Evap-4 Technical Note

Deposition Rates and Flux Currents for Silver, Gold, and Copper, Using Mini E-beam Evaporator Evap-4

This technical note presents the results of measurements taken for deposition rates and flux currents of various metals deposited using the High Capacity Four Pocket Mini E-Beam Evaporator (Evap-4). Silver, gold, and copper were among the metals tested, each having distinct properties that influence their deposition behavior. Silver, with a melting point of 961°C, is prized for its excellent conductivity and resistance to corrosion. Gold, with a melting point of 1064°C, is widely recognized for its stability and resistance to oxidation. Copper, with a moderate melting point of 1085°C, is known for its high thermal conductivity and is commonly used in a range of applications.

The data provided in this technote aims to enhance understanding of the deposition process for these metals using the Evap-4.

Experimental Conditions

The experimental setup for metal deposition using the Evap-4, mounted on a 30deg angle port on a HV Box chamber as shown in Figure 1. Deposition rate was measured using an Inficon cool drawer QCM mounted on a linear shift mechanism, with source-to-QCM distances of 100mm and 200mm. The same configuration was used for all metals, ensuring consistency in the deposition process.

1. For **silver**, silver from a spent sputter target was loaded into a Mo 1000mm³ crucible, filled to approximately ¼ capacity, and placed into pocket 1 of the Evap-4. The deposition power was limited to 70W, and the chamber base pressure was maintained below 2e-7 mbar.
2. For **gold**, gold from a spent sputter target was loaded into a W 1000mm³ crucible (¼ full) and placed into pocket 2 of the Evap-4. Deposition conditions included a maximum deposition power of 150W, and the chamber base pressure was kept below 5e-7 mbar. Deposition rate and ion flux were measured using the same QCM setup as for silver.
3. For **copper**, a Ta 1000mm³ crucible was filled approximately ¼ full with copper filings and loaded into pocket 3 of the Evap-4. The maximum deposition power for copper was set to 160W, and the chamber base pressure was maintained below 5e-7 mbar.

Figure 1 Evap-4 mounted inside the box chamber with pocket 3 powered up.

In all cases, the deposition rate was measured with the same QCM setup, ensuring uniformity across the deposition experiments for each material. Flux plates in a mini e-beam evaporator measure the deposition rate of evaporated material onto a substrate. Positioned in the vapor path, they detect the amount of material landing on their surface. Typically, quartz crystal microbalances (QCMs) are used, which change oscillation frequency as material deposits, allowing precise measurement of the deposition rate. This data is fed back into the system to adjust the e-beam power, ensuring uniform and controlled deposition across the substrate.The ion flux for each material was measured using the flux plate associated with the pocket and recorded using the dedicated software.

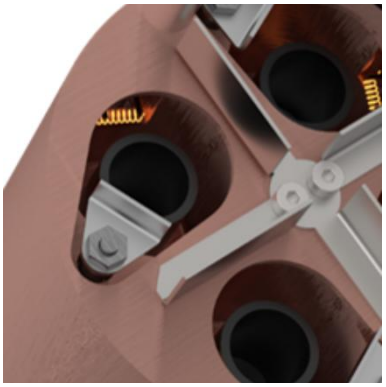

Figure 2 Zoom-in of Flux Plates in a Mini E-beam Evaporator System

Flux plates are positioned above each pocket to measure the small ion current that is produced during the vaporisation of the evaporant. The ion current is small, only a few nA, but importantly this ion current is proportional to the deposition rate, so can be used an alternative means to measure the thickness of material being evaporated.

Results

The results of metal deposition experiments using the Evap-4 showed distinct behaviors for each material, including deposition rates, ion flux stability, and issues related to coating and shorting.

For **silver**, the deposition rate and ion flux were measured up to 70W at source-to-QCM distances of 100mm and 200mm (Figure 3). At 70W and a 200mm source-QCM distance, a high deposition rate of 40Å/s was observed. At 100mm, the deposition rate was 10Å/s, following the expected $1/r^2$ dependence, demonstrating stable deposition throughout the 1.5-hour run. However, the ion flux showed instability, with sharp fluctuations between 16nA and 999nA, making it difficult to accurately deduce the flux. This instability was attributed to an intermittent short caused by the unshielded flux plate ceramics, though the flux current returned to background levels (5nA) after each measurement. Post-deposition, the silver was confined to the bottom of the Mo crucible with no material creep, but asymmetric positioning of the melted Ag in the crucible was observed, due to the EVAP-4 being mounted on a 30deg angle port. Figure 3 shows the post-deposition condition of the Mo crucible.

