EPM Process Instructions

Tools

- 2x Titanium tweezers, Industry #00 (McMaster 5175A1)
- X-Acto knife with fresh blade
- Diamond Needle File, Rectangular, 170/200 grit, 5.1 mm wide x 1.4 mm thick (McMaster 4252A34)
- Stereo Microscope (e.g. Leica Zoom 2000)
- Loctite 50mL cartridge dispensing gun (McMaster 74695A71)
- Panavise (McMaster 8464A63)
- Magnetic field strength meter (e.g. AlphaLab GM-2)
- (OPTIONAL) Temperature-controlled Oven (e.g. Barnstead/Themolyne 1400)
- (OPTIONAL) Ultrasonicator in fume hood (e.g. Branson 1200)
- (OPTIONAL) X-Ray machine

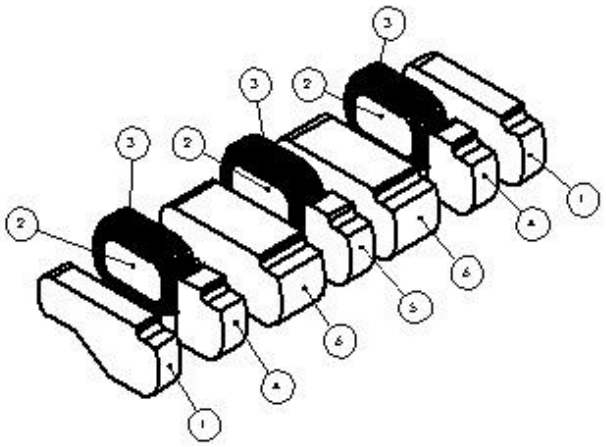
Consumables

- Loctite E60-HP Epoxy, 50 mL cartridge (McMaster 6430A28)
- Loctite Bayonet Mixer Nozzle, 5.9", with Luer Lock Hub (McMaster 74695A53)
- Blunt tip dispensing needle, 25 gauge, Luer Lock, Stainless and PTFE (McMaster 75165A686)
- Metal weighing dishes
- Isopropanol
- Kimwipes EL-X delicate task wipers
- WD-40
- Packing Tape (Staples, Quick Start)
- General Purpose Dust Remover

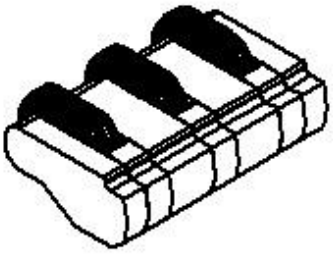
Parts

Prototype 1x2 EPM Assembly
(2) EPM Pole End
(2) EPM Pole Middle
(2) EPM Neodymium (North) Magnet
(1) EPM Neodymium (South) Magnet
(3) EPM Alnico Magnet
(3) EPM Coils

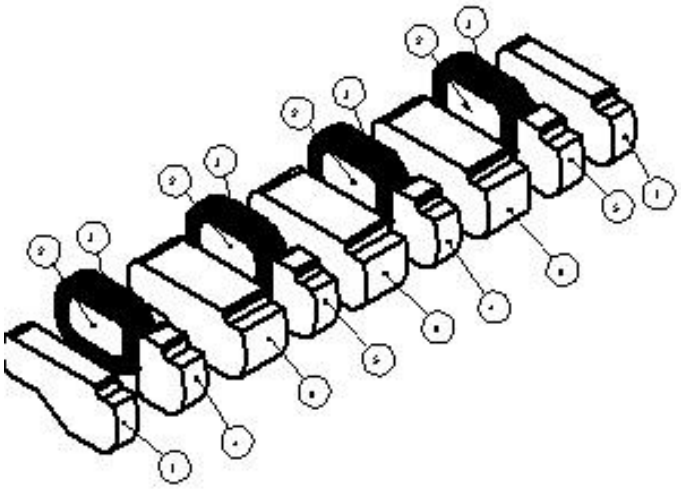
Prototype 2x2 EPM Assembly
(2) EPM Pole End
(3) EPM Pole Middle
(2) EPM Neodymium (North) Magnet
(2) EPM Neodymium (South) Magnet
(4) EPM Alnico Magnet
(4) EPM Coil



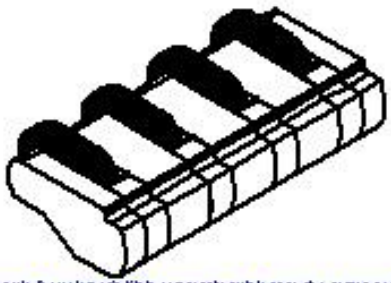
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1		Pole End	2
2		Alnico Magnet	3
3		Coil	3
4		Neodymium Magnet (North)	2
5		Neodymium Magnet (South)	1
6		Pole Middle	2



