Original Question:



P.S: Here are a few parameters that are provided to the tool.

Power: 10KW

Voltage: 10KV constant

Current: Variable

Rise1 & Soak1: 5min & 1min /8min & 2min

Rise1 Power: 4% (for intermetallic crucible)

Rise2 & Soak2: 5min & 1min /8min & 2min

Rise2 Power: 8% (for intermetallic crucible)

Ramp down: 5min

Rate of deposition: 0.1nm/sec

Beam Pattern: Spot Beam at the center of the crucible

Crucible Volume: 20cc

Material fill %: As recommended 67-75%

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| **#** | **Asnwering** | **From** | **Answer** |
| 1 | Steffen Paul | ? | Don’t bother with the crucible liner. Just melt a big chunk of aluminum directly in the pocket. It will not adhere to the walls so you will be able to remove it if you need to swap materials. |
| 2 | Carlos Gramajo | RIce | I have discussed these procedures with my colleagues here at Rice. We do not have much problems with e-beam evaporation of Al.  What we have concluded is that you might need to sweep your beam and ramp down much slower. We are using the glassy coated graphite and it is about the same volume. You might have to increase power a little bit due to the sweeping, but this will give a more uniform heat distribution on your source material. |
| 3 | Howard Northfield | University of Otawa | Don't use a spot beam, use a pattern beam. |
| 4 | Youry Borisenkov | Columbia University | Here at Columbia we use a Fabmate crucible for Al e-beam depositions. We suggest using e-beam to our users only when they tried the thermal evaporation and if didn't work for their needs.  The crucible does break often (I would assume every 3-5 depositions) and the only thing that looks helpful so far is ramping up and down slowly (you mentioned 5 min, this is what we do for both up and down ramps).  It would be helpful to get a summary of your findings :) |
| 5 | Owain Clark | University of Southampton | Doesn’t always work we find, eventually some enterprising user will find a way to melt an Al ingot onto a cooled hearth which should in theory not happen. But I do agree if this is not an issue and you can dedicate a pocket then this is the best method. Some electron beam gun cooling channel design and water flows will get you a lot farther then others in this respect.  In the last year I spent some time personally trying to improve our standard long throw Al evaporation process. We use 40cc pockets and there is no choice but to use a crucible because multiple materials use the pockets and ultimately it makes multi user/project operation easier. Al is cheap to refill, and the odd crucible is just noise in the tool budget too.  What I found ultimately was that alumina was the best. Power to deposit was significantly lower than any other crucible for a given rate because due to the thermally insulating properties of Al2O3 the entire Al crucible load melts and becomes totally molten, this gives a very easy to control deposition with a large vapour emitting area and even with a 1m+ throw distance rates of 2-5A/s at the wafer were no trouble for ~1kW of input power. The downside is that Al2O3 always cracks, no matter now gentle you are with preconditioning. But considering the overall budget of tool operation a new crucible every few months is not significant. The crucible outer wall stays cold and any Al that moves through the cracks cools and does not transmit further – this gives the cracked crucible physical stability. Eventually after several months and many um of Al you see the power for a given deposition rate slowly start to increase. This is the cue that Al moving through cracks has begun thermal contact with the pocket and is a sign to prepare to swap the crucible for a new one. Al in this crucible stays perfectly shiny following deposition for its entire lifetime.  For graphite, coated graphite or fabmate the crucible will eventually crack, and the Al will react with the liner. The liners I tested like this gave a yellow-ish hue to the Al after only a few depositions which I presume is C contamination (although I have not yet tested it via elemental analysis). The colour change is obvious by eye. Power vs Al2O3 is approximately double for a given rate due to increased thermal conduction through the crucible, and you cannot melt the entire Al contents.  Using metallic crucibles such as W the Al will creep eventually ruining the deposition by demanding significantly more power required for a given rate as it goes over the top of the crucible, only a small spot can be melted, and the power required is 2-3x more than Al2O3. Crucibles are physically unreactive and Al stays pure but it does not take long before creep renders them useless.  So all in, if you must use a crucible for Al I would recommend Al2O3 or a similar thermally insulating unreactive material. And I would always take any material vendor suggestions with a pinch of salt and just a starting point. Tool vendors I listen more closely too but seeing is always believing. Try the options yourself and draw your own conclusions based on expected theory. Al2O3 has been our standard crucible for over a year now and both research and enterprise users of the tool are happy. Keep a pre melted 2nd crucible ready to go as needed and all is fine. |
| 6 | Zhichao Wang | ? | We use a pattern beam with the pattern sweeping/rotating constantly during the deposition, and a fabmate crucible. The rest of the parameters are pretty similar. The highest deposition rate we've tried is 15 Angstrom/s. |
| 7 | Michael Yakimov | ? | One of things which may hinder Al deposition from carbon crucible is Aluminum carbide formation on the surface. It will show up as yellow stuff on the surface after venting, eventually decomposing in the air.  It is a part of tribal knowledge for me; I couldn't find a good reference in 5 minutes. there is mention of the effect here:  https://link.springer.com/article/10.1007/BF00792405 |
| 8 | Shane Patrick | University of Washington | We also don’t use a crucible - for either Al or Cr actually. |
| 9 | Ryan Rivers | ? | The best way around the aluminum crucible shattering problem is to use a FABMATE crucible, but also to use a carbon spacer under your liner. A 1/8" thick carbon disk works in a pinch, you can get fancier with some machine shop time. We use them in all our ebeam tools the Marvell NanoLab and I've only seen a handful of crucible liners shatter from thermal load in the last decade.  Primary cause of crucible liner breaks are incomplete thermal contact on one side of the crucible. When you're pouring too much heat in to make up for that contact, one side goes red hot, the other never gets there. Thermal expansion drives the rest. The spacer prevents your liner from cooling through the sides and only cools at the bottom. You heat with less joules in, so less shock. Lets your entire crucible heat more evenly and more readily stabilize through the problematic regions of melt formation. |
| 10 | Brent Gila | ? | Agreed, carbon spacer under the crucible for Al is the way to go. |
| 11 | Ted Wangensteen | ? | Ryan has hit on the key thermal explanation, and the best way to help this is the Carbon spacer he mentioned.  We used this on Lesker tools.  Kurt Lesker sells the spacer, but I'm not sure what tool you are using. |
| 12 | Joe Maduzia | Univerity of Illinois | We struggled for a while getting Al to work well in e-beam evaporator. It works very well with a slow heat and cool using a tungsten crucible liner. The Al doesn’t wet over the liner, and the liner doesn’t crack. You can still burn through it with the e-beam if you aren’t paying attention to fill level though. |
| 13 | Shimon Eliav | Hebrew University | Here is my two cents for this nice discussion.  I agree with Ryan, Brent and Ted: the simple spacer does the job. After some trials, here at Hebrew University we use intermetalic crucibles with an special format manufactured by Angstrom Engineering that mimics the spacer effect. Here is the description:    It is quite expensive, 245$ each, but lasts for many evaporations. We also have slow heat up and cooling down ramps.  Once I saw at Princeton a simple thermal evaporator using a Graphite boat, also from Angstrom. The trick they use there is to consume all the Aluminum in the boat in the end of the evaporation. Seems to work nicely. |