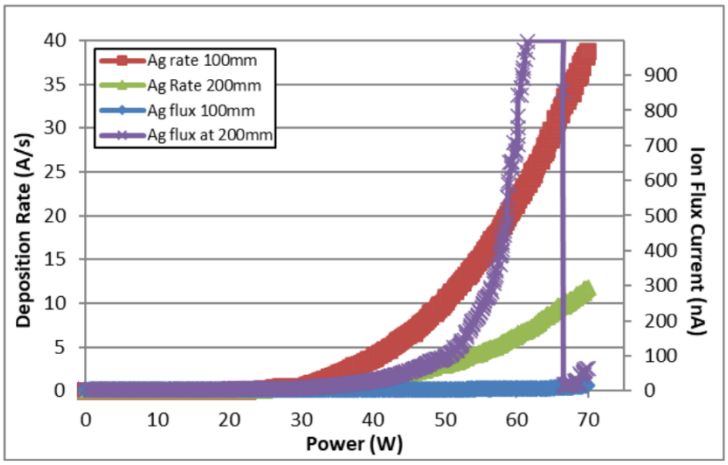

Figure 3 Deposition rate and Ion Flux current for Ag in Mo crucible

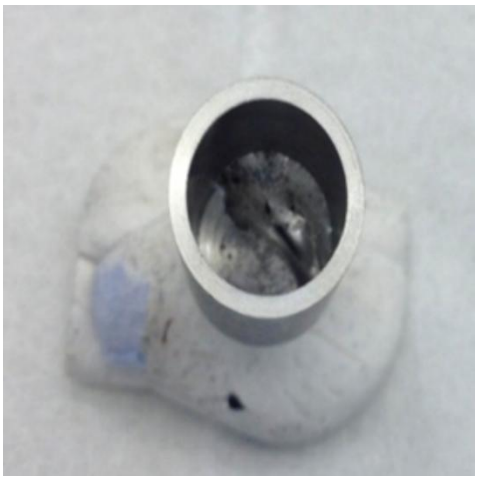

Figure 4 Ag in Mo crucible after 70W deposition

For **gold**, the deposition rate and flux were measured for source-to-QCM distances of 100mm and 200mm, with results plotted in Figure 5. The deposition rate reached up to 4Å/s at 150W. A high flux current of 550nA was also observed at 150W. The ion flux current exhibited a stable correlation with the deposition rate above 65W, as shown in Figure 6. This high ion flux allowed for precise control of the deposition rate without relying solely on the QCM, as monitoring the flux current alone provided sufficient control. The deposition rate showed the expected $1/r^2$ dependence with the 100mm and 200mm QCM distances.

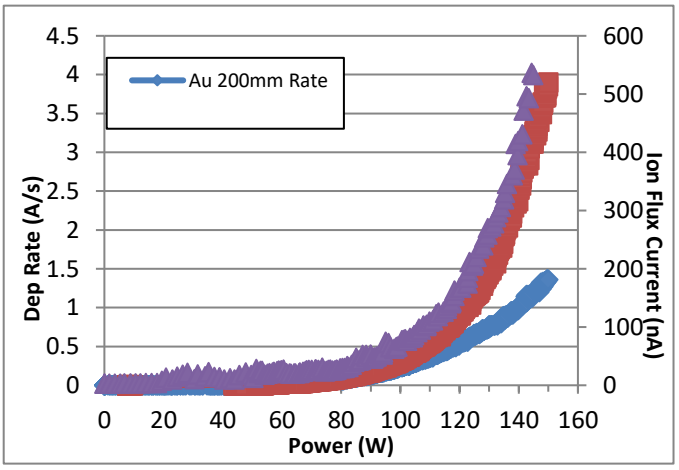

Figure 5 Power and ion flux current for Au deposition in W crucible

After the deposition, the Evap-4 was removed from the system and inspected for material creep and coating. The gold metal wetted the inside of the crucible, but there was no material creep outside of the

crucible (Figure 7). A thin film of gold was observed around the pocket of the Evap-4.

