HEMT Processing Flow Chart

1. Sample description

Sample name:

Mobility :

2DEG concentration:

Sample Shape

2. Mesa layer

Sample Cleaning.

- Boil in warm acetone for 5-10 minutes. Do not put sample in hot acetone. Put sample in acetone before put on hot plate. Before taking out the sample from hot acetone, wait acetone cooling down or squeeze acetone on the surface of sample.(Do not make acetone dry on the sample surface)
- Rinse acetone on sample with IPA.
- Blow dry with N_2 gas.
- Check if clean or not , with microscope, if needed, you can use Q-tip inside acetone

Patterning with positive process

- Bake sample at 110 ^{0}C on hot plate for 1-2 minutes to dehydrate
- Spin coat AZ5214 with 5000 rpm for 30 s (resist thickness is around 1.2 μm).
- Check uniformity of PR with microscope
- Bake sample for 1 minute at 110 ^{0}C on hot plate.
- After mesa mask alignment, expose 18 sec.
- First develop for 70 sec with 100 % of AZ-327 developer
- Dip sample in DI water for 30 seconds
- Blow dry with N_2 gas and check with microscope. If need more development, develop 5 sec more. Keep repeating 5 sec developing until you get good development pattern. Every time, after dipping the sample in developer, dip in DI water for 30 sec.
- Check the PR thickness with Alpa step (thickness of 1.2 micron), if you need.
- Oxygen asher cleaning for 30 s with 300 V for descum. (parallel plate plasma asher)

ICP-RIE Etching

- Etching with Cl_2, BCl_3, Ar gas in ICP-RIE.
- Clean sample with BCl_3 for 20 sec with 15 sccm flow rate, 3 mT of pressure, 100 V of bias (25- 50 W) for 1st , and 100 W for 2nd.
- Etch for 100 sec with Cl_2 of 15 sccm and Ar of 5 sccm flow rate, and 3 mT of pressure, 100 V of bias, and 100 W. Etched thickness will be 1200-1500 Å.
- Boil in warm acetone to clean PR residue for 10 min.
- Rinse acetone with IPA
- Blow dry with N_2 gas.
- Check with microscope if sample is clean or not.
- If sample is not clean, repeat cleaning. (You can use Q-tip inside Acetone)
- Check the etch depth with Alpa step (Height of around 1200 Å, Etch height is very

variable depending on the condition of ICP-RIE)

- Measure the isolation between mesa and mesa. (should be in MΩs)

3. Fiducial Layer

Sample Cleaning.

- Boil in warm acetone for ten minutes. Do not put sample in hot acetone. Put sample in acetone before put on hot plate. Before taking out the sample from hot acetone, wait for acetone to cool down or squeeze acetone on the surface.
  *Make sure acetone does not dry on sample surface.
- Because fiducial layer is the first layer, it should be extremely clean. If needed, can scrub gently with Q-tip in acetone solution.
  *However do not use Q-tip with acetone after the deposition of the any metals.
- Rinse acetone on sample with IPA
- Blow dry with N_2 gas.
- Check with microscope
  *Make sure sample is extremely clean.

Patterning with image reversal process

- Bake sample at 110 ^{O}C for 1-2 minutes to dehydrate on hot plate
- Spin coat AZ5214 on sample (5000 rpm / 30 sec) ($t_R \approx 1.2$ μm)
- Check uniformity of coating surface under microscope
- Bake sample for 1 minute at 110 ^{O}C on hot plate.
- For edge-bead removal, expose for 30 sec with edge removal mask and develop with AZ327 developer for 30 sec and clean with Q-tip with acetone.
  * You can use Q-tip with acetone without exposure and development. (Recommend this method because it can be reduce defects on PR due to contacts of mask during the alignments)
  * Make sure there is no residue of photoresist at edge bead area. The residue at corner and edge is very thick.
- Check edge-bead removal with microscope.
- After obtaining good alignment (<0.4 micron) for fiducial mask, expose for 5 sec.
- Bake for 1 minute at 120 ^{O}C on hot plate
- Wait for 1-2 min. for sample to cool down.
- Expose for 35 sec without mask.
- Develop for about 30 sec with 100 % of AZ-327 developer.

