

PARTICLE ADHESION AND REMOVAL IN POST-CMP APPLICATIONS

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OUTLINE

- ❑ ***Goals and Objectives***
- ❑ ***Approach***
- ❑ ***Preliminary Results***
 - ❖ ***Particle Removal Mechanism***
 - ❖ ***Double layer***
 - ❖ ***Covalent bonds between for silica on thermal oxide films and glass particles on glass substrates***
 - ❖ ***Adhesion induced deformation***
- ❑ ***Key Preliminary Research Results***

Surface Preparation Technology Requirements -- Long Term**

YEAR	1999	2000	2002	2005	2008	2011	2014
TECHNOLOGY NODE	180nm		130nm	100nm	70nm	50nm	35nm
FEOL Particle Size(nm)	90	82.5	60	50	35	25	18
FEOL Particles (#/cm ²)	0.064	0.06	0.064	0.051	0.052	0.052	0.052
BEOL Particle Size(nm)	180	165	130	100	70	50	36
BEOL Particles (#/cm ²)	0.064	0.06	0.064	0.051	0.052	0.052	0.052
Surface Roughness (nm)	0.15	0.14	0.12	0.1	0.08	0.08	0.08
Critical surface metals(*10 ⁹)	9	7	4.4	2.5	--	--	--
Organics (*10 ¹³ atoms/cm ²)	7.3	6.6	5.3	4.1	--	--	--

** ---- The International Technology Roadmap for Semiconductors, 2000

Goals and Objectives

- ◆ To determine the adhesion force for different particles on different substrates in different solutions experimentally.
- ◆ To understand and determine the onset of large adhesion forces after polishing such as the development of covalent bonds.
- ◆ Study the removal and adhesion forces for alumina and silica slurry particles from silicon wafers (with different films, TOX, W, Cu, TaN, BPSG, etc.).
- ◆ Develop better cleaning guidelines and techniques to reduce surface defects after polishing.
- ◆ In addition, the effect of polishing pressure on the slurry particle adhesion force will be determined.

Approach

- ◆ ***Fundamental Approach***
- ◆ ***Experimental and modeling approach to determine, understand and predict:***
 - ◆ ***Particle Adhesion Force***
 - ◆ ***Adhesion force increase due to:***
 - ◆ ***Particle Deformation***
 - ◆ ***Covalent Bonds***
 - ◆ ***CMP***
 - ◆ ***Slurry and Cleaning Solution Chemistry***
 - ◆ ***Pad hardness, compressibility and tensile strength***
 - ◆ ***Particle shape***
 - ◆ ***Surface Roughness***

Approach

- ◆ ***Fundamental Approach***

- ◆ **Key Particle Removal Parameters**

- ◆ Particle shape
- ◆ Polishing pressure
- ◆ Particle size
- ◆ Particle composition
- ◆ Slurry and cleaning solution chemistry
- ◆ Chemical reactions giving rise to covalent bonds
- ◆ particle deformation
- ◆ Double layer effect
- ◆ Cleaning liquid surface tension
- ◆ Surface and particle surface energy (hydrophilic or hydrophobic)

PARTICLE REMOVAL

- ❑ **Nano-scale particles will be a challenge to current cleaning techniques.**

- ❑ **The most widely used cleaning techniques:**
 - ✓ **non-contact method (megasonic cleaning)**
 - ✓ **contact cleaning method (brush scrubbers)**

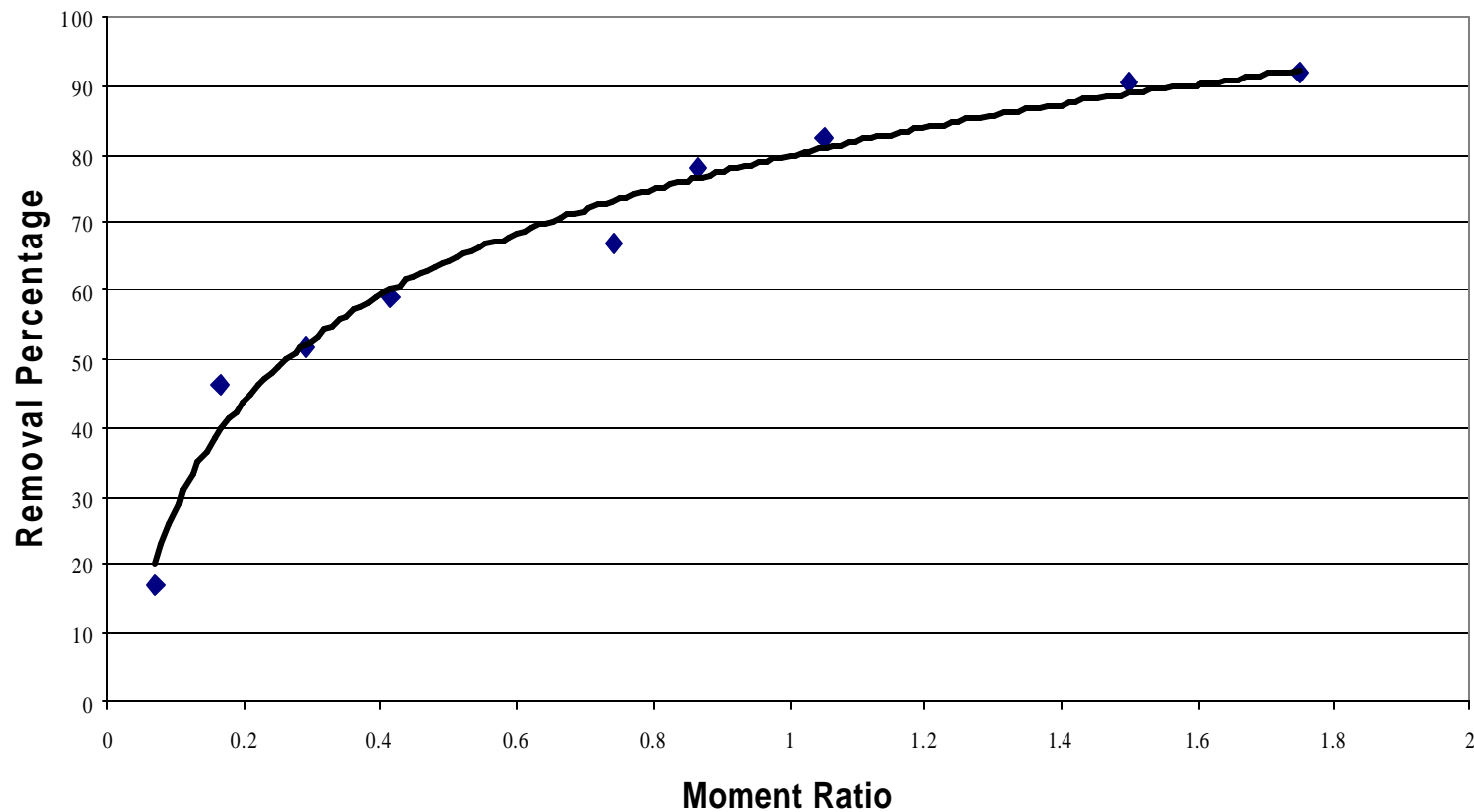
- ❑ **The two basic elements that need to be understood are :**
 - ✓ **Particle Adhesion**
 - ✓ **Particle Removal**

