PVD of Ruthenium and Cobalt for Next-Generation Metallization

Copper has carried the signals inside microchips for many decades. As logic scaling pushes towards the 18A and 14A nodes, the narrowest interconnect lines are approaching the 10 nm scale, and copper dual-damascene metallisation is becoming harder to extend [1]. Ruthenium (Ru) and cobalt (Co) have emerged as two of the leading alternatives, and physical vapour deposition (PVD) is central to the research needed to qualify them.

This blog explains why copper struggles at the smallest dimensions, why Ru and Co are attracting so much attention, and what researchers need from a PVD source or system when developing Ru and Co thin films for advanced interconnects.

Why does copper struggle at advanced nodes?

Copper's resistivity rises sharply once interconnect dimensions fall below its electron mean free path (MFP) of roughly 39 nm. At these widths, electrons scatter far more often at surfaces and grain boundaries [2].

Copper also relies on diffusion barrier and liner layers that cannot be thinned at the same rate as the line itself. These layers take up a growing share of the trench and reduce the cross-section left for conduction [1,2]. Narrower lines also carry higher current densities, which increases the risk of electromigration: metal atoms are pushed along the line until voids form and the interconnect fails.

The leading alternatives Ruthenium and Cobalt

A recent tutorial review from IMEC names six elemental metals as promising candidates for advanced interconnect metallisation: rhodium, ruthenium and iridium from the platinum group, plus nickel, cobalt and molybdenum [1]. Cobalt has already been integrated into the local interconnects of commercial devices, and ruthenium is considered a potential barrierless replacement for copper [1].

Ruthenium's MFP of about 6.7 nm makes its resistivity much less sensitive to scaling than copper's. Its high cohesive energy also gives it inherent resistance to electromigration, and its chemical stability allows a simpler, barrierless integration scheme [2].

Reliability still depends heavily on how the film is grown. In situ transmission electron microscopy of cobalt lines stressed at around 5×10^6 A/cm² showed that line width and grain structure influenced electromigration damage more than temperature did across the 600 to 900 °C range [3]. In practice, film microstructure becomes a design parameter, and it is largely set during deposition.

How PVD conditions shape Ru and Co thin films

Recent work on magnetron-sputtered films shows how strongly Ru and Co properties

respond to the deposition process. In RF magnetron sputtered Ru films on SiO_2/Si substrates, the homogeneity of the sputtering target's microstructure directly affected deposition rate, surface roughness and crystallisation. Film resistivity also tracked the resistivity of the target [4].

Cobalt shows a similar sensitivity. In DC magnetron sputtered Co films, raising the sputtering power from 15W to 60W changed the films from amorphous to polycrystalline and lowered resistivity from 276 to 99 μΩ.cm [5].

For researchers working on liners, seed layers, capping layers or barrierless conductors, this means source stability, power control, target choice and a clean vacuum environment all determine whether a Ru or Co film is fit for interconnect studies.

Why choose Nikalyte for Ru and Co thin film research

Nikalyte develops PVD sources and deposition systems mainly for research groups working on thin films and nanoparticles. For sputtered films, our Stellar magnetron sources, including the 2 inch Stellar-2 come with standard or high-strength magnets. The high-strength option is designed for magnetic targets such as cobalt [6].

E-beam evaporation is well suited to high-melting-point metals such as ruthenium. The EVAP-4 mini e-beam evaporator has four independently controlled crucibles, each with a 1 cc pocket volume. Its software can run a single pocket, several pockets in sequence to build multilayers such as Ru/Co, or all four together for co-evaporation, all without breaking vacuum [7].

For work on nucleation and the earliest stages of film growth, the NL-UHV nanoparticle source with the NL-DX3 three-head magnetron deposits ligand-free nanoparticles from up to three materials, either individually or as alloys, and the NL-QMS mass filter lets you select particle size in real time [8]. Researchers at Montanuniversität Leoben and Empa have used the NL-DX3 to show that substrate bias can raise the deposition of size-selected 8 nm and 1.8 nm Cu nanoparticles by up to 32 % [9], to quantify nanoparticle flux in situ [10], and to build porous films from Cu nanoparticles smaller than 10 nm [11].

These sources can be combined in the NL-FLEX deposition system, which accepts up to six sources (magnetron sputter, mini e-beam, thermal boat and nanoparticle) and handles substrates up to 4 inch wafers. It reaches a base pressure of 5×10^{-7} Torr and includes quartz crystal microbalance monitoring and recipe control software with data logging [12].

Conclusion

As interconnects shrink towards the 10 nm scale, copper's resistivity and reliability limits are driving the move to ruthenium and cobalt. The performance of these metals depends on grain structure, crystallinity and purity, which are set by the deposition process. Flexible,

well-controlled PVD is therefore essential for the research that takes Ru and Co from thin film studies to next-generation semiconductor interconnects.

Planning Ru or Co thin film research for advanced interconnects? Contact us at sales@nikalyte.com to speak with a PVD specialist about a sputter source, the EVAP-4 or a deposition system configured for your application.

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