- Rinse 30 sec with DI water
- Blow dry with nitrogen gas and inspect sample under microscope.
- Keep repeating 3-5 sec developing until good clean patterns are obtained. Make sure all marks are opened clearly.

  * Development time can be variable every time. Make sure not to overdevelop.
- Check the PR thickness. (thickness of 1.2 micron)

Deposition of Metal.

- Oxygen descum for 30 sec with asher
- Dip sample in 1 to 2 solution of HCl-DI water mixture for 30 s.
- Dip sample in DI-water for 30 s.
- Blow dry with nitrogen gas.
- Load sample in Evaporator.
- Deposit Mo/Au (600/1300 Å). Mo deposition produces a lot of heating. When you deposit Mo, deposit with rate of about 1 Å/s to 100 Å and then 2-3 Å. After 300 Å deposition, stop and wait for 5-10 min and deposit next 300 Å

Lift-off

- Dip sample in acetone and boil to remove resist and overlayed metals
- After acetone is boiling, spray acetone hard on sample surface, which is inside acetone, with a squeezer bottle. Or you can use plastic pipet.

  * Make sure acetone does not dry on sample surface (Wait acetone cooling down before take sample out)
- After lifting metal off, put sample in clean acetone for 2 minutes. Rinse with IPA or dip in IPA for 1-2 minutes
- Blow dry IPA with nitrogen gas
- Check fiducial marks with microscope

4. Ohmic layer

- When you fabricate HEMT, every time prepare TLM pattern together for ohmic annealing study.
- Obtaining good Ohmic layer is most important to fabricate good devices.

Sample Cleaning.

- Boil in acetone for ten minutes.
- Rinse acetone with IPA
- Blow dry with N_2 gas.
- Check with microscope

Patterning using image reversal process

- Bake sample at 110 ^{O}C for 1-2 minutes to dehydrate on hot plate
- Spin coat AZ5214 on sample (5000 rpm / 30 sec)
- Check uniformity of photoresist with microscope
- Bake sample for 1 minute at 110 ^{0}C on hot plate.
- Do edge-bead removal
- After obtaining good alignment with ohmic layer mask (<0.4 micron), expose for 5 sec (55-60 mJ/cm^2).
- Bake for 1 minute at 120 ^{0}C and wait for 1-2 min to cool down
- Expose for 35 sec (390-400 mJ/cm^2).without mask.
- Develop for 30 sec with 100 % of AZ327. To get good pattern, if need, repeat development more by step of 3 seconds.
- Check under microscope. Check if the space and edge shape between two ohmic pads are clean and straight. If under-developed, open areas are not clean. If over-developed, the line between source and drain will be bent and space will be smaller.
- Check the PR thickness with (thickness of about 1.2 micron)

