Increase manufacturing quality with reliable liquid flow measurement

Reliable liquid flow measurement plays an important role in semiconductor process management. Flow meters can effectively monitor wet processes to ensure a constant flow of the liquid or manage volume dispensing at the points of use. By implementing an accurate and reliable flow measurement, fabs can significantly improve their process quality.

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REPRODUCIBILITY and maintaining strict quality control throughout the entire wafer manufacturing process are top priorities in the semiconductor industry. Thus, stable and highly accurate flow measurement is essential for many semiconductor manufacturing steps. Non-contact clamp-on flow meters have proven to fulfill this demanding task reliably. The ultrasonic sensors measure through the wall of the tube or pipe and substantially reduce the risk of contamination or leakage of hazardous fluids. With the SEMIFLOW flow meter series, the ultrasound specialist SONOTEC has developed metal-free contactless flow meters particularly designed for the requirements in the semiconductor industry – also for hazardous environments. The compact sensors with integrated electronics board are available in multiple sizes suitable for all common rigid plastic tubes and pipes used in fabs. In order to guarantee continuous high product quality, a tight liquid flow monitoring is necessary.

From liquid storage containers to the application in the process, the liquid flow must be monitored and tracked, e.g., to measure the volume flow in a transfer line or to control the volume output at the points of use. Ultrasonic flow meters can be implemented in low- and high-volume manufacturing settings and used reliably regardless of the type or blending of the chemicals in the tube.

Reliable monitoring of slurry consumption in CMP

Chemical-mechanical planarization or polishing (CMP) is one of the leading technologies to manufacture state-of-the-art microelectronic components and micro-electro-mechanical systems (MEMS). In order to produce modern integrated circuits with multiple wiring levels and smallest line widths, highly precise flat and smooth surfaces are needed. CMP processes have become also very important in the finishing of wafer-thinning

processes and the production of vertical contacts through the silicon wafer. Since the industry is persistently looking for further ways to reduce the structure width, the requirements in process design are becoming more detailed and stringent. Hence, CMP processes are getting more complex and quality standards grow constantly. As a consequence, process parameters have to be monitored very closely at various steps to avoid deviations in product quality that might lead to costly failures.

In CMP processes, flow meters accurately monitor the dispensing of slurry on the polishing plate. Additionally, they are installed to count the volume flow to calculate the amount of slurry used at this process step. Flow sensors also monitor precisely the consumption of slurry in supply tanks or in the pipe system to determine the transfer volume. Every fab uses its own slurry blending. Non-contact flow meters are well-suited for contamination-free flow or volume measurement of liquids, work independently of the slurry composition and are free of wear and tear.

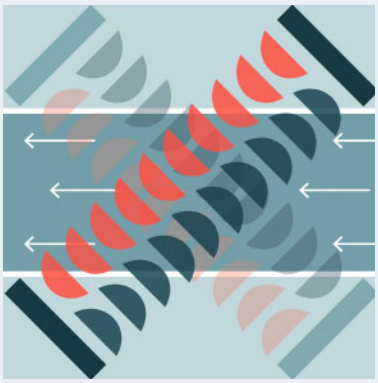
Efficient slurry blending and dispensing at each point of use

Large semiconductor manufacturing sites commonly implement slurry mixing and blending systems to ensure optimal slurry concentration for the specific process requirements. For the slurry preparation, the different components are mixed with DI-water. With regard to achieve exactly the predefined slurry concentration at the point of use, highly accurate flow meters monitor the volume flow rate of the components from buffer tanks to the mixing container. This real-time control with contactless flow sensors ensures proper blending of the chemicals at high production rates and specific mixing ratios.

Automatic slurry dispense platforms guarantee an efficient slurry distribution during continuous operations in CMP manufacturing environments. In order to have a redundant system monitoring, non-contact flow meters are installed in addition to each distribution pump to make sure that the defined product quality remains constantly at the same high level. Contactless ultrasound flow measurement guarantees that the slurry or chemical in the pipe or tube is not contaminated or influenced by the measurement device. Additionally, the flow sensor can conveniently be replaced or moved to another position without having to intervene in the closed pipe system.

