Agenda

• Background Hach Ultra Analytics
• Particles
  • Particle Sources, types and definitions
  • Size, behavior, movement and adhesion
• Electrostatic Attraction & ESD
• Controlling particle contamination
• Particle counters
  • Theory & practice
  • Measurement challenges
• Trends in HDD & Semiconductor Industries
• ISO Standards
• Q&A
Who is Hach Ultra?

- 460 associates
- 4 manufacturing facilities
- 125 Representatives in Asia, Europe, South America
- Anatel, HIAC, Orbisphere, HYT, Met One, Polymetron

Mission Statement:

Excellence in products and services combined with application expertise. Delivers instrumentation and solutions to maximize process efficiency and quality, minimize operating costs and meet regulatory reporting requirements.
Electronic Market Product Offering

- Particle Counters
  - LPC
  - APC
- Vacuum
- Remotes
- Silica analysers
- TOC analysers
- Conductivity & PH
- Sodium
- Dissolved Gases
Particle Sources, types and definitions

- Particles can be produced by many sources
- Inert (nonliving) & Inorganic (from matter never alive)
  - Generally from one item rubbing against another
    - Cutting, Electric motors, Plastic disintegrating in UV light
    - Humans shed many inert particles
- Viable (living) & Organic (from living mater)
  - Living microorganisms bacteria, viruses and fungi
  - Dead skin cell is an inert organic particle
  - A cold virus is a viable organic particle
- A grain of copper dust is?
Size

CD surface

Typical sizes of interest in particle counting

1μm

.5μm

.3μm

.1μm
Human hair: 75 - 100 µm

Visible: 35 - 50 µm

Skin Flake: about 20 µm
How do small particles behave?

• They move through the air and fluid by means of
  • diffusion and ballistic forces

• They stop moving and they accumulate on surfaces through
  • gravity, electrostatic adhesion, and friction

• In liquids, particles may adhere to air bubbles, cling to the walls of a duct or container, or agglomerate into a larger mass.
Movement – Diffusion

- Particles suspended in a fluid (liquid or gas) are moved and dispersed by several related forces: currents, thermal variation, and Brownian motion.

- Currents are the **laminar** (smooth) and **turbulent** (rough) movements of a fluid. **Currents** are a result of pressure differences, with the fluid always moving from an area of higher pressure to an area of lower pressure. Particles suspended in a laminar flow tend to remain in that part of the fluid.

  - In air, a lateral (side-to-side) movement is called **advection**; a vertical (up and down) movement is called **convection**.
Movement – Diffusion

- **Thermal variation** - Temperature differences in a air/fluid contribute to currents, particularly convective (vertical) currents.

- **Warming** a air/fluid will also increase Brownian motion. This causes the molecules to be more energetic, and consequently they collide more frequently and are farther apart. This is why warm air is less dense than cold air and tends to rise.

- **Brownian motion**: The default state of particle motion, continually colliding and bouncing off of each other. Over time, Brownian motion results in a more-or-less random distribution of particles.
Movement – Diffusion

- **Ballistic Forces:**
  Particles can be ejected from a tool or process causing them to move against the prevailing air flow.
Particle Settling Rates

Average settling time in a still air room with an 8' ceiling:

- **< 1.0µ**: 8.5 hours
- **1.0µ**: 10 min.
- **5.0µ**: 5 min.
- **10µ**: 2.5 min.
- **15µ**: 34 sec.
- **30µ**: 12 sec.
- **50µ**: 3 sec.
- **100µ**: Permanently suspended

Particle Size in microns
Lack of Movement – Adhesion

- **Electrostatic adhesion:** Particles can carry static electricity the same way a balloon rubbed against your hair can. This causes particles to be attracted and stick to a surface that carries the opposite charge.

- **Agglomeration:** In liquids, particles tend to agglomerate around (stick to) gas bubbles.

- **Accretion:** Particles can stick to each other. This can be the result of electrostatic adhesion or other "sticky" forces. Under certain conditions, it is common for two particles to stick together forming a doublet.
Lack of Movement – Adhesion

- **Friction**: A particle can get caught on a rough surface where the movement forces are not strong enough to dislodge it. This mechanism, along with electrostatic adhesion, is the basis for most types of filtration.
Electrostatic Attraction & ESD

- Virtually all materials can become charged. The level of the charge is affected by material type, speed of contact and separation, humidity as well as other factors.

- As Electrostatic Attraction (ESA) increases, it also increases the rate of particle deposition on the surfaces we are trying to keep particle free.

- If the charge is not reduced/eliminated, Electrostatic Discharge (ESD) can occur creating catastrophic or latent failures in electronic components.
Electrostatic Attraction & ESD

• Management strategies for ESA/ESD include providing ground paths for the charge, such as wrist straps, specialized flooring and work surfaces for conductive materials.