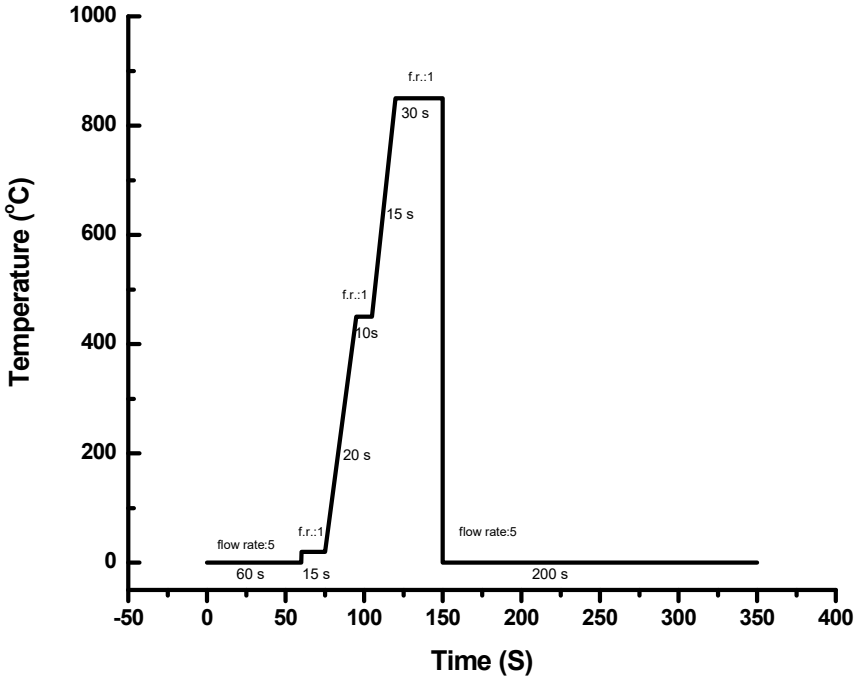
Deposition of Metal.

- Oxygen descum for 30 s with Asher
- Before depositing metal, do pre-deposition treatment with Master-RIE for 1 or 2 min with a bias of - 300 V, 55 % of RF power, 40 % of $SiCl_4$ flow, and 30-35 mT of pressure.
  * Try to etch until slightly above 2-DEG depth
  * Every time when use master RIE, clean the chamber mechanically. If it was used for metal etching even once, it does not etch GaN materials properly.
- Dip sample in HCl-DI water (1:2) for 30 s.
- Dip sample in DI-water for 30 s.
- Blow dry with nitrogen gas.
- Load sample in evaporator.
- Deposit Ti/Al/Mo/Au or Mo/Al/Mo/Au (150/600/350/500 Å)
- Before switching to other metal, wait 2 minutes
- When deposit Mo, wait 5-10 minutes for every 20 nm deposition. Do not deposit 350 Å of Mo at once or with higher deposition rate.

- Lift-off
- Dip in acetone and boil to remove resist and overlayed metals.
- After start boiling, spray acetone with squeezer bottle or with plastic pipet.
- After lifting off the metal, dip in IPA for 2 minutes and blow dry with N_2 gas.
- Check with microscope
- After lift-off, boil in warm acetone for the 20 min to get rid of residue of photoresist.
- Check if the space and edge shape between the two ohmic pads are clean and straight.

Annealing

- Split TLM sample several pieces
- Anneal at different temperatures with RTP (800, 850, 900 ^{0}C) in N_2 ambient for 30 sec.(give a step at 450 ^{0}C)



- You can use file name of 850PY, 800PY. Before run the process, check the parameters of the recipe.
- After finishing the process of annealing wait 5 minutes to cool down.

- Measure resistance and obtain contact resistance.
- Choose best temperature and perform the time dependence study (ex, 30, 45, 60, 90 sec)
- After deciding best temperature and time with TLM pattern, apply to real HEMT device sample

5. Gate layer

Sample Cleaning.

- Boil in acetone for ten minutes.
- Rinse acetone with IPA
- Blow dry with N_2 gas.
- Check cleanness of sample under microscope

Patterning with Photolithography using image reversal process

- Bake sample at 110 ^{0}C for 2 minutes to dehydrate on hot plate
- Spin coat AZ5214 on sample (5000 rpm / 30 sec)
- Check uniformity with microscope
- Bake sample 1 minute at 110 ^{0}C on hot plate.
- Do edge bead removal
- After obtain good alignment with gate layer mask (<0.4 micron) expose for 5 sec.
- Bake for 1 minute at 120 ^{0}C
- Expose for 35 sec without mask
- Develop for 30 sec with 100 % of AZ327 developer. To get good pattern, if needed, repeat development more by step of 3 sec. Every time rinse with water for 30 sec