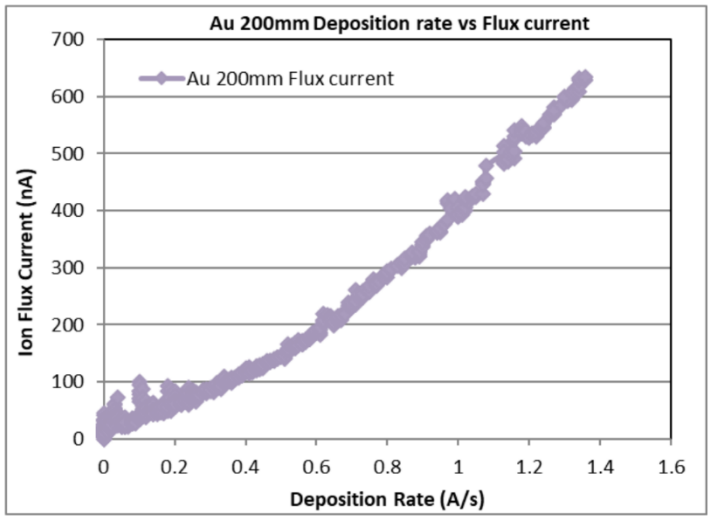

Figure 6 Flux current vs deposition rate for Au in W crucible

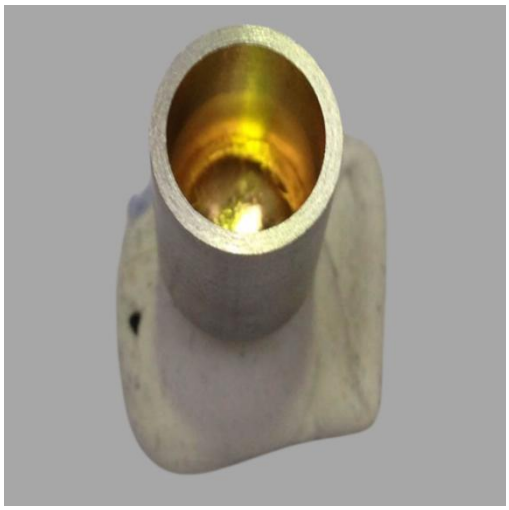

Figure 7 Au in W crucible after deposition at 150W

For copper, the deposition rate and flux were measured for a source-to-QCM distance of 100mm, with results plotted in Figure 8. The deposition rate reached up to 60 Å/s at 146W, and a steady flux current was measured up to 138W. A linear correlation between flux and deposition rate was observed for rates up to 15 Å/s (Figure 9).

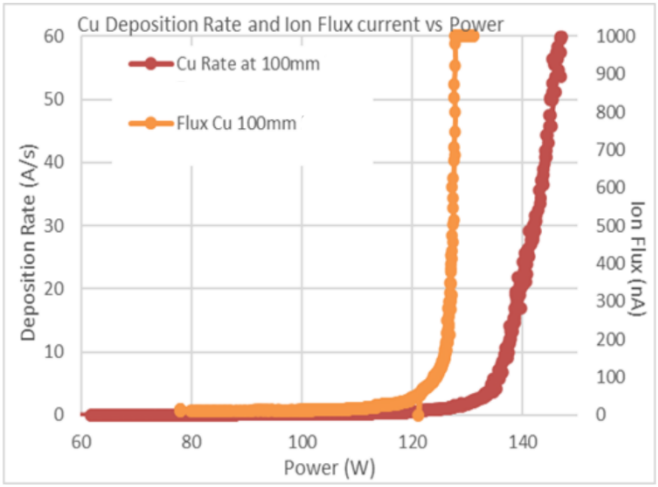

Figure 8 Power and ion flux current for Cu first deposition

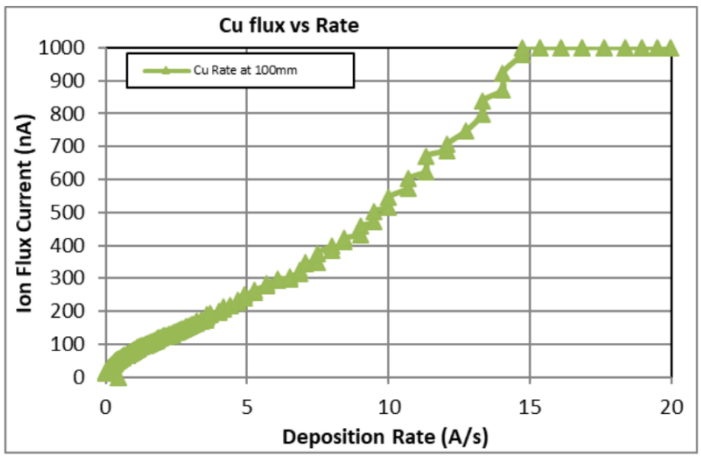

Figure 9 Flux current vs deposition rate for Cu in Ta crucible

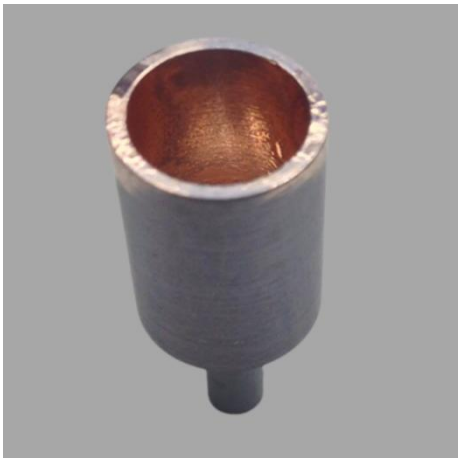

Figure 10 Cu in Ta crucible after deposition at 146W

Conclusion

The deposition experiments for silver, gold, and copper, using the Evap-4 demonstrated promising results, with each material exhibiting distinct and favorable characteristics under controlled deposition conditions.

- **Silver** achieved high deposition rates, particularly at extended source-to-QCM distances, demonstrating stable performance over the 1.5-hour deposition time. While some flux instability was observed, the deposition process itself remained robust and consistent, providing valuable insights into its behavior under different conditions.
- **Gold** showed excellent correlation between deposition rate and ion flux, particularly at higher powers, allowing for precise control over the deposition process, and the successful wetting of the gold within the crucible further confirms the effectiveness of the system for gold deposition.
- **Copper** exhibited very high deposition rates with a strong linear correlation between deposition rate and ion flux, demonstrating the Evap-4's capability to handle high-performance deposition processes. Even with material buildup, the system maintained a stable deposition environment, offering clear potential for further optimization.

Overall, the Evap-4 demonstrated its versatility and effectiveness for depositing a range of metals. The results underscore its potential for high-precision deposition, offering valuable data.