MDK
Prototype 1x2 EPM
Assembly BOM Alpha
SHEET 1 OF 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1		Pole End	2
2		Alnico Magnet	4
3		Coil	4
4		Neodymium Magnet (North)	2
5		Neodymium Magnet (South)	1
6		Pole Middle	2



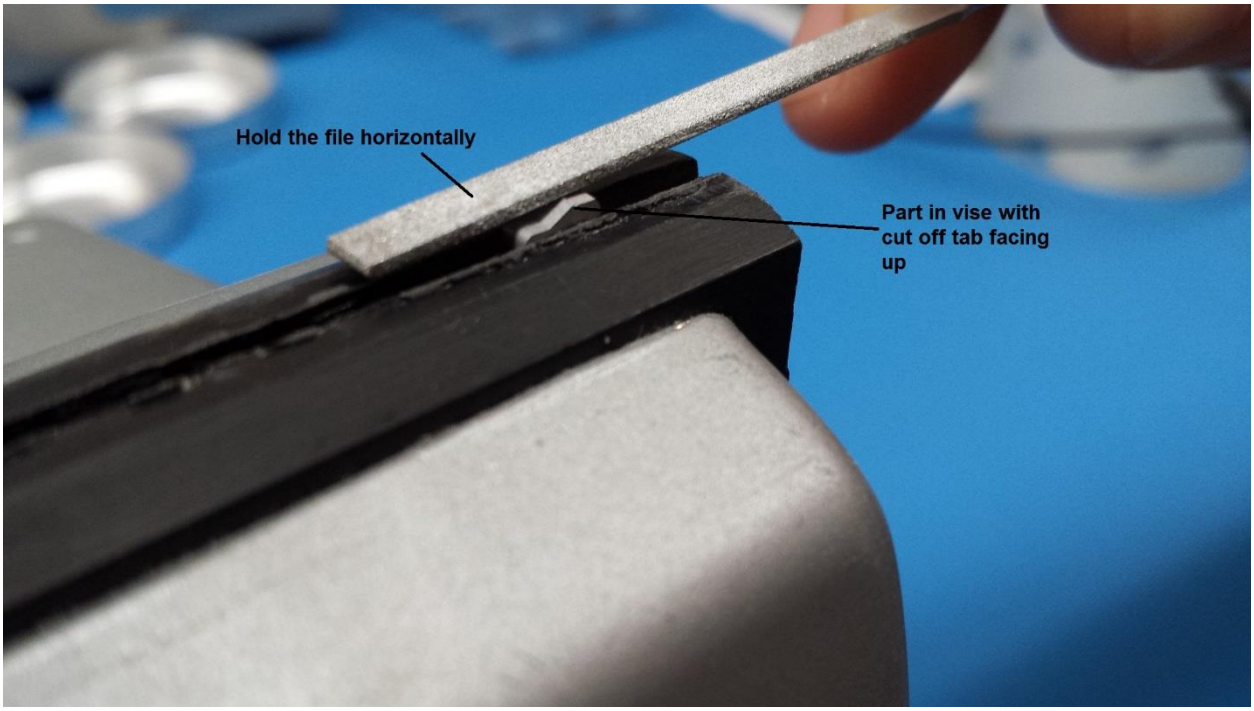
MDK
Prototype 2x2 EPM
Assembly BOM Alpha
SHEET 1 OF 1

