EXHIBIT AC

MATERIALS PVD UPDATE

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In This Issue

Source

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Applied Materials has developed a new source for deposition of Ti and TiN films in sub-half micron features, the Vectra IMP source. It relies on a new metallization technology, Ion Metal Plasma (IMP), to overcome traditional limitations of PVD sources. Exceptional results are possible with this new technology. Up to 70% bottom coverage is achieved on sub-quarter micron structures with aspect ratios as great as 8:1 (cover photo). Because the bottom coverage is so high, thinner deposited barrier or liner layers achieve the same or better device results compared to thicker films deposited by collimation or long throw techniques. And the Vectra IMP source achieves exceptional bottom coverage without the high cost associated with collimated or long throw PVD.

Deposition Dynamics

In PVD, step coverage is governed by the angular distribution of material arriving at the wafer surface. A "tighter" angular distribution (more material arriving at near normal incidence) leads to better bottom coverage. To alter the angular distribution using traditional PVD techniques, it is necessary to physically filter the flux of sputtered metal atoms. This is usually done by inserting a collimator between the target and substrate, or by increasing the target-to-wafer spacing (long throw). The disadvantage of collimation is that physical filtering of the flux dramatically reduces its volume. The largest practical aspect ratio for physical filtering is about 2:1. At larger aspect ratios, the deposition rate becomes unacceptably low and preventive maintenance (PM) increases. Physical filtering is not likely to be acceptable for vias or contacts below 0.35 µm (Fig. 1).

IMP source, a medium density pl
(10^{11} cm^{-3} < n < 10^{12} cm^{-3}) is cre
between the target and substrate. S
tered metal atoms passing through
region become ionized. A high ele
field, or self bias, develops in the b
dary layer separating the plasma fro
substrate (the sheath). This self
accelerates the metal ions in a ve
normal to the substrate. The plasr
maintained by inductively coup
energy from an RF generator int
plasma (Fig. 2). The self bias that d
ops between the plasma and the sub
can be optionally modulated by ap
ing independent AC bias powe
the substrate.

The probability of sputtered r
atoms ionizing depends on their

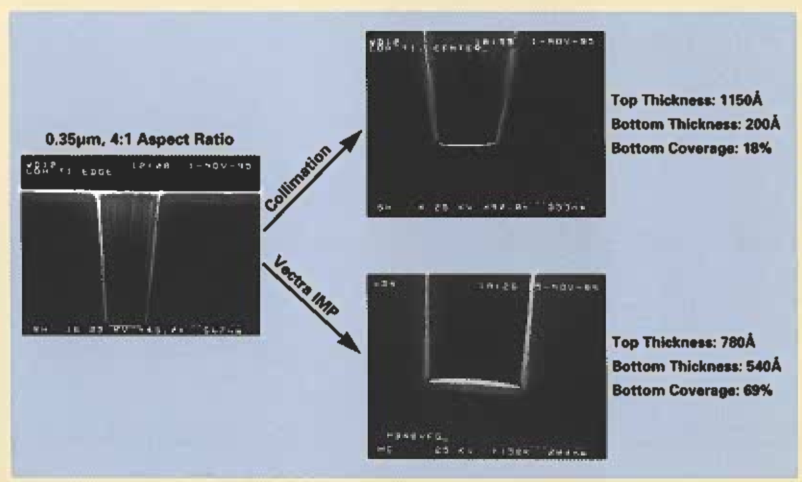

Fig. 1: I Ti/TiN e superior bottom coverag less fiel depositi compar collimat PVD

dence time in the plasma. Longer residence times lead to a higher ionization probability. Sputtered atoms are ejected from the target with relatively high energies (~1 to 10eV). These fast atoms have very short residence times. Operating the source at relatively high pressure slows down the metal atoms because the number of collisions between the sputtered metal atoms and the background gas increases. Longer residence time increases the probability of metal atom

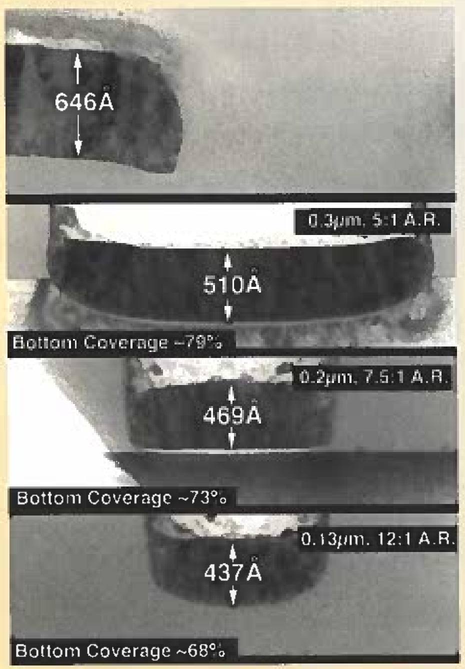

Fig. 3: Contact width does not substantially affect the amount of material deposited at the bottom of the contact, making IMP technology highly scalable for different device geometries

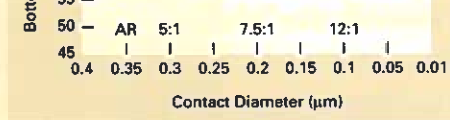

Fig. 4: Bottom step coverage for IMP TiN as function of contact diameter and aspect ratio (AR) for contacts of Fig. 3, IMP technology can be extrapolated to sub-0.1 μm applications

ionization. Excellent bottom coverage results are obtained only if the Vectra IMP source is run at pressures greater than 10 mTorr—pressures much greater than normally encountered in traditional PVD.