Particle Adhesion

- ◆ **Adhesion between a contaminant particle and a wafer occurs in three basic steps:**
 - ◆ Long-range attraction forces draw the particle towards the surface
 - ◆ The contaminant particle touches the wafer at one point of contact
 - ◆ Short range van der Waals force dominates near the surface and the contact area increases.
 - ◆ Deformation may occur due to adhesion-induced deformation thereby increasing the adhesion force the deformation stops and the system is in equilibrium.

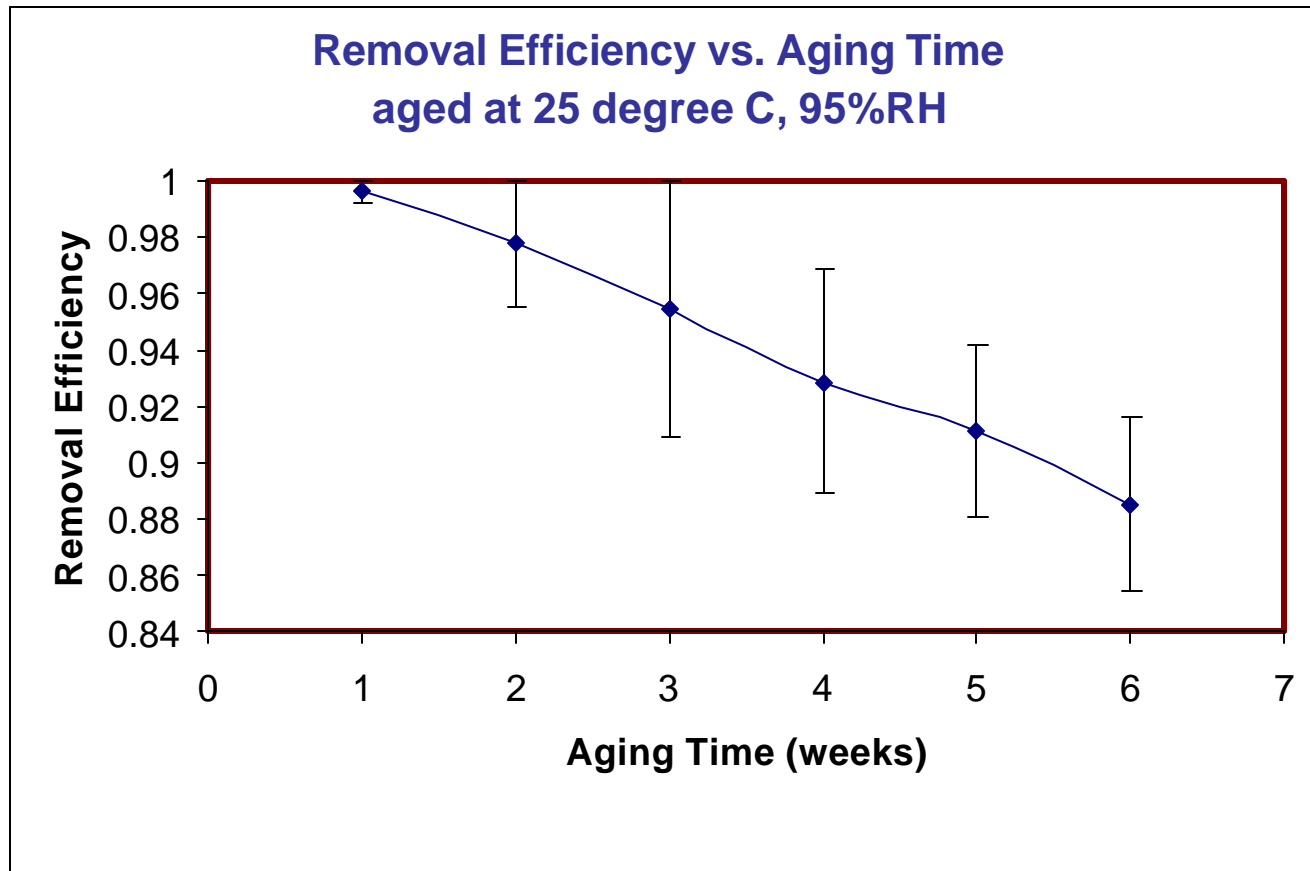
Removal Percentage vs. Moment Ratio (Silica Removal Experiment)

