Impact of Rod Lifetime on Working Distance in the Mini E-Beam Evaporator

The recommended working distance for co-evaporation or sequential evaporation from multiple pockets in a Mini E-Beam Evaporator is highly dependent on both the source geometry and the rod's length and diameter. The overlap distance of the emission cones from adjacent pockets plays a crucial role in achieving uniform deposition. This is especially relevant for both the Compact Four Pocket Mini E-Beam (EVAP – 4C) and High Capacity Four Pocket Mini E-Beam (EVAP – 4) systems. Experimental results demonstrate a significant decrease in the overlap distance as the rod material is consumed during the evaporation process. This technical note presents the findings related to the change in overlap distance between two adjacent pockets over the rod's lifetime, discussing the sensitivity of overlap distance to rod usage for both the EVAP – 4C and EVAP – 4 systems.

Experimental Calculations

A schematic illustrating the pocket and evaporation cone geometry is shown in Figure 1. The evaporation cone for each individual pocket is influenced by several key parameters: the rod diameter (r), the distance from the top of the rod to the top plate (x), the top plate thickness (t), and the top plate opening (L). The standard parameters for both the High Capacity Four Pocket Mini E-Beam (EVAP – 4) and Compact Four Pocket Mini E-Beam (EVAP – 4C) are provided in Table 1.

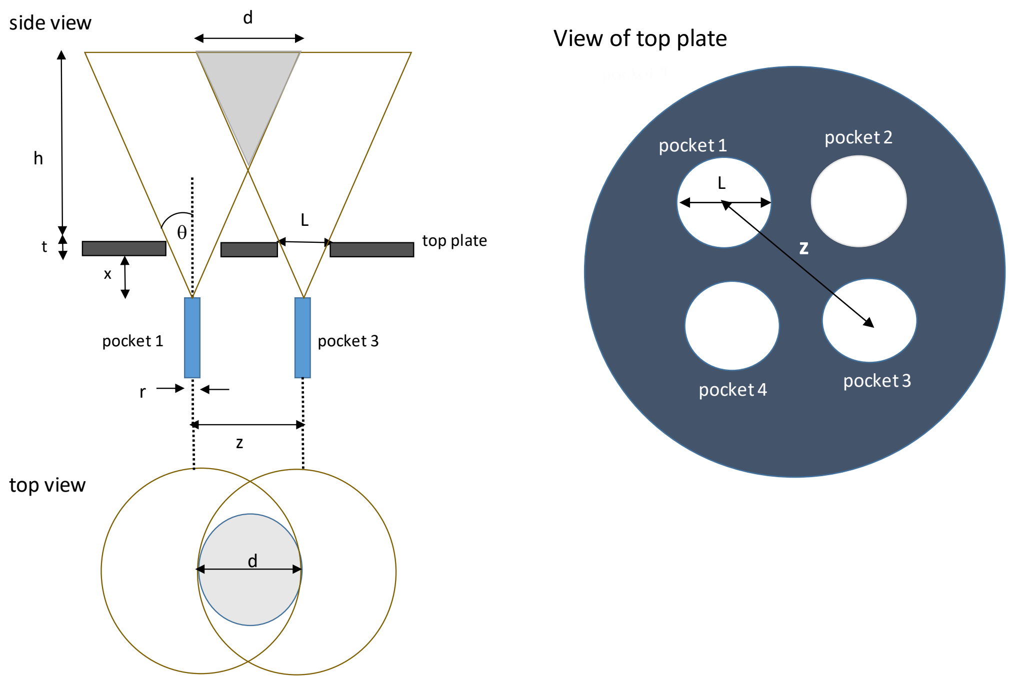

Figure 1: Pocket and evaporation cone geometry for the High Capacity Four Pocket Mini E-Beam (EVAP – 4).

Parameter	EVAP- 4	EVAP-4C
x (mm) *	3	5
t (mm)	3	3
z (mm)	31	17
L (mm)	16	8

Table 1: Standard measurements for High Capacity Four Pocket Mini E-Beam (EVAP – 4) and Compact Four Pocket Mini E-Beam (EVAP – 4C).

EVAP-4 Technical Note

The overlap diameter represents the diameter of the region at a given working distance (h) where the emission cones from two adjacent pockets overlap, as illustrated in Figure 1. As the working distance increases, the overlap diameter also increases. The evaporation overlap area (A) is estimated by calculating the area of a circle with a diameter equal to the overlap diameter (d), as shown in the schematic.

For the purposes of these calculations, a 2mm rod diameter is considered, as it is compatible with both the EVAP – 4 and EVAP – 4C systems. A standard starting rod length of 27mm is assumed. During the evaporation process, the rod gradually "spends" or shortens, and as a result, the rod effectively moves deeper into the pocket. This leads to an increase in the value of x over the rod's lifetime, affecting the overlap distance and area as the evaporation process progresses.

