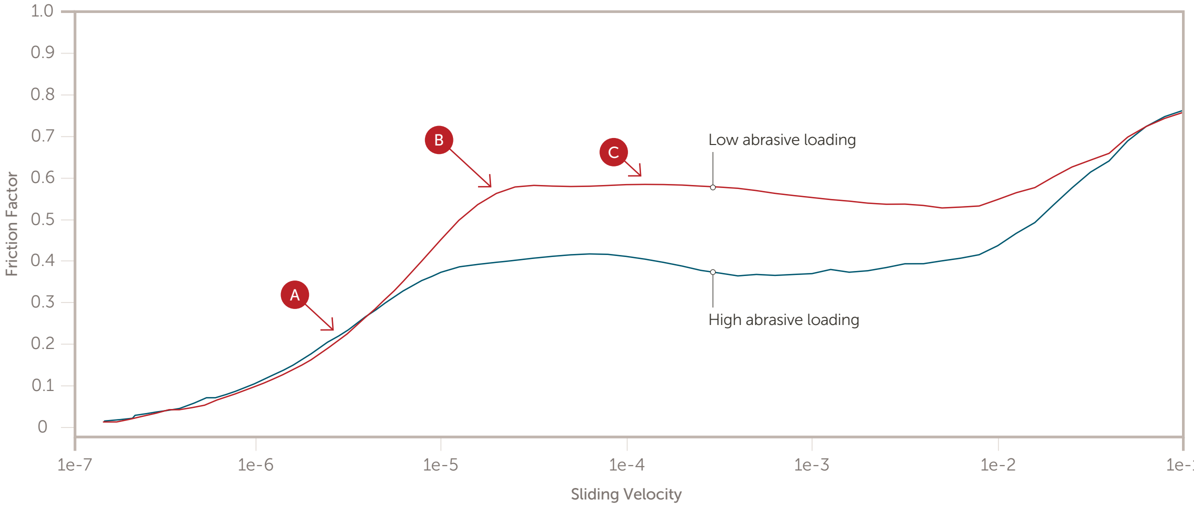
Output: The Stribeck Curve

- Friction factor vs. sliding velocity graph.
- Key Regions:

A	Static friction range
B	Limiting friction point
C	Kinetic friction range

Results

Friction Factor vs. Sliding Velocity



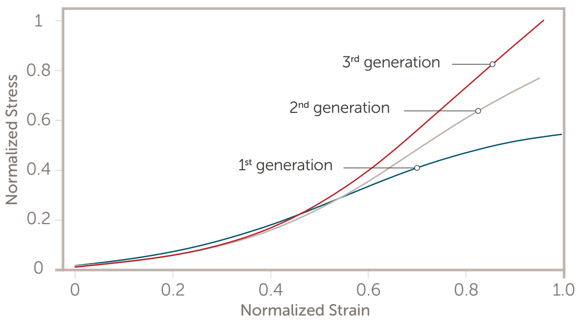
OPTIMIZING MATERIALS PROPERTIES

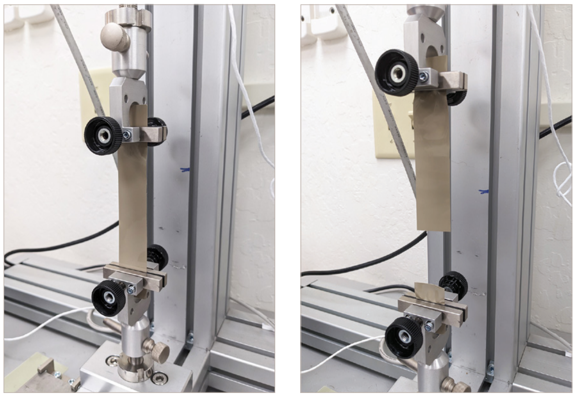
Methodology

- Strips of bulk, isotropic materials are prepared with standardized dimensions.
- Samples are mounted into grips and the grips are separated at a set rate until break.
- Force and displacement outputs are recorded and converted to stress and strain based on sample geometry.
- Stress vs. strain is graphed, and key properties are calculated from those values.
- Material toughness can be increased while maintaining similar performance through optimization of the polymer binder.
- Higher toughness materials are more difficult to fracture and damage.

