**Continuous Measurement vs. Periodic Sampling**
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Traditional methods of measuring the large particle counts (LPC) in CMP slurry rely on the dilution of a small sample to reduce the number of particles passing through an optical sensor at any one moment to a manageable level. To maintain reasonable productivity, a slurry sample < 1 ml is diluted between 10x and 10,000x, and a portion of the diluted mixture is measured to represent the bulk slurry particle size distribution (PSD). In production systems, samples can be drawn automatically 6 times per hour. Drawing the sample requires less than 1 minute each time, resulting in an absence of slurry monitoring during most of the operating day. In contrast, the SlurryScope continuously measures 15 ml/min of undiluted slurry that can be returned to the supply stream after measurement.

Periodic sampling of CMP slurry in a production environment provides a basis for process engineers to determine what actions may be required to keep the slurry system operating within specifications. This periodic sampling is particularly effective for detecting persistent LPC characteristics that affect the entire volume of slurry in the fab system. The complexities of fab operations infrastructure and slurry distribution systems provide a myriad of opportunities for sporadic events to affect a volume of slurry that can flow through the system for some time as a plug before it disperses throughout the system volume. Such sporadic events may not be effectively captured by periodic monitoring, as illustrated in the chart below. This kind of behavior has been observed in fab slurry distribution systems during online testing of the SlurryScope.

![Chart illustrating continuous and periodic sampling](chart.png)
The sampling period may or may not coincide with the occurrence of an LPC excursion. In the event that a single sampling period would capture such an excursion, it is likely that the relatively consistent data both before and after the excursion would favor a conclusion that the high data point was a measurement anomaly rather than an accurate depiction of a real fab event. The opportunity for such an event to trigger a corrective action investigation to prevent further occurrences would be lost. Furthermore, it would be difficult to correlate any sporadic scratch defects on production wafers during this time period with a specific slurry LPC excursion. It would also be difficult to identify the root cause activity in the fab that caused the LPC excursion in the first place. The root cause may be a one-time event, or it may be a routine activity in the fab that is not recognized as possibly causing LPC excursions.

With continuous monitoring over an extended period of time, it would be possible to identify patterns in LPC point excursions that correlate to events taking place in the slurry distribution system. Any event that causes an increase in large particles is an event that needs to be eliminated or severely restricted, as each represents an increased risk for wafer scratching. If only periodic slurry sampling is available, the opportunity to identify and correct these potential sources of scratching is lost.

In addition to isolated LPC excursion events, the routine operation of a fab slurry distribution system (SDS) lends itself to periodic and recurring shifts in LPC data. Typical practices that can result in LPC shifts include:

- Slurry supply replenishment
- Slurry lot changes
- Filter changes
- Pump changes
- Maintenance of SDS slurry metrology sensors
- DI water system maintenance
- Shut down, cleaning and requalification of one polishing tool attached to the SDS
- SDS stop and restart

In addition to routine intentional events, there are unplanned and unintentional events that can result in both sporadic and systematic LPC shifts. Examples of such events include:

- Improperly seated filter
- Damaged filter
- Damaged pump diaphragm
- Turning valves in the SDS, especially those used infrequently
- Partially turned valve causing high shear turbulence and agglomeration
- Mechanical bumping of SDS pipes, especially in dead legs
- Changes in ambient temperature

The figure below illustrates cyclic movement in LPC data as observed by the Vantage SlurryScope in a sub-fab installation. In this example, the LPC excursions are occurring at intervals of 7-8 minutes, which may or may not coincide with the slurry sampling period of a dilution sensor. It is more likely that the periods will not match, resulting in discrete measurements by the dilution sensor that will vary between two extremes without
any obvious pattern. It is only with continuous monitoring that the cyclic nature of the LPC can be observed and used to identify the root cause.

In working with a variety of production facilities, Vantage has observed alternating cycles lasting four hours at each LPC level, over a period of days (data not shown here). This behavior was traced to a faulty slurry pump that was rotated into SDS operation at regular intervals. Diagnosing and resolving this problem would have been much more difficult without the continuous LPC data that provided a complete picture of the SDS behavior. In comparison to the limited amount of data available to a fab engineer using prior techniques, the SlurryScope provides an abundant resource for monitoring isolated LPC excursions, periodic cycles in LPC counts, and steady trends in baseline LPC counts over time. Because this amount of information had not been available previously, there is no established protocol for responding to SlurryScope data in a fab environment. This is, however, not entirely different from the situation in which periodic slurry particle monitoring was first introduced in the industry. While continuing to monitor slurry particles with existing methods, each fab engineer will need to monitor the SlurryScope data in his facility for some period of time until cause-and-effect correlations to LPC shifts are recognized and understood. To some extent, this learning curve will need to include monitoring the defect levels on production wafers to determine which LPC events are likely to result in polishing defects and potential yield loss. As the cause-and-effect relationships
driving LPC behavior become well understood, the performance of the slurry system will stabilize at the level required for high productivity and low slurry-related defect levels.