• For plastics and other insulators, ionization is used to neutralize charges on this type of material. The ionization process generates negative and positive ions that are attracted to the surface of the charged object, neutralizing the charge.

• A good particle control program works closely with efforts to control ESA and ESD.
Controlling Particle Contamination

• There are four ways to control particles:
  • Eliminate existing particles in the manufacturing environment
  • Prevent or restrict the importation of new particles into the process environment
  • Prevent the generation of new particles by the manufacturing process
  • Limiting the movement of what is left
• But “you can not fight what you can not see and measure” so this created the need for particle counter instrumentation!
Particle Counters and the Principles of Light Scattering

- Laser Diode
- Mirror
- Detector
- Particle
- Light Trap
Particle Sizing

The larger the particle, the larger the corresponding output pulse from the sensor.
Theory of Operation

There are three basic elements in all particle counting systems:

1) **The sensor**
   The sensor is the device that detects particles using a light scattering method of detection.

2) **The sample delivery system**
   The sample is delivered to the sensor by the use of a vacuum pump.

3) **The counting electronics**
   The particle counts are processed and displayed by “on board” circuitry or in software in Facility Monitoring Systems (FMS).
Challenges: Sensor Resolution

Causes of poor resolution:

**Contamination.** A buildup of particles in the sensor can disturb the light path.

**Misaligned sensor.** A misaligned sensor must be returned to the factory for alignment.

**Failing laser diode.** This sensor must also be returned to the factory for diode replacement.
Challenges : Shape and Shininess

- **Shape**:
  - All Particle counters are calibrated using smooth, spherical (round) latex test particles, yet real world particles come in many shapes.
  - The shape and orientation of the particle as it passes the viewing area effects how it is sized.

- **Shininess (Albedo)**:
  - Some particles are more reflective than others. If it is highly reflective (bright) it will create a larger pulse, if it is non-reflective (dark) it will “trick” the particle counter into thinking a smaller particle has passed through the laser.
Challenges: Coincidence Errors

Coincidence Loss Inside a Sensor

- Coincidental Loss
- Aggregation
- Single Particle
Challenges: Effects of flow on sizing

The amplitude of the sensor output is a function of the particle’s residence time in the view volume.

1.0 cfm flow rate

0.5µ particle

= Optimum flow

1.2 cfm flow rate

0.5µ particle

= Flow is too high. The particle appears smaller than it actually is

0.8 cfm flow rate

0.5µ particle

= Flow is too low. The particle appears larger than it actually is.
Trends and ISO Standards -

HDD Industry

- Particle contamination continues to be a leading cause and predictor of drive failures
- Cleanroom monitoring, while still important, is being deemphasized, while mini-environment and in-process testing is growing in importance
- Movement from LMR to PMR triggered many changes that are still rippling through the contamination control groups
- Transition from 0.3um to 0.2um “remote particle counters” is gaining momentum, with increased R&D interest in “high end” 0.1um counters
- Next generation of heads/media will drive the focus to even smaller particles… From a recent Hitachi news release, “… current drive heads can read media where the tracks are 70 nanometers apart. The CPP-GMR heads will be capable of reading media where the tracks are 50 nanometers apart or smaller. Fifty nanometer tracks hit in 2009, and 30 nanometer tracks are expected to hit in 2011.“
- Increased desire for more open and flexible FMS solutions
Trends and ISO Standards -

Semiconductor Industry

• Particle contamination continues to be a leading challenge to yields in semiconductor manufacturing
• Cleanroom monitoring is being deemphasized, while mini-environment, in-process and/or tool specific testing is growing in importance
• 0.2um “remote particle counters” are standard. Major customers are asking for 0.1um or smaller remotes NOW!
• Open FMS systems that interface or are incorporated into larger scale (SCADA) packages and manufacturing/tool control software
• New chip designs will increase the need for new contamination control strategies for even smaller particles
Trends and ISO Standards -

ISO Standards –

- **ISO 14644** for Cleanroom Monitoring/Compliance Testing, is well established.
- Customers up and down the supply chain are looking to this standard to insure good control processes are in place, monitoring is on-going and periodically independently audited.

- **ISO 21501–4** is a new standard that will bring some much needed consistency and technical rigor, to calibration procedures and verification methods for Particle Counters.
References/Credits -

• How Particle Counters Work – John Moir, Training Mgr. – Hach Ultra Analytics
• Principles of ESD Control – ESD Association – Compliance Engineering
• Controlling Electrostatic Attraction of Particles in Production Equipment – Arnold Steinman – Ion Systems
• Basic Guide to Particle Counting – Particle Measuring Systems
• Definitions - Wikipedia
• ISO14644 and ISO21501-4 – International Organizations for Standardization – Geneva Switzerland