Removal Percentage Moment Ratio

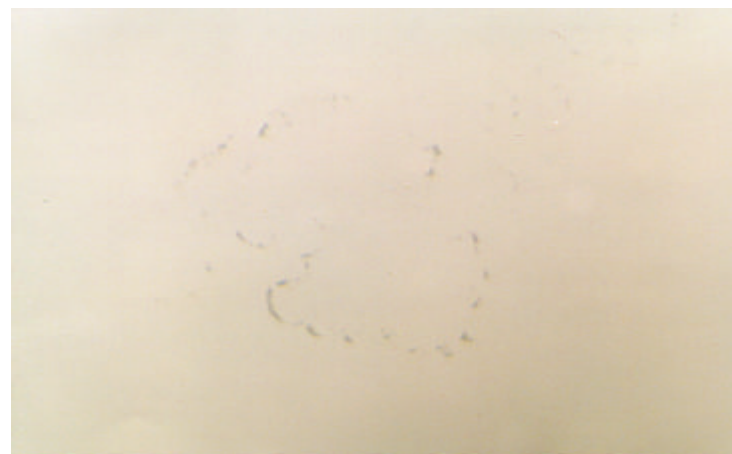


RESULTS

Aging Effect on Glass Particle Removal from FPD

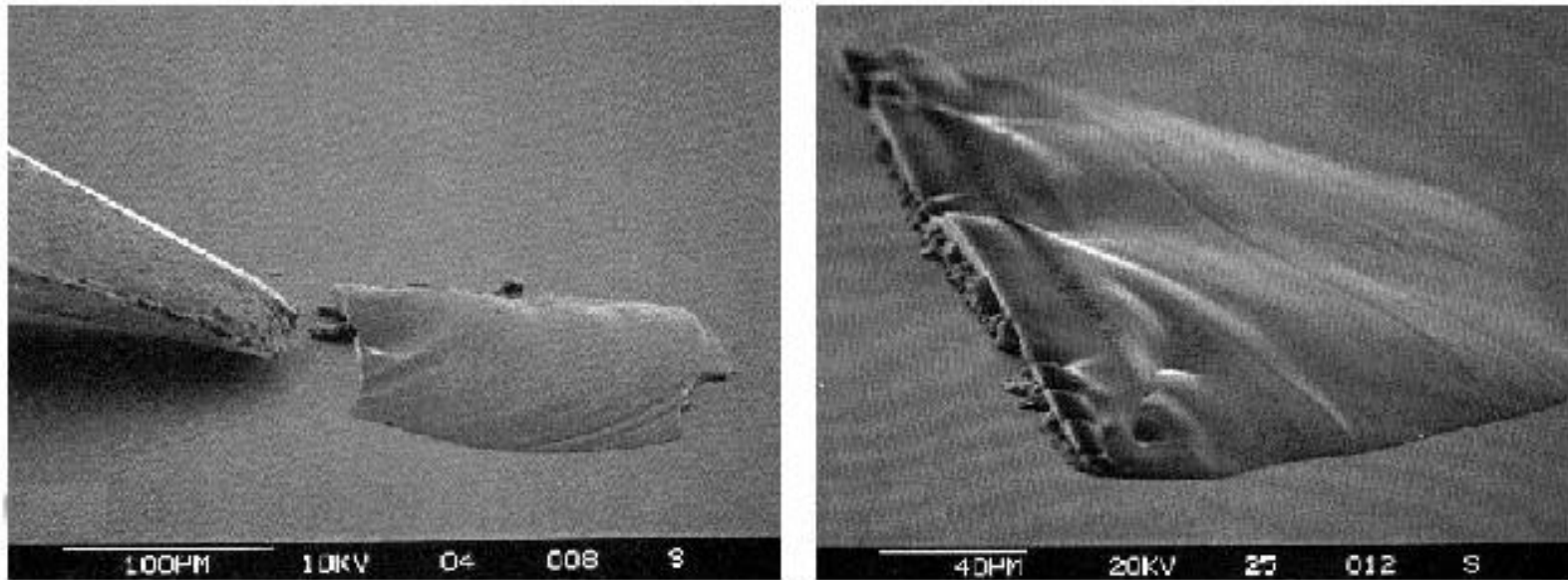


RESULTS



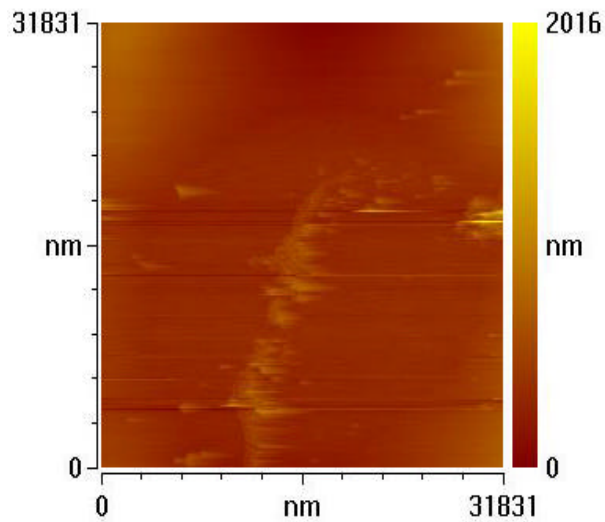
Imprints on the glass surface (megasonic cleaned after aging)