Patterning with electron beam lithography

- Bake sample at 200^{0}C for 2 minutes to dehydrate on hot plate.
- Spin coat PMMA 950 K with thickness of around 1000 Å (for example, 950 K, C2, 4000 RPM for 1 min)
- Bake for 2 minutes at 200^{0}C on hot plate.
- Spin Coat PMMA-MAA copolymer with thickness around 3500 Å (PMMA-MAA Co-polymer, 9 %, 5000 RPM for 1 min)
- Bake for 2 minutes at 200^{0}C on hot plate.
- Spin coat PMMA 50 K with thickness of 500 Å (PMMA 50 K, A2, 5000 RPM for 1 min)
- Bake for 2 minutes at 200^{0}C on hot plate.
- Mount sample in electron beam lithography equipment.
- Write pattern with electron beam lithography (refer ELB manual at end of this manual)

- Develop for 2 minutes with 1 to 3 of MBIK and IPA solution
- Rinse for 30 second with IPA
- Check with microscope. If after deposition and lift-off, gate is peel off also, do not increase develop time, increase EBL exposure dose through dose test.

Deposition of Metals.

- Oxygen descum for 30 s with asher
- Dip sample in HCl:DI water (1: 2) for 30 s.
- Dip sample in DI-water for 30 s.
- Blow dry with nitrogen gas.
- Load sample.
- Deposit Ni/Au (300/2000 Å)
- Before switch to other metal, wait couple of minutes.

Lift-off for photolithography

- Dip in acetone and boil to remove photoresist and overlayed metals.
- After start air bubbling between wafer and metal, spray lift-off solution on the surface of sample or use plastic pipe
- After lifting off, dip in IPA for a couple of minutes and blow dry.
- Check with microscope

Lift-off for Electron Beam Lithography

- Dip in 1 to 1 solution of methanol and CH_2Cl_2 (Methylene Chloride) and boil it
- After start air bubbling between wafer and metal, spray lift-off solution on the surface of sample or use plastic pipet.
- After peel off, dip in acetone for 1 minute
- Dip in IPA for 2 minute and blow dry
- Check with microscope

6. Overlay layer

Sample Cleaning.

- Boil in acetone for 5 minutes.
- Rinse acetone with IPA
- Blow dry with N_2 gas.
- Check with microscope

Patterning

- Bake sample at 110 ^{0}C for 1-2 minutes to dehydrate
- Spin coat AZ5214 on sample (5000 rpm / 30 sec). If you want deposition more than 5000 Å of metal, spin coat with 3500 rpm for 30 s ($t_p \approx 1.7$ μm).
- Check uniformity with microscope
- Bake sample 1 minutes at 110 ^{0}C.
- Do Edge-bead removal
- Check edge with microscope.
- After get good alignment for overlay mask(<0.4 micron), expose for 5 sec(5000 rpm) and for 7 sec (3500 rpm)
- Bake for 1 minute at 120 ^{0}C
- Expose for 35 sec(5000 rpm) and for 50 sec (3500 rpm)
- Develop for 30 sec (5000 rpm) and for 35 sec (3500 rpm) with 100 % of AZ327. If needed, develop more by step of 3 seconds.
- Check the PR thickness (thickness of 1.2 micron for 5000 rpm and around 1.7 for 3500 rpm)

Deposition of Metal.

- Oxygen descum for 30 sec with asher
- Dip sample in HCl-DI water (1 : 2) for 30 s.
- Dip sample in DI-water for 30 s.
- Blow dry with nitrogen gas.
- Load sample in evaporator
- Deposit Ni/Au (300/2000-3000 Å)
- Before switch to other metal, wait a couple of minutes

Lift-off

- Dip in acetone and boil to remove photoresist and overlayed metals.
- After start air bubbling between wafer and metal, spray lift-off solution on the surface of sample or use plastic pipe
- After lifting off, dip in IPA for a couple of minutes and blow dry.
- Check with microscope