Using the Lehighton Contactless Probe System for Metallization Applications

Introduction

One of the biggest problems in controlling metallization processes is that most measurement techniques are destructive. Product wafers cannot be measured directly using these destructive techniques. One way around this to use a Contactless Eddy Current Probe such as the Lehighton System. While the thickness cannot be directly measured using this system, the bulk resistivity of sputtered material remains constant enough to allow the use of a sheet resistance measurement to infer thickness. Once the correlation between actual thickness and sheet resistance is established, the Eddy Current Probe can be used for online control of the metallization process. Since this measurement can be made directly on product wafers by operators immediately after metallization, SPC techniques may be used to feedback information to control metallization equipment.

There are two problems using Eddy Probe that can be overcome with proper planning and the use of SPC. The first problem is that Eddy Current Probing measures the resistivity of the entire thickness of substrate as well as the metallization layer of interest. Secondly, the topography of the structures on wafers influences the sheet resistance of the metal layer. A smooth wafer will have a lower sheet resistance than a wafer with dense topography for the same mass of metal deposited. This difference is predictable for different densities of topography, depending on the tortuosity of the electron path in the metal layer.

The common method for characterizing metal thickness is to use a patterned metal layer measured by a stylus profilometer. Using this for online control can be difficult because measurement occurs several steps after metallization in the process. Also this method requires highly skilled personnel for doing the measurements and interpreting the results. Finally, it is a time consuming measurement where only a limited number of points may be easily measured. It is necessary to obtain the physical thickness of the metal layer using a stylus probe, but it is not necessary to use the stylus probe as the primary feedback for SPC on metallization equipment. Once the relationship between sheet resistance and physical thickness has been established and maintained, the Lehighton Probe is much better for online

208 Memorial Drive PO. Box 328 | Lehighton, PA 18235-0328
TELEPHONE (610) 377-5990 | (800) 535-1112 FAX (610) 377-6820
lei@lehighton.com | http://www.lehighton.com

control of the metallization process because of its mapping capability, speed of measurement, and ease to use.

Method

As sputtering targets erode, the sputtering time or sputtering power must be adjusted to compensate. Also the uniformity of deposition may change. This particularly is true for systems that utilize multi-piece targets since the different pieces erode at different rates. It is critical to have effective control over these processes to anticipate the adjustments needed to keep the process in control. Used in conjunction with a periodic stylus profilometer or SEM measurement. Eddy Current measurements on product wafers can provide immediate online feedback.

The basis of using the Eddy Current Probe is to calculate a bulk resistivity value by correlating sheet resistance and physical thickness. It is common practice to calculate a bulk resistivity by comparing sheet resistance of metal on test wafers with physical thickness measured after patterning the test wafers. As mentioned before, product wafers will have different sheet resistance values for the same mass of metal deposited. An apparent bulk resistivity value can be calculated by measuring sheet resistance on product wafers versus physical thickness in the same manner as for test wafers. Different product families will have different apparent bulk resistivities based on the topography of the circuits. Figure 1 shows the relationship of apparent bulk resistivity to circuit density for four different hypothetical product families. The circuits that have larger core areas, such as DRAMs, will have higher apparent bulk resistivity values because a larger fraction of the total area is densely packed.

Bulk resistivity is calculated using the following relationship:

$$\rho_b\ (\mu\Omega\text{-cm}) = R_s\ (\Omega/\text{sq.})\ * t(\mu m) * 100$$

Where ρ_b is bulk resistivity, Rs is sheet resistance and t is thickness

In practice, the actual bulk resistivity of the metal changes very little as targets wear. Also the relationship of the apparent bulk resistivity from product family to product family tends to remain constant as well. If the substrate wafer is greater than 10 Ω-cm the contribution of the wafer to the total resistivity is minor. Therefore, these values, once established, can be used to

208 Memorial Drive PO. Box 328 | Lehighton, PA 18235-0328
TELEPHONE (610) 377-5990 | (800) 535-1112 FAX (610) 377-6820
lei@lehighton.com | http://www.lehighton.com

normalize the sheet resistance values that are obtained from the Eddy Current Probe and thus can be used for SPC.

For online SPC, the following is an example of a suggested procedure that may be followed:

1. Measure the physical thickness once per week or after target change for each sputter machine. Use stylus profilometer on patterned test wafer and compare to the thickness value obtained from weekly SEM step coverage monitor.
2. Calculate bulk resistivity from physical thickness and sheet resistance. This bulk resistivity shall be charted. If the value is out of control, then bulk resistivity values may need to be adjusted or sputter equipment may need maintenance.
3. Operators shall measure one wafer from each cassette run through metal deposition on the Lehighton System.
4. The operator shall enter the product type in the program. The program will calculate the thickness mean and sigma by using the previously obtained apparent bulk resistivity values for each product types. Only representative high volume products are measured.
5. The system outputs a thickness value calculated as follows:
   $T\ (um) = \rho_b(u\Omega\text{-}cm)/(R_s*100)$
6. Plot thickness mean and within wafer sigma on control charts. Take action based on control charts.
7. Update apparent bulk resistivity values on a periodic basis.