By monitoring the slurry composition and concentration with automatic dosing and blend correction throughout the entire pipe system, precise metrology options are used. Via additional tank or mixing stations in the fab, blend corrections can be processed. For this step, highly accurate and reliable flow meters control the related pumps. Thus, the exact slurry blending can be ensured and efficiently used. Additionally, flow meters guarantee both system and component redundancy throughout the entire wafer manufacturing process.

Engineering Principle of Ultrasonic Flow Meters



Ultrasonic transducers are the heart of any ultrasonic flow sensor. They consist of piezoelectric ceramics or composites that expand or contract when a DC voltage is applied, depending on the sign of the voltage (inverse piezoelectric effect). By applying an alternating voltage, the piezoelectric expands and contracts periodically and emits a sound wave corresponding to the excitation frequency. This sound wave is sent out as a pulsating ultrasonic beam from an excitation transducer and is detected by a receiving transducer. The signal is evaluated electronically and output via various signal outputs (digital + analog).

Transit-Time Technology

There are different ways how ultrasonic signals can be utilized to calculate flow rates. SONOTEC's SEMIFLOW sensors work on the basis of transit-time technology.

With this method, the transit-times with and against the flow direction of a medium are measured with high precision by time-to-digital converters. In the direction of flow, the transit-time of an ultrasonic wave is shorter than against the flow. The time difference combined with geometrical information of the tubing allows to determine the flow rate and volume. This method causes neither a pressure drop in the tube nor a risk of leaks, as it can be applied in a completely non-invasive and non-intrusive manner. When appropriately calibrated, transit-time can work on almost all liquids, independent of viscosity, density, color or electromagnetic properties of the fluids. Ions and particulate matter are not required to calculate the measurement. Additionally, the contactless measurement method does not cause any wear or tear for the sensor. Thus, the clamp-on ultrasonic sensors are maintenance-free.

In large manufacturing facilities, transfer pumps control the slurry supply via fab-wide loop pipe systems. For redundancy reasons, implemented clamp-on flow sensors monitor the liquid flow or volume in the pipe system.

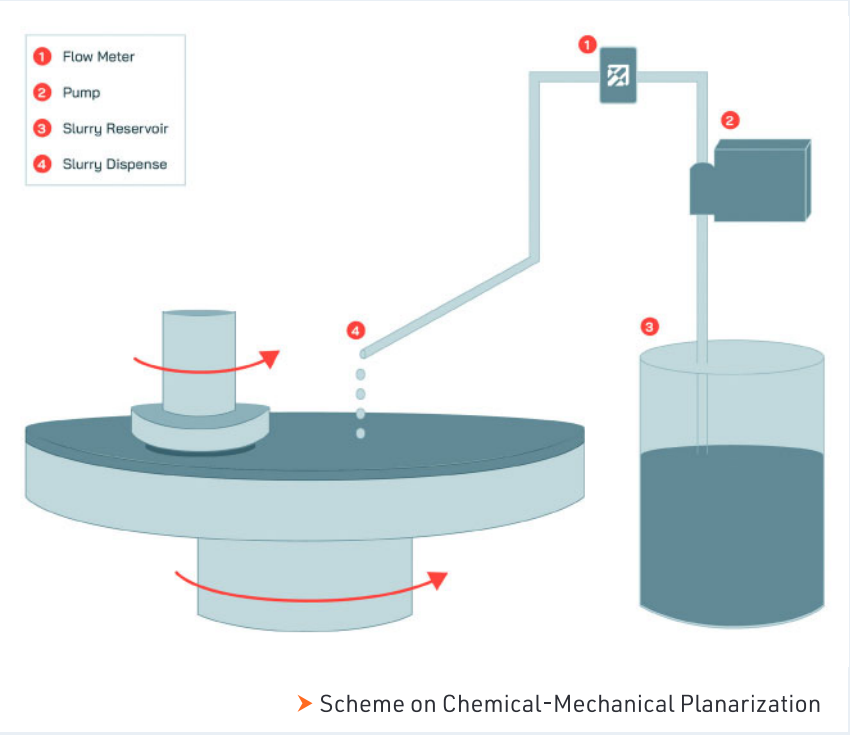
Precise distribution of photoresist in lithography applications