RESULTS

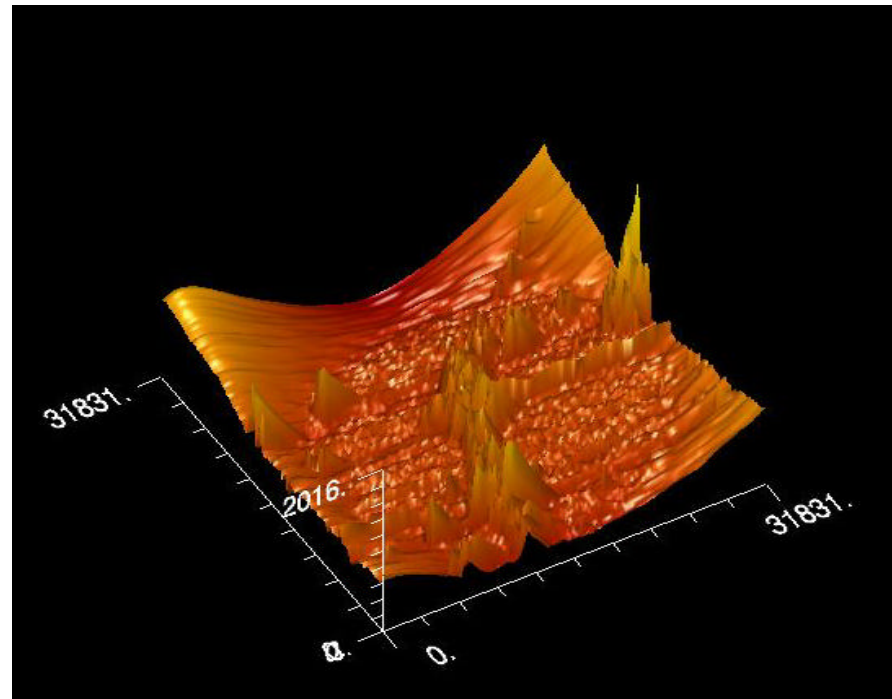


SEM image of glass chips(large bonding areas matched-flat surfaces in contact low profile)

RESULTS

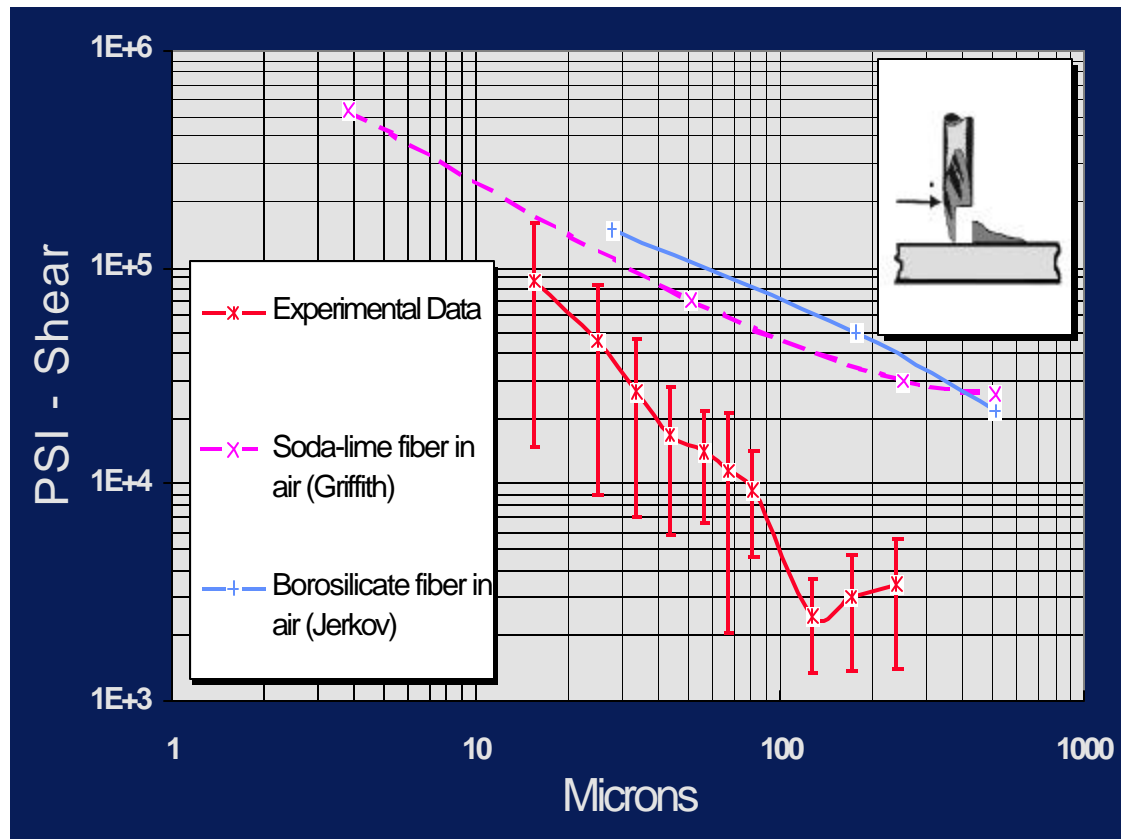


AFM micrograph of surface imprints



AFM three dimensional view of imprints

RESULTS

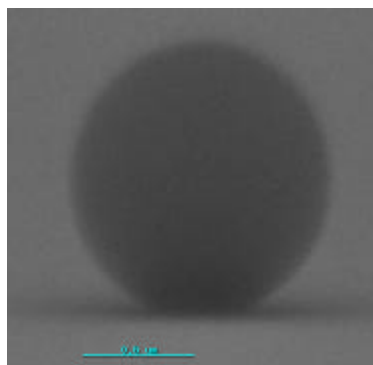


Bond strength vs. particle diameter (Experiment data compared with Griffth's tensile strength of glass fiber and with Jerkov's tensile strength of glass fiber)