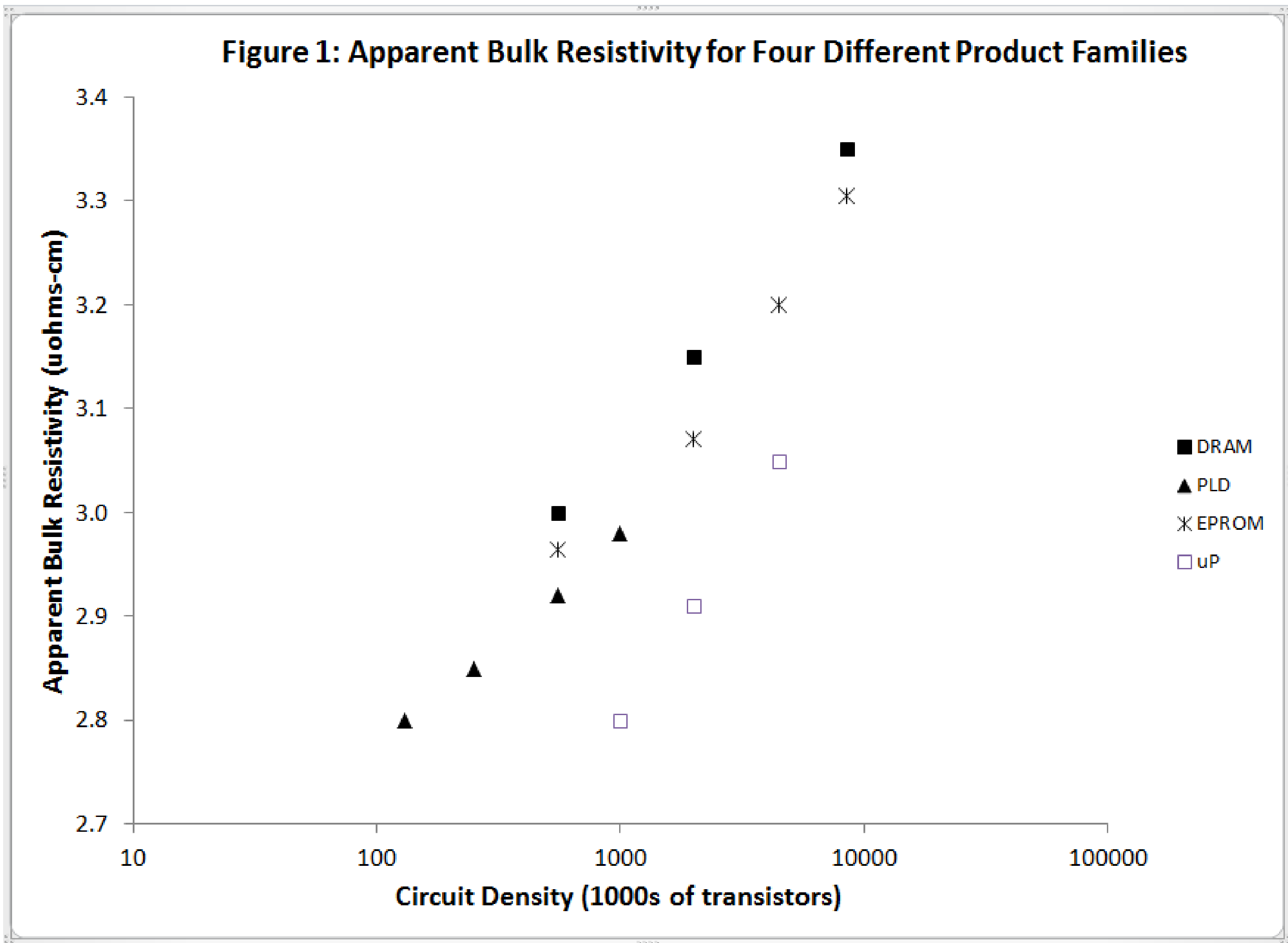
Discussion

The Lehighton Eddy Current Probe software can be used to make this conversion by product type, so that operators online can generate their own control charts. A control chart of thickness can be used to provide feedback for sputter time or sputter power adjustments as the target wears. A control chart of within wafer uniformity can be used to change power ratios, assess target wear and determine when a target change may be needed. Traditionally these determinations have been made by engineering personnel. Effective use of SPC and the Lehighton system can allow operators to make these adjustments themselves. Bulk resistivity therefore only needs to be recalculated on a periodic basis using a stylus profilometer for SEM,

208 Memorial Drive PO. Box 328 | Lehighton, PA 18235-0328
TELEPHONE (610) 377-5990 | (800) 535-1112 FAX (610) 377-6820
lei@lehighton.com | http://www.lehighton.com

instead of using these physical thickness measurements for direct control of the metal deposition process.

The mapping capability of the Lehighton can be used to discern subtle changes in deposition uniformity. These maps are useful for understanding the way targets wear. Also, they may be used for problem solving purposes. Competing Eddy Current Probes will measure only up to nine sites, which is not enough to discern these subtle patterns. The Lehighton Probe can plot up to hundreds of sites in a short amount of time. Stylus profilometers or SEM measurements of physical thickness take far too long to measure more than a few sites per wafer. Therefore the Lehighton Probe is a superior instrument for understanding process sensitivities and problem solving as well as process control.



208 Memorial Drive PO. Box 328 | Lehighton, PA 18235-0328
TELEPHONE (610) 377-5990 | (800) 535-1112 FAX (610) 377-6820
lei@lehighton.com | http://www.lehighton.com