Results

he overlap distance (d) as a function of rod length for the High Capacity Four Pocket Mini E-Beam (EVAP – 4) and Compact Four Pocket Mini E-Beam (EVAP – 4C) is shown in Figure 2 for working distances of 100mm and 200mm. In Figure 3, the same data is plotted as the overlap distance as a percentage of the maximum value for a new rod (initial rod length of 27mm), illustrating the reduction in overlap as the rod shortens. The data clearly demonstrates that the EVAP – 4 exhibits a significantly larger overlap distance compared to the EVAP – 4C at both working distances.

At a 200mm working distance, the maximum overlap diameter for the EVAP – 4 is 451mm, while for the EVAP – 4C, it is 141mm. The relationship between the overlap distance (d) and rod length is non-linear, with the most significant drop in d occurring early in the rod's lifetime. For example, a 2mm decrease in rod length (from 27mm to 25mm) results in a 25% reduction in overlap distance for the EVAP – 4 (from 451mm to 335mm) at 200mm working distance, as shown in Figure 3. The same 2mm decrease for the EVAP – 4C results in a 21% reduction in overlap distance (from 141mm to 111mm).

At a 100mm working distance, the percentage drop in d due to a 2mm decrease in rod length is slightly higher for both models, with a 25.8% reduction for the EVAP – 4 and a 22.7% reduction for the EVAP – 4C. Figure 3 emphasizes the strong influence of rod length on the overlap distance. For a 5mm decrease in rod length (from 27mm to 22mm), the EVAP – 4 experiences a significant 50% reduction in overlap distance at 200mm working distance, while the EVAP – 4C experiences a smaller 41% reduction. These results underline the importance of carefully monitoring rod length during operation to ensure consistent and uniform overlap for optimal deposition.

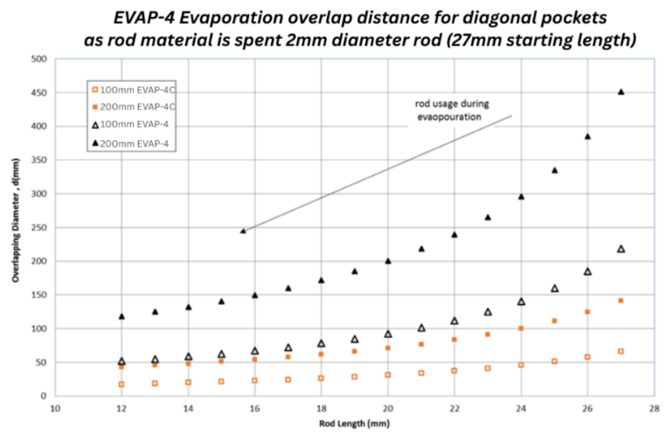

Figure 2: Overlap distance, d, as a function of rod length for the High Capacity Four Pocket Mini E-Beam (EVAP – 4) and Compact Four Pocket Mini E-Beam (EVAP – 4C) at working distances of 100mm and 200mm.

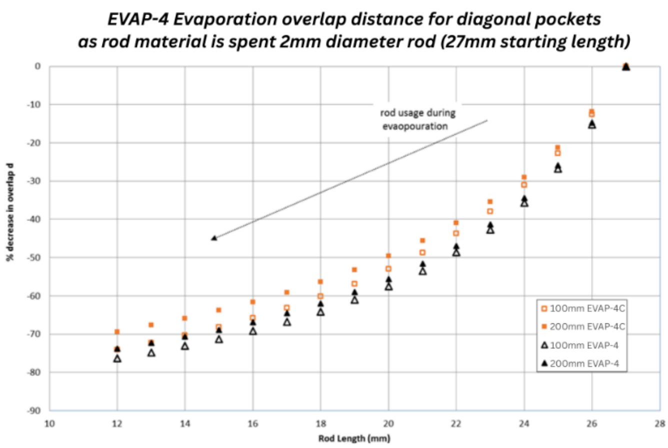

Figure 3: Percentage decrease in overlap distance as a function of rod length for the High Capacity Four Pocket Mini E-Beam (EVAP – 4) and Compact Four Pocket Mini E-Beam (EVAP – 4C) at working heights of 100mm and 200mm.

The calculations demonstrate that the EVAP – 4 provides a significantly larger overlap distance for a given working distance compared to the EVAP – 4C, which allows for a closer working distance for the

EVAP – 4 when accommodating a specific sample size. For instance, with a new 27mm rod, at a working distance of 100mm, the EVAP – 4 can uniformly co-evaporate over a full 8″ wafer (203.2mm), while the EVAP – 4C can only handle up to a 2″ wafer (50.8mm). However, the EVAP – 4 is more sensitive to changes in rod length as the rod is used. When the rod is reduced to 25mm, the EVAP – 4 can only accommodate a 6″ wafer (152.4mm), whereas the EVAP – 4C can still uniformly co-evaporate a full 2″ wafer (50.8mm).

The overlap area (A) for both the EVAP – 4 and EVAP – 4C is plotted against rod length in Figure 4. Since the overlap area is proportional to the square of the overlap diameter, the area decreases even more rapidly as the rod is spent. For example, a 2mm decrease in rod length results in the overlap area decreasing from 1600cm² to 880cm² (a 45% reduction) for the EVAP – 4 at a 200mm working distance. For the EVAP – 4C , the same 2mm reduction gives a decrease from 156cm² to 96cm², or a 38% reduction.