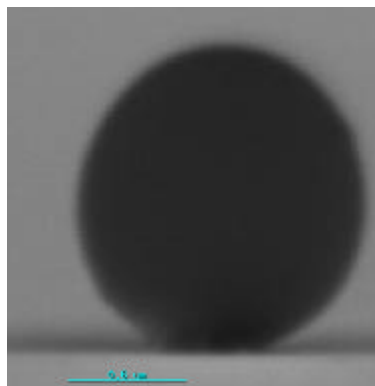
RESULTS

One Week Aging

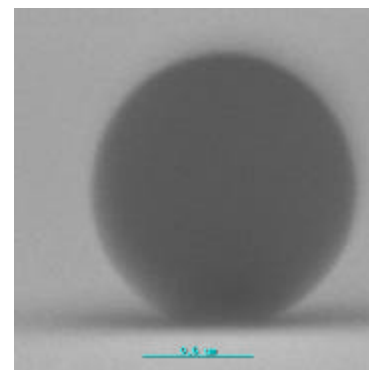
Dry surface, 55%RH aging



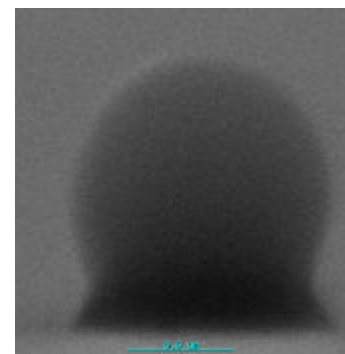
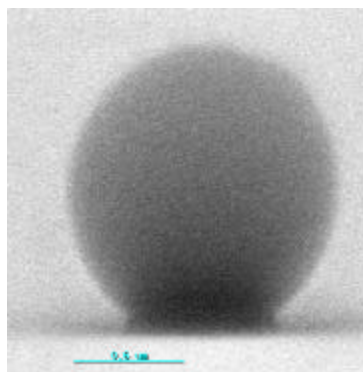
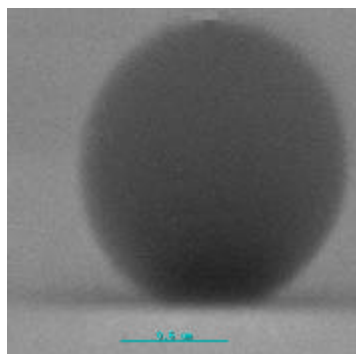
Wet surface, 55%RH aging



Wet surface, 100%RH aging

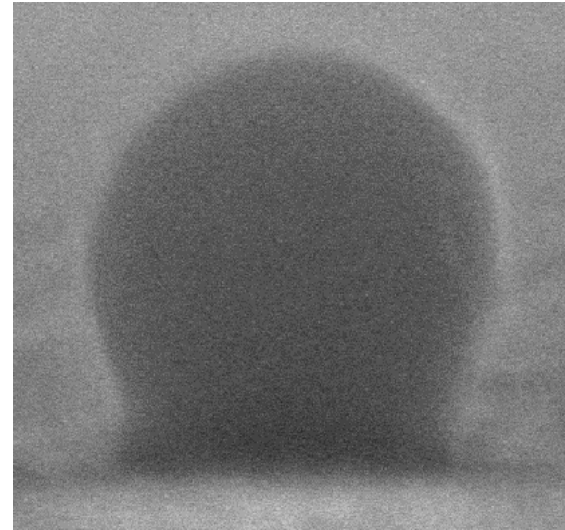
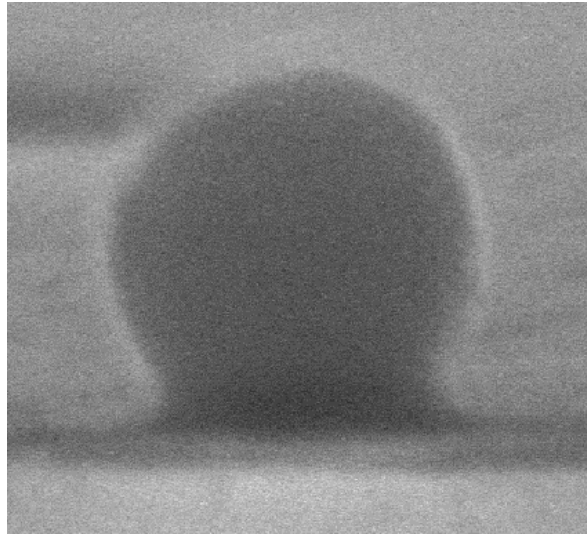


Six weeks aging



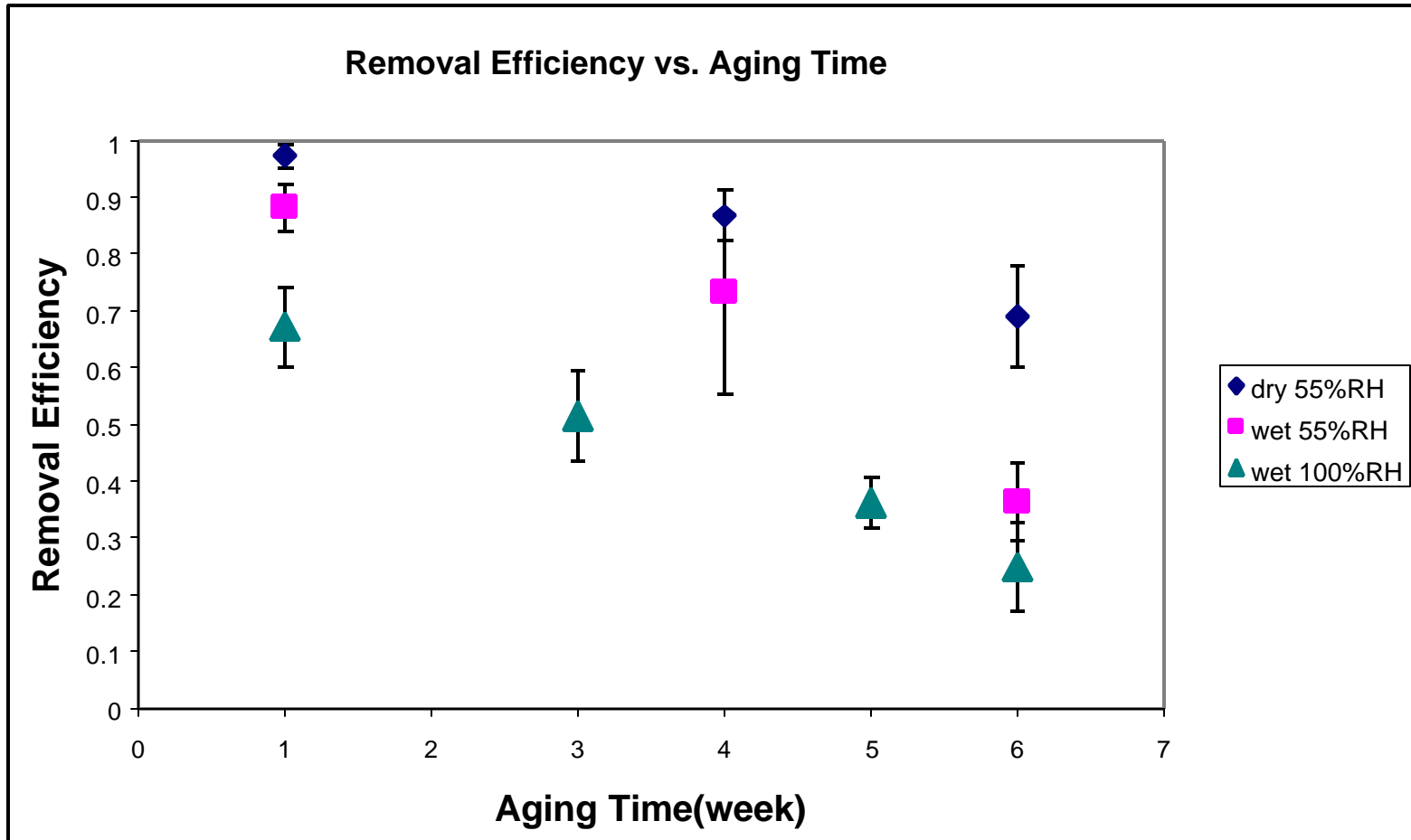
1.58um Silica Particle on Thermal Oxide Wafer