Results

Tensile Testing



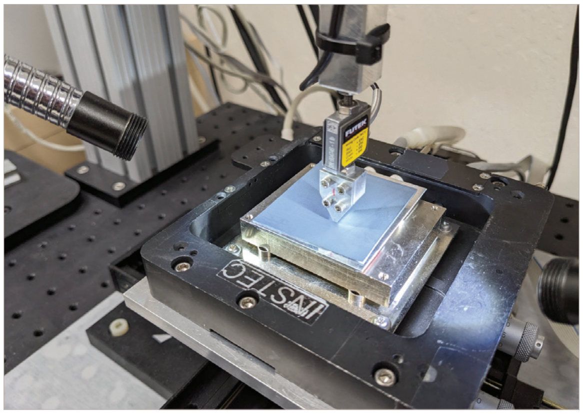


RESULTS: OPTIMIZED MATERIALS PROPERTIES FOR REDUCED SURFACE DAMAGE

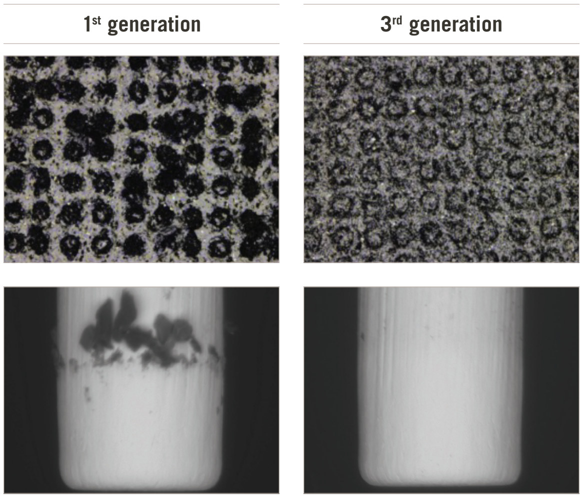
Methodology

Wear Testing

- Single vertical pin used to simulate cleaning process.
- Pin inserted into cleaning material:
  - 150 µm overtravel
  - 150 µm indexing
  - 10,000 touchdowns
- Material surface imaged using a combination of optical and laser confocal microscopy to measure depth of damage.



Results



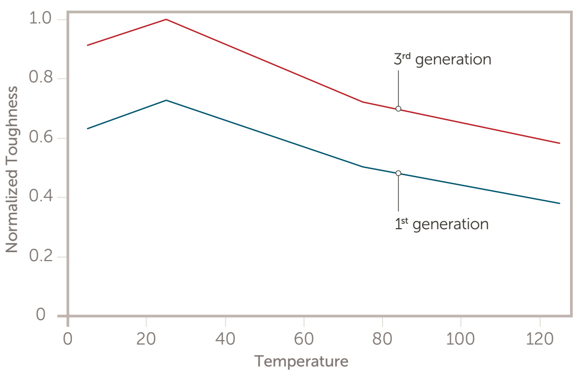
- 1st generation material shows extensive damage after probing with debris present on the pin.
- 3rd generation material has <10% the damage and no debris present on the pin.

RESULTS: TEMPERATURE DEPENDENT MATERIAL PROPERTIES

Methodology

- Tensile material properties were tested at different temperatures.
- A cantilever pin was inserted into the material 5,000 times with 80 µm overtravel in one location at room and high temperature.

Normalized Toughness vs. Temperature



Results

	25°C	125°C
1st generation		
3rd generation		

- Material toughness is temperature dependent.
- 3rd generation materials have higher toughness across all temperatures and exhibit lower material damage at high temperatures.

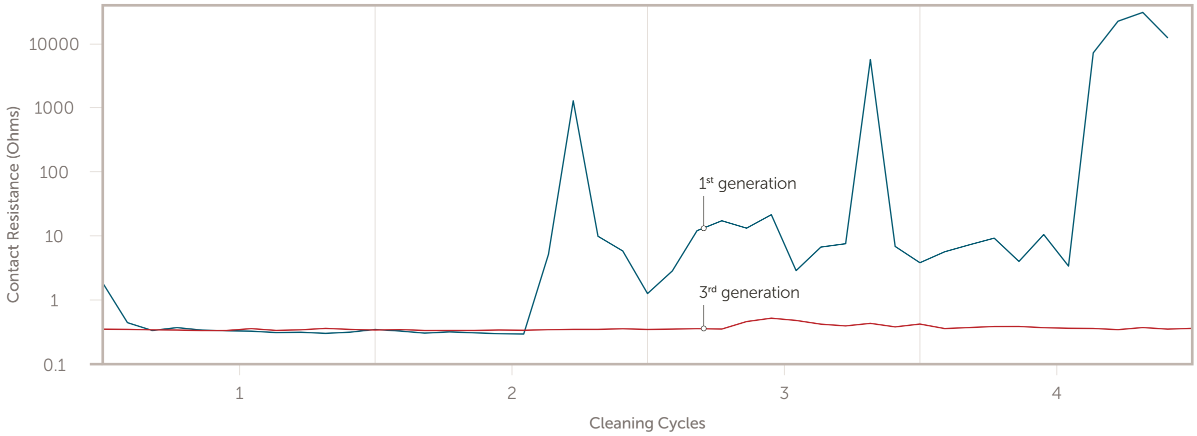
RESULTS: CONTACT RESISTANCE

Methodology

- The pins were inserted into the cleaning media at 150°C at 150 µm overtravel.
- Resistance was measured every 10 touchdowns on a separate grounding pad for 100 total touchdowns.
- The experiment was repeated for four cycles.

Results

Contact Resistance vs. Cleaning Cycles



CONCLUSIONS

Tribology and mechanical properties are integral to predicting cleaning performance of the cleaning media. As an object penetrates the media at speeds below the limiting friction point, little to no wear can take place. Since the limiting force is directly proportional to the normal force acted upon the pin by the composite, it is dependent on modulus. Material properties are also temperature dependent. Lower mechanical performance at higher temperature leads to a higher rate of polymer debris formation. The nature of the surfaces in contact must also be considered in the design of the cleaning media. In this case, higher abrasive loading lowers the force needed to overcome the limiting force allowing the surfaces to slide against each other and more wear takes place.

Comparing 1st versus 3rd generation cleaning media, the 1st generation media has significantly lower mechanical properties and debris is clearly generated on the pins during standard insertion tests. This debris provides an insulating barrier between the pin and the contact point resulting in a rise in contact resistance. In contrast, the 3rd generation cleaning media has been tuned to withstand the stress and strain exerted on it. After extreme abuse and multiple insertions, the surface exhibits minimal damaged and debris does not accumulate on the pin.

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