Electrochemical Etching of Gold Using a Novel Cyanide- and Thiourea-Free Solution for IC Applications

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Due to its unique chemical, physical, and electrical properties, as well as its superior radio-frequency performance, gold has been the metal of choice for interconnect metallization in compound semiconductor devices targeted for high frequency and high power applications. Gold metallization is generally realized through electrochemical deposition using either cyanide-based or sulfite-based electrolytes.[1-2] As opposed to copper interconnects that are currently mainly formed using a damascene process, gold interconnects are primarily formed using through-mask plating. Following electrochemical deposition, a gold seed layer has to be removed to form electrically functional interconnects.

The removal of gold seed layer can be achieved using reactive ion etching, wet etching (chemical etching), or electrochemical etching (deplating or reverse plating). While reactive ion etching of gold has been demonstrated to be an alternative [3], wet etching and electrochemical etching are considered to be the standard techniques. In wet etching gold is chemically removed, with either iodine-iodide solution or cyanide-based solution. For microelectronics applications, electrochemical etching is generally preferred over chemical etching that usually causes pronounced undercutting, marked surface roughening, and excessive loss of deposited metal. Electrochemical etching of gold has been primarily performed using thiourea-based solutions. However, thiourea is a suspected carcinogen. There are health and environmental concerns regarding its continuous use. In this paper, we report our effort on the development of electrochemical etching of gold without using cyanide and thiourea to address this challenge.

Experimentally, the electrochemical behavior of gold dissolution was studied in a three-electrode electro-chemical cell consisting of a gold-deposited platinum rotating disc electrode, a saturated calomel electrode, and a platinized titanium electrode. Electrochemical etching of gold from diced wafer pieces was performed using a modified rotating disc electrode assembly that grips and electrically contacts the specimen, whereas electro-chemical etching of gold from whole wafers was carried out on Semitool's plating/deplating tool. Several different etch solutions, along with other process conditions, were considered and evaluated in this study. In particular, it was found that the etch solution composed of iodide salt and a sacrificial stabilizer as well as a pH buffer and a surface-active agent yielded satisfactory results.

In the thiourea-free electrochemical etching solution, iodide is the active component that forms complex with gold ion and thus makes gold electrolytically oxidizable in aqueous solution. Since iodide is both chemically and electrochemically oxidizable, the use of a stabilizer is required to make the etch solution stable enough for practical applications. As a result of side anodic reactions, the current efficiency of electrochemical etching of gold with the iodide-based solution is lower than the theoretical value, and the current efficiency depends on the current density used. This current-efficiency variation is similar to the etch process using a thiourea-based solution and can be addressed by process condition control and/or end-point detection. Shown in Figure 1 is the plot of electrode potential against galvanostatic etching time for the removal of a 500 Å gold seed layer. As can be seen from this figure, the potential increase before the conclusion of the etching can be used to detect the endpoint of the process.

Presented in Figure 2 are SEM micrographs showing gold seed layer prior to etching and the removal of the seed layer following the etching with the thiourea-free solution. Comparative testing results show that the line resistance of gold feature and the current leakage between adjacent gold features on wafers processed using the novel thiourea-free etching solution are equal to or superior to those obtained using thiourea-based etching solution. In this paper, the results obtained with other etching solutions such as hydrochloric acid-based solution will also be presented and discussed.

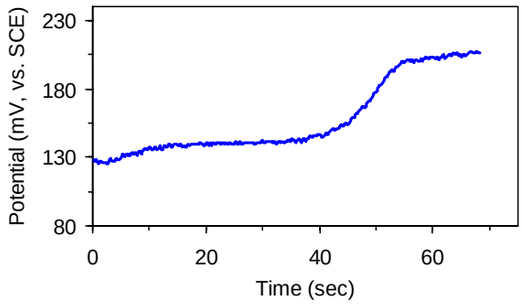

Figure 1. Electrode potential as a function of galvanostatic etching time

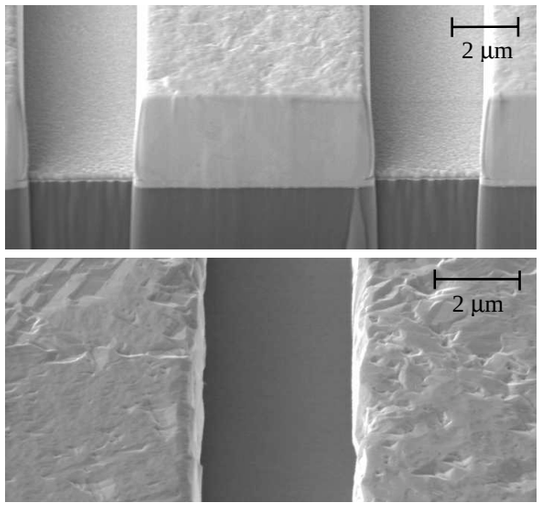

Figure 2. SEM micrographs taken (top) prior to gold seed layer etching and (bottom) after seed layer removal.

References:

1) R. Williams, *Modern GaAs Processing Methods,* Ch.15, Artech House, Boston, 1990.
2) P.A. Kohl, "Electrodeposition of Gold" in *Modern Electroplating*, 4th edition, M. Schlesinger and M. Paunovic ed., John Willey & Sons, New York, 2000.
3) P. Werbaneth, T. Lester, J, Pakulska, *Micro Magazine*, **21**(6), 47 (2003).