RESULTS

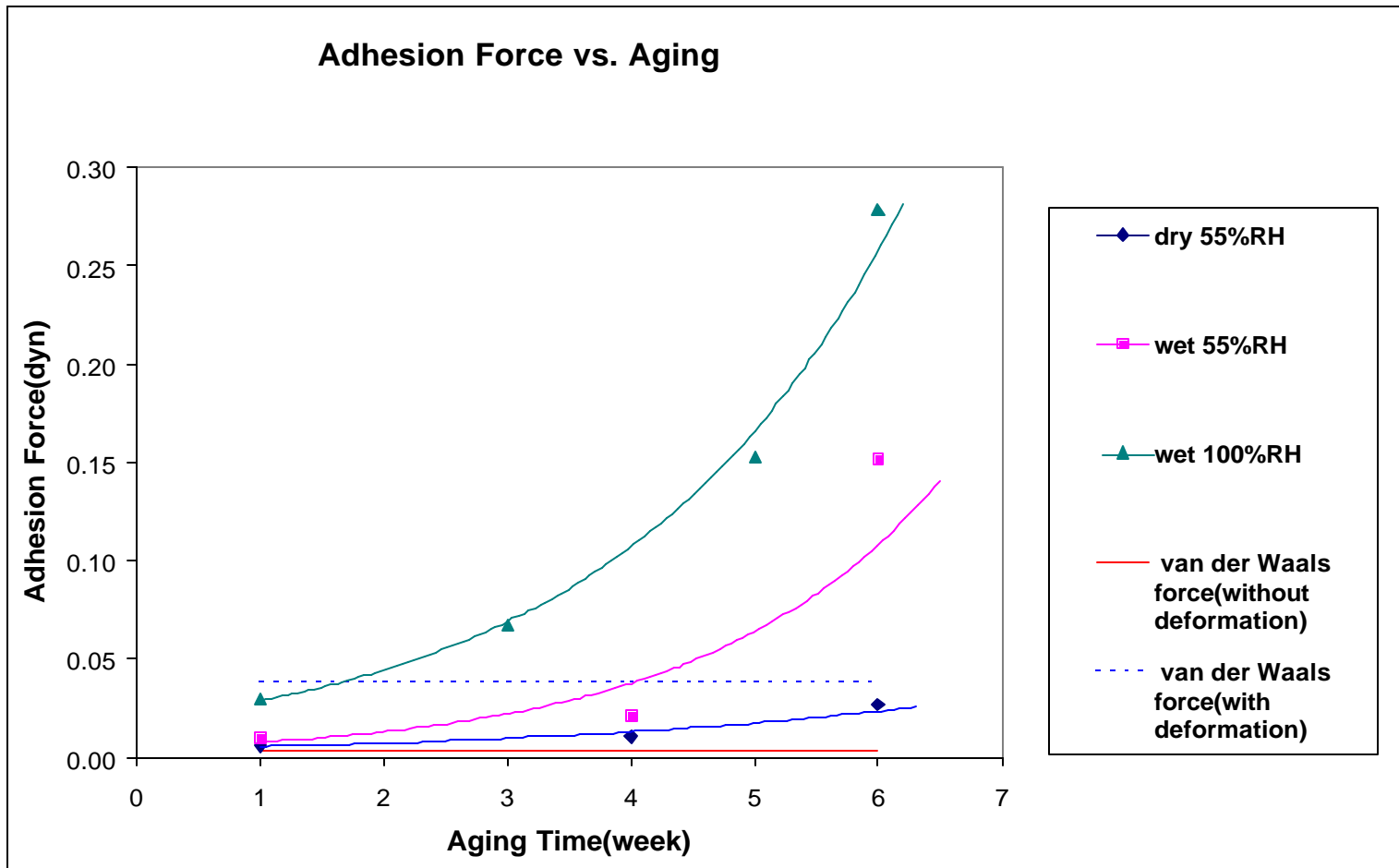


1.58 μ m silica particle on slurry wetted
oxide surface within one hour

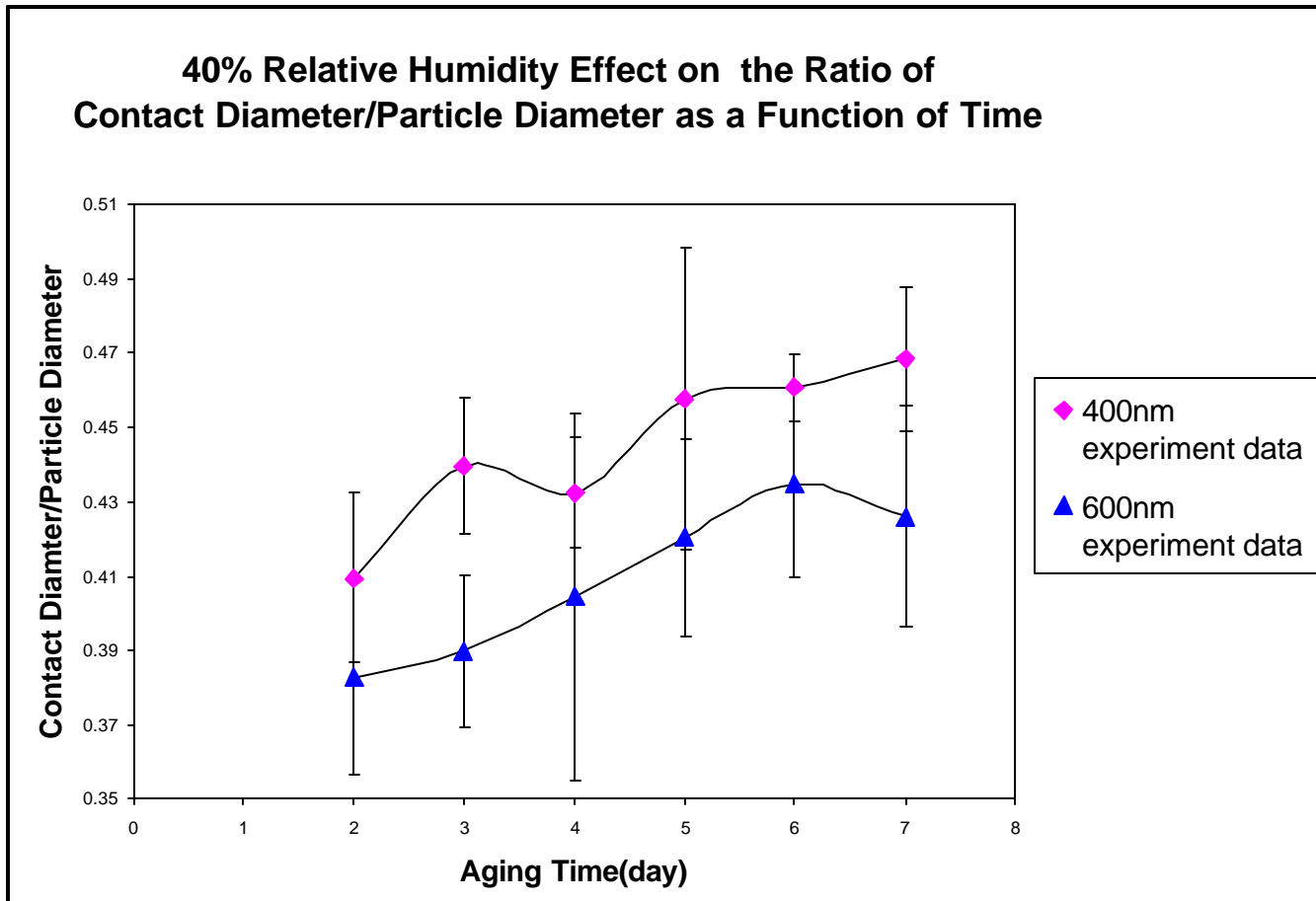
RESULTS



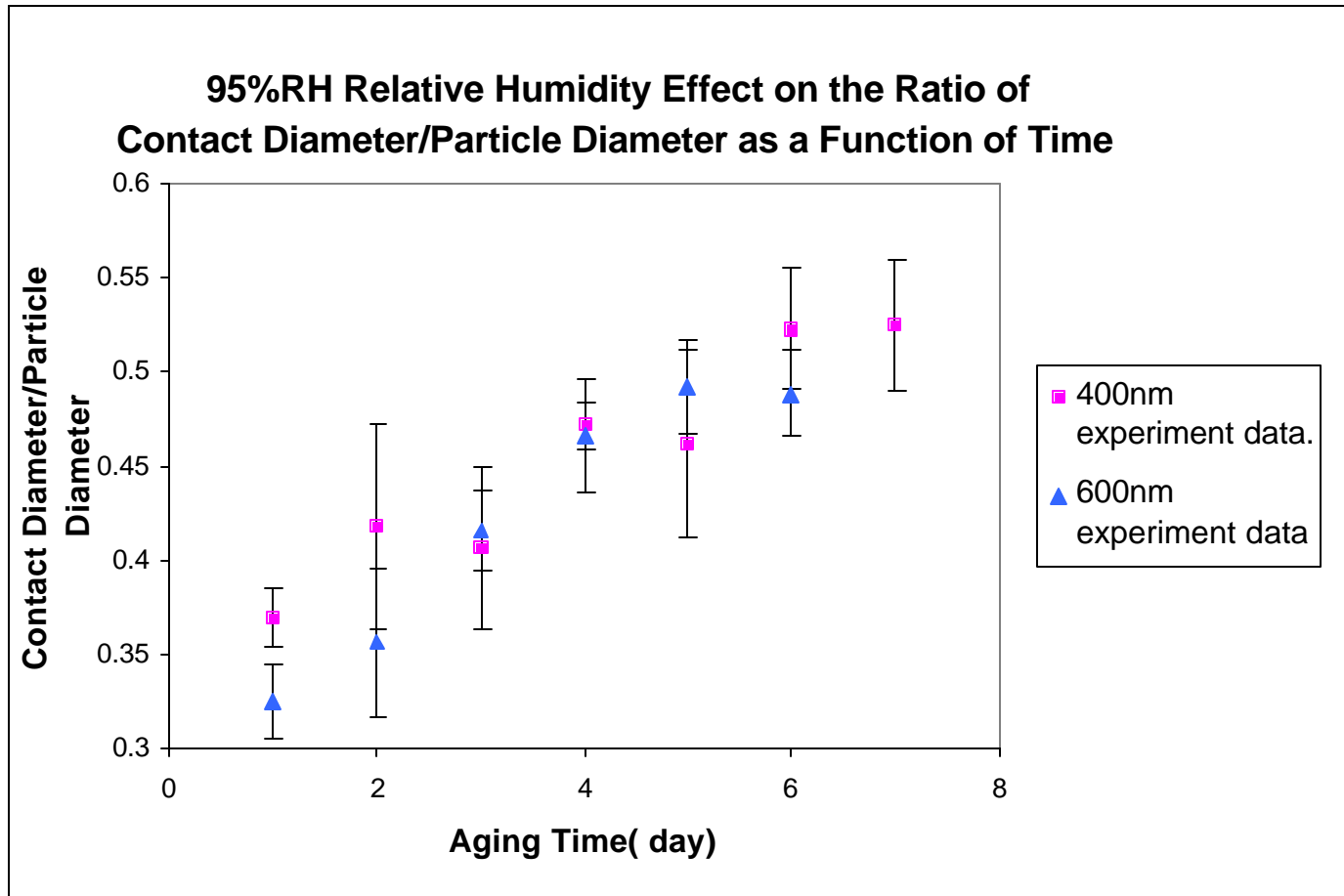
RESULTS



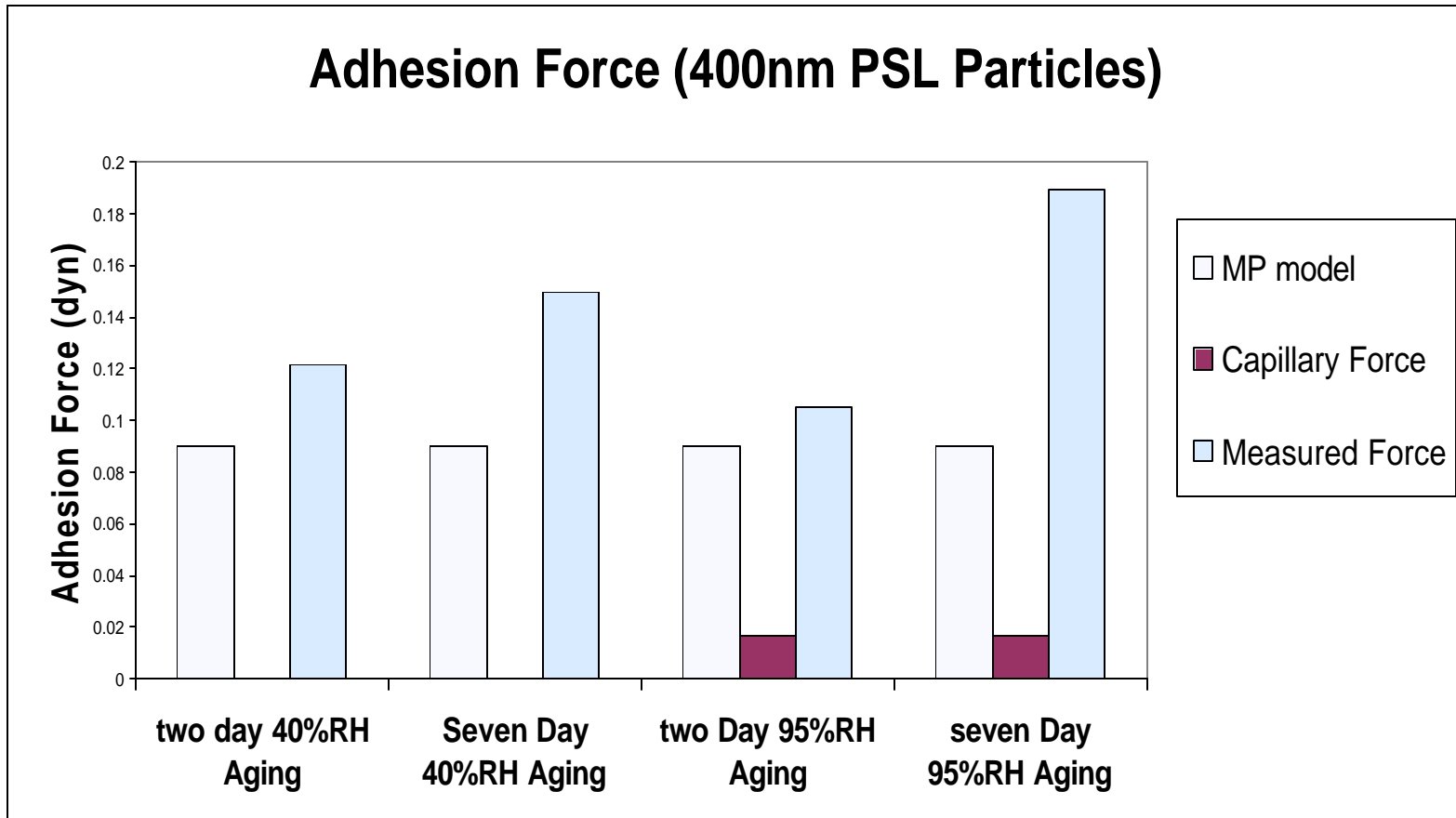
RESULTS



RESULTS



RESULTS



SUMMARY

- ◆ **Moisture plays a significant role in silica particles' adhesion on silicon oxide substrate. The adhesion force significantly increases with moisture.**
- ◆ **The large meniscus indicates that initially, hydrogen bond forms and as moisture reacts between the surface and the particle, covalent bond forms around the periphery of the particle. If considering practical surface condition, the measured adhesion force fall between hydrogen and covalent bonds.**

SUMMARY

The average pressure exerted by surface force between PSL particle and silicon oxide surface is

$$P = \frac{2w_A}{z_0}$$

P is found to be 1.6×10^9 Pa, which is comparable to the Young's modulus of the polystyrene (2.55×10^9 Pa) and far in excess of its yield strength (10.8×10^6 Pa). This confirms that it is plastic deformation taken place.

- ◆ Contact diameter between the particles and the substrate increase with time logarithmically.
- ◆ For the same aging time, high humidity (95%RH) shows significant increase in particle deformation compared to the 40%RH conditions. Capillary force tends to accelerate the adhesion-induced deformation process.
- ◆ For the same aging conditions, smaller particles encounter larger deformation.
- ◆ The plastic deformation is caused by adhesion and capillary stresses that exceed the yield strength of PSL particles.