With Vectra IMP technology, the bottom coverage characteristic of the film is not substantially affected by contact width, making the process highly scalable to different device geometries (Fig. 3). Extrapolating the bottom coverage performance shown in Figure 3 indicates that Vectra IMP technology can

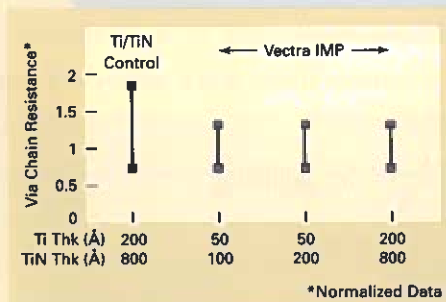

Fig. 5: IMP Ti and TiN barrier/liner films exhibit tightly distributed, low contact resistance, even for extremely thin films in a comparison performed on W plugs

have been completed that compare the barrier/liner performance of IMP Ti and TiN films with collimated films. In one study, W plug chains were deposited with 200Å Ti/800Å TiN by conventional PVD and with varying thickness layers of IMP Ti/TiN to as thin as 50Å/100Å. The plugs deposited with IMP films show lower average contact resistance and a tighter distribution than the plugs with conventional PVD (Figs. 5 and 6). IMP films exhibit more tightly distributed performance compared to conventional barriers, even as film thickness decreases, because the high bottom coverage typical of IMP films ensures that a sufficient amount of material is deposited into the bottom of the hole, reducing the requirement for

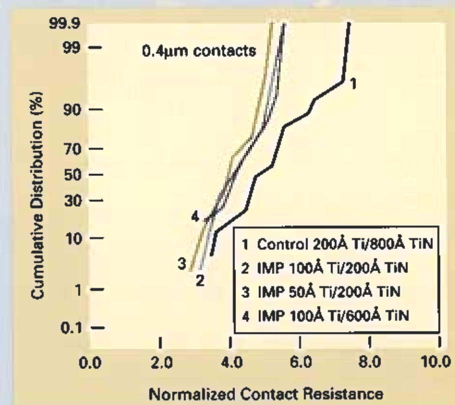

Fig. 6: Contact resistance of various thickness Vectra IMP Ti/TiN liners is compared with conventional PVD Ti/TiN for a W plug application

Fig. 7: The Vectra IMP source is designed for compatibility with widebody PVD chambers

thick overall films. Device and TEM results confirm that film coverage is continuous and conformal even though sidewall coverage can be as low as 10%. The combination of highly efficient film performance and extremely simple, easily maintained hardware make Vectra IMP barrier and liner films extremely cost effective compared to other available technologies.

The Vectra IMP chamber will be released under the Applied Materials PDP (Product Development Process).[1] Under the PDP, the Vectra Source will be thoroughly performance evaluated as a source for Ti, TiN and Ti/TiN films. The Vectra Source (Fig. 7) will be available to customers in the first calendar quarter of 1997 both on new Endura® and Centura® PVD systems and as a field upgrade to widebody chambers.

References

1. "The Product Development Process," *Applied Materials HP PVD Update*, Dec. 1995, Vol. 2, No. 4, p. 2.

aluminum alloy interconnects in advanced integrated circuits. Formation of $TiAl_3$ at the Ti/Al interface during high temperature processing influences circuit performance. In this study, sheet resistance was characterized for both Ti/Al-0.5%Cu and Ti/Al-0.5%Cu-1.0%Si bilayer films at 440°C and 480°C. The change in resistivity due to $TiAl_3$ growth was further studied for the Ti/Al-0.5%Cu-1.0%Si bilayer film at 480°C.

The rate of $TiAl_3$ formation depends on annealing temperature, time and alloy content of Cu and Si in the Al matrix. Both Cu and Si retard $TiAl_3$ formation, but Si exhibits a stronger effect than Cu.[1,2] The addition of Si increases the activation energy and reduces the Ti/Al reaction rate significantly.[3,4] At 430°C, Al-Ti interdiffusivity is reduced by an order of magnitude with the addition of 1.0%Si in the Al-0.5%Cu matrix.[2]

Experimental

Titanium films were deposited on 150 mm SiO_2 wafers (3 kW, 4 mTorr, 200°C). Al-0.5%Cu-1.0%Si and Al-0.5%Cu films were then deposited on top of the Ti films (9 kW, 2 mTorr, 175°C).

After deposition, the wafers were annealed for different durations in an empty chamber at a heater temperature

oxygen ion beam with an incident of 60° was used on both rotatin stationary samples. X-ray diffra (XRD) analysis was used to dete the phase content and grain size films. XRD was performed on the in normal incidence mode (θ/2θ glancing incidence mode (α = Transmission electron microscopy (equipped with energy dispersion trometry (EDS) was used to exami interface microstructure and che composition. TEM cross sections prepared by gluing pairs of sample to-face and then mechanically pol the samples to electron transparenc milling was used for a short durat clean the sample surfaces.

Results and Discussion

The sheet resistivity of Ti/AlCu b

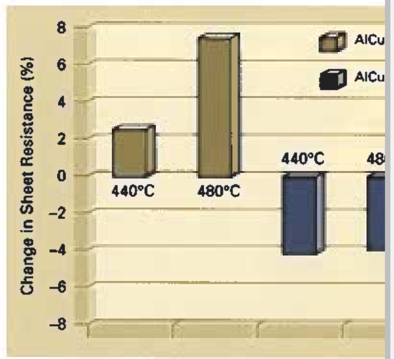

Fig. 1: Sheet resistance behavior of and AlCuSi films deposited on Ti af minutes of annealing time at 440°C 480°C