Use of electroplated copper for on-chip metallization in ultra-large-scale integrated circuits (ULSI) devices is gaining momentum because of the low cost and high throughput of the process. Electroplated lines and trenches with submicron dimensions, however, are strongly affected by changes in the composition of the plating solution, thereby creating a high demand for control techniques. The most dynamic ingredients of electroplating solutions are organic additives. Even a small imbalance between components of the additive system can cause various defects in the filling of the trenches and properties of electroplated copper. On-line monitoring and control of these additive components is therefore desirable. Cyclic voltammetric stripping (CVS) analysis has long been used for just such a purpose in the manufacturing of printed circuits.

Numerous chemical and electrochemical processes (i.e. thermal decomposition, cathodic reduction, occlusion in the deposit, anodic oxidation, drag-out) contribute to additive consumption, as does time-dependent chemical decomposition in the bulk solution. Additive dosing is often done based on time or amp.
redesign of the proprietary on-line acid copper bath controller* to meet the particular requirements of the semiconductor industry (Fig. 4). The unit, supported by all major additive suppliers, samples up to four plating tanks and standard solutions. It incorporates analysis for brightener, leveler, carrier and contamination level, and it replenishes the plating solutions as needed. The accuracy and reproducibility of on-line analysis are significantly better than lab instruments because the on-line unit includes temperature control, automatic calibration, reproducible conditioning and it eliminates human variations.

Table 1 summarizes results of on-line analysis of several Damascene plating solutions at high, middle and low levels of additive specifications. Results indicate very good accuracy and reproducibility of analysis for all components. Figure 5 illustrates the history of one plating solution followed for 160 measurements. Before measurements #79 and #130, the customer performed carbon treatment procedures.

In both cases, treatment effectively removed brightener, but left intact most parts of carrier the component.

**Early Warning**

Under ideal conditions, Damascene plating is performed at steady-state conditions, and readings in production solution are almost as stable as in standard solution. However, an on-line analyzer provides an early indication of process malfunctioning—e.g., dosing pump failure (Fig. 6).

To test response of CVS to changes of additive levels, a series of additive spikes to a production solution was performed and measured. Figure 7 shows the results obtained for these spikes. Because of the extremely high cost of wafers, a significant amount of work is being performed to correlate CVS results to the performance of the plating baths with different levels of additives and inorganic components.

Although organic additives present the main challenge in controlling plating solution, one needs to monitor inorganic components as well. Therefore, a new generation of CVS units is capable of monitoring both organic and inorganic components (copper, acid and chloride). All components are analyzed by potentiometric titration using proprietary procedures.

Table 2 summarizes the results of analysis for standard solution.

At the preparation time of this paper, the analyzer was tested at 10 facilities for an overall period of seven years, including four facilities performing Damascene plating for a 12-month period. Testing included several 5,000-wafer marathons. Use of the analyzer allowed manufacturers to keep the process in a very tight window, resulting in a high yield of wafers. Results of the analyzer are in excellent correlation with results of bench-top analyzers. Results of long-term testing of the analyzer at customer facilities are now available.

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