In semiconductor manufacturing, the process of photolithography describes the processing of circuit board designs on silicon wafers by means of light. The process starts with coating the wafer with a chemical layer called photoresist. The layer of the photoresist must be extremely precise. For the exact volume dosing of these photoresist layers, highly accurate flow meters are implemented to redundantly monitor the pump behavior. By implementing non-contact ultrasonic air bubble detectors from SONOTEC, even smallest air bubbles can be detected that might occur in the coating

Fundamentals on Chemical-Mechanical Polishing / Planarization (CMP)

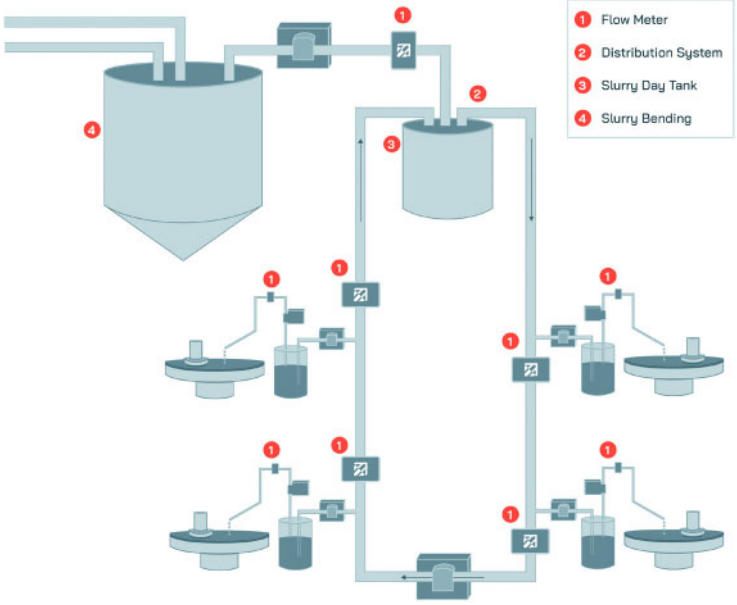
CMP is a key technology in any semiconductor fabrication. It is applied in both, substrate as well as device fabrication. Advanced semiconductor devices easily need more than 30 CMP processes to get to its final stage. CMP aims on perfect smooth surfaces with almost no remaining topography.

To that, the wafer surface is polished using a slurry and a polish pad. Slurry describes a chemical fluid that contains abrasive nanoparticles dispersed in acidic or basic solution. During the CMP process step the wafer is pressed on the rotating polish pad, while slurry is continuously dispensed. Specifically, the slurry chemically modifies the uppermost surface layer, which is then mechanically cracked and removed by slurry abrasives.



Scheme on Chemical-Mechanical Planarization

process. In a further step, light passes through a photomask and creates an optical image of the circuit layout on the wafer. The generated light reacts with the photoresist which is washed away in the next process step. Thus, the underlying oxide layer is exposed. By using certain acid baths, further oxide and residues of the underlying silicon layer are removed. As the acid baths have to be kept with an even filling level, non-contact flow meters precisely monitor the filling of the wet benches. Thanks to the non-contact measurement method it is not necessary to replace the sensor after cleaning procedures or servicing. The described process is repeated several times with different combinations of chemicals and masks, building up the layout structure of the later processor. Finally, the doping process is applied to the exposed silicon, changing its electrical properties. Current photolithography processes often include around 30 or more separate masks to layer circuit patterns on top of each other.



Scheme on Slurry Management and Distribution

Increasing manufacturing effectiveness and yield with fab-wide liquid transport management

Considering the efforts and costs of recently planned and established new fabs, it is crucial to implement and maintain efficient operations, keep equipment uptime as high as possible, and optimize the yield of high-quality products. Installing highly accurate and reliable flow meters for liquid process management as part of a tight production control system improves manufacturing efficiency, reduces manufacturing costs, and avoids downtime in the production cycle.

Latest sensor technology offers real-time data that gives feedback for real-time control systems to reduce cycle-time and improve yield. Independent from flow range and flow volume, SONOTEC offers a broad portfolio of compact ultrasonic flow meters and air bubble detectors suitable for various tube and pipe sizes to enable a fab-wide flow control system – also in hazardous environments.

The non-contact flow sensors operate cost-efficiently and reliably in low volume or bulk chemical distribution systems. Subsequently, highly reliable continuous chemical fab supply chains can be established to increase efficiency and yield.