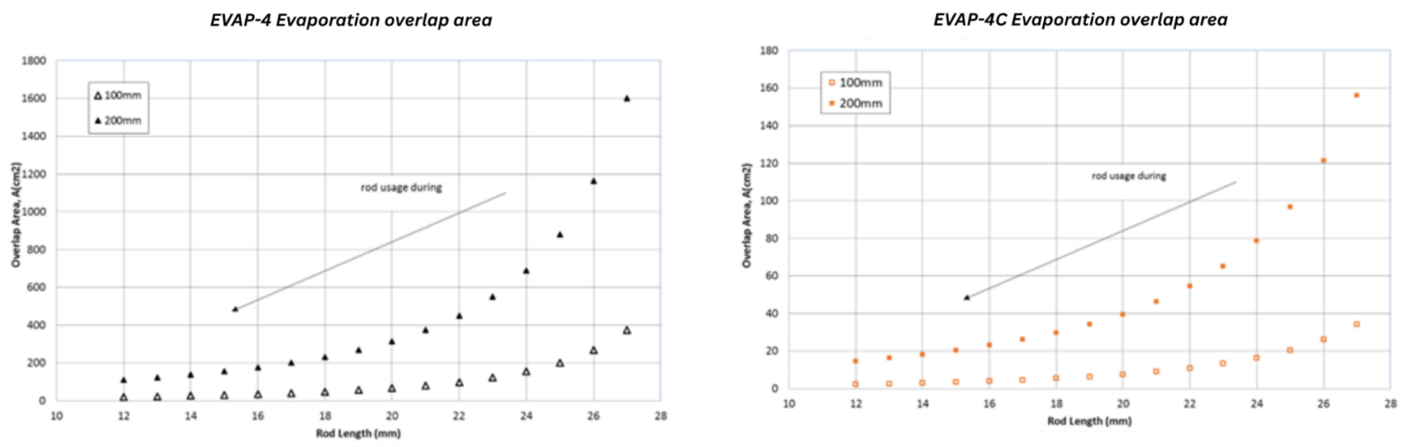

Figure 4: Overlap area as a function of rod length for the High Capacity Four Pocket Mini E-Beam (EVAP – 4) and Compact Four Pocket Mini E-Beam (EVAP – 4C) at 100mm and 200mm working distances..

For most practical applications, the rod diameter is the key parameter when setting up an evaporation process. Another consequence of a shortening rod length is the effective lengthening of the working distance from the rod tip to the sample. This results in an inverse square reduction in the deposition rate over the rod's lifetime. Figure 5 illustrates this by plotting the deposition rate as a percentage of the rate for a new rod (27mm) as the rod length decreases. A significant 10% reduction in deposition rate is observed for a 6mm reduction in rod length (from 27mm to 21mm). While this decrease in rate is less pronounced than the change in overlap diameter, it affects the entire deposition area.

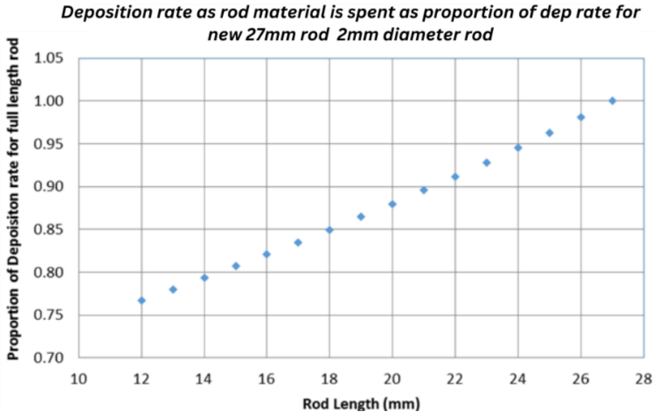

Figure 5: Deposition rate as a percentage of the rate for a new 27mm rod, plotted against decreasing rod length.

The use of a QCM (Quartz Crystal Microbalance) to measure the deposition rate and thickness of the deposited layer can help the user automatically adjust for these changes in deposition rate. However, care must be taken if the deposition rate is measured only at the start or just before a deposition, as this could fail to capture changes in the rate as the rod length decreases over time.

Conclusion

The calculations demonstrate that the overlap distance is highly sensitive to changes in rod length, with the most significant shift occurring early in the rod’s lifetime. This highlights the importance of closely monitoring and accounting for even small variations in rod length, particularly at the start of a new rod's usage. Notably, the EVAP – 4 is more responsive to changes in rod length than the EVAP – 4C, owing to the larger initial overlap distance with a fully extended rod. Despite these differences, the percentage change in overlap area with decreasing rod length is similar for both sources, emphasizing the robustness of this relationship across the system models.

These findings underscore the value of accurately estimating rod usage during evaporation processes and setting the working distance according to both the sample size and the expected minimum rod length. By factoring in these variables, users can optimize the evaporation setup for improved uniformity and efficiency, ultimately ensuring consistent results throughout the lifespan of the rod.