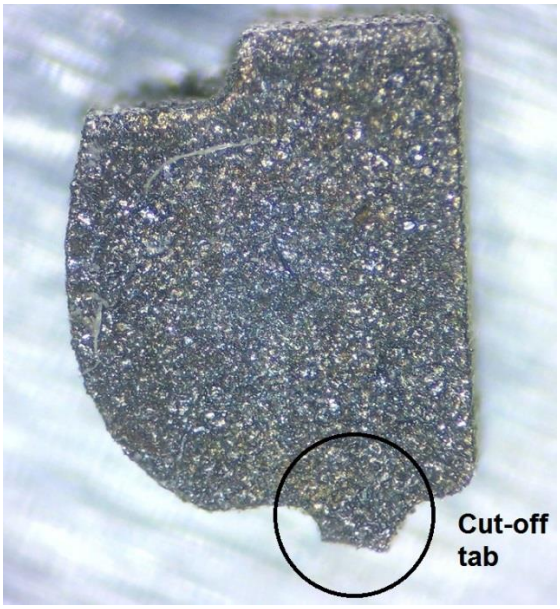
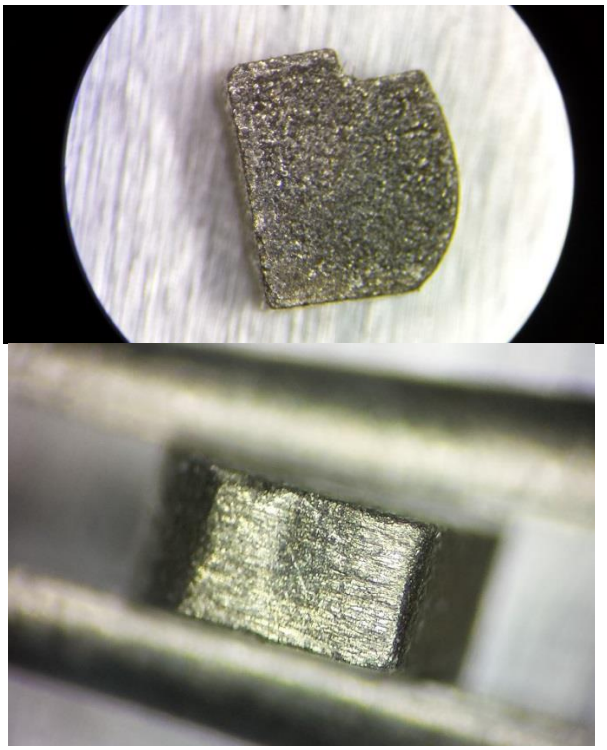
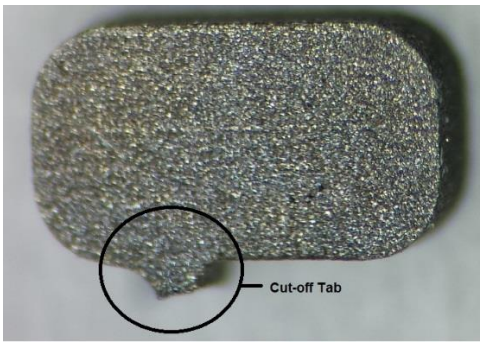
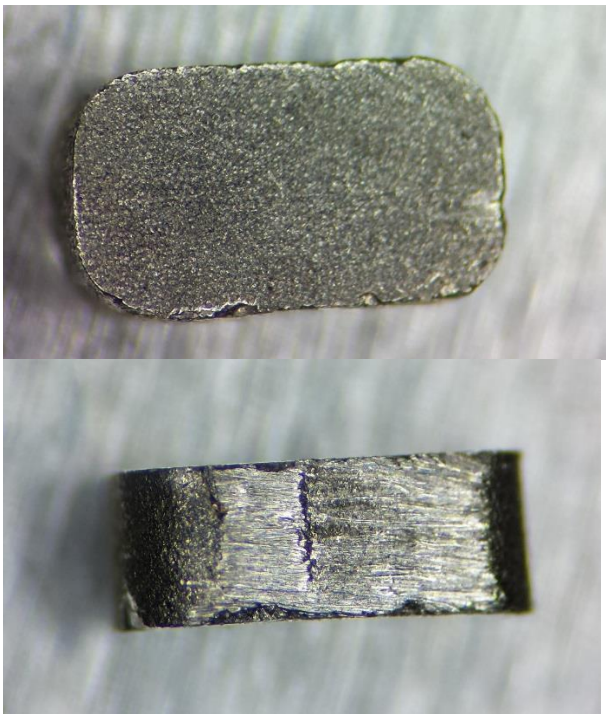
Process: Preparing Parts

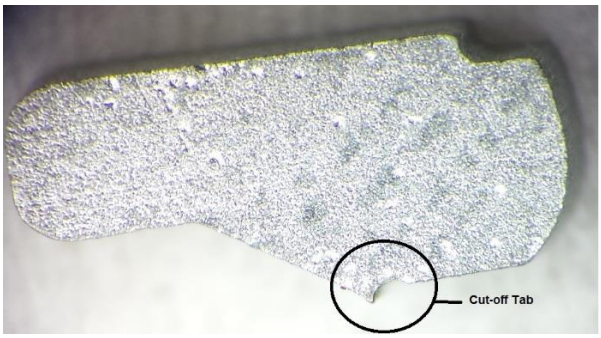
1. Place the file on the microscope stage and apply WD-40 to the file by spraying and spreading.

2. Inspect each of the *EPM Pole End* and *EPM Pole Middle* parts under the microscope. Identify the cut-off tabs and identify the mating faces.

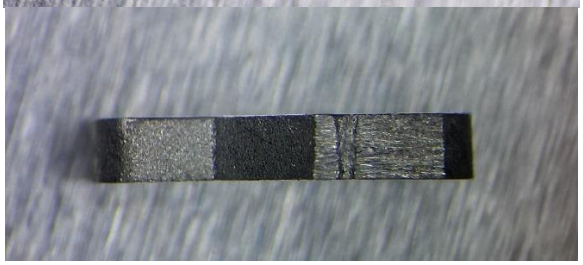
3. Remove the cut-off tabs. To do this, place piece in the vise with the side to be filed facing up. File off the tab using the flat side of the file. You know you are done when the face no longer has a bump from the tab. Do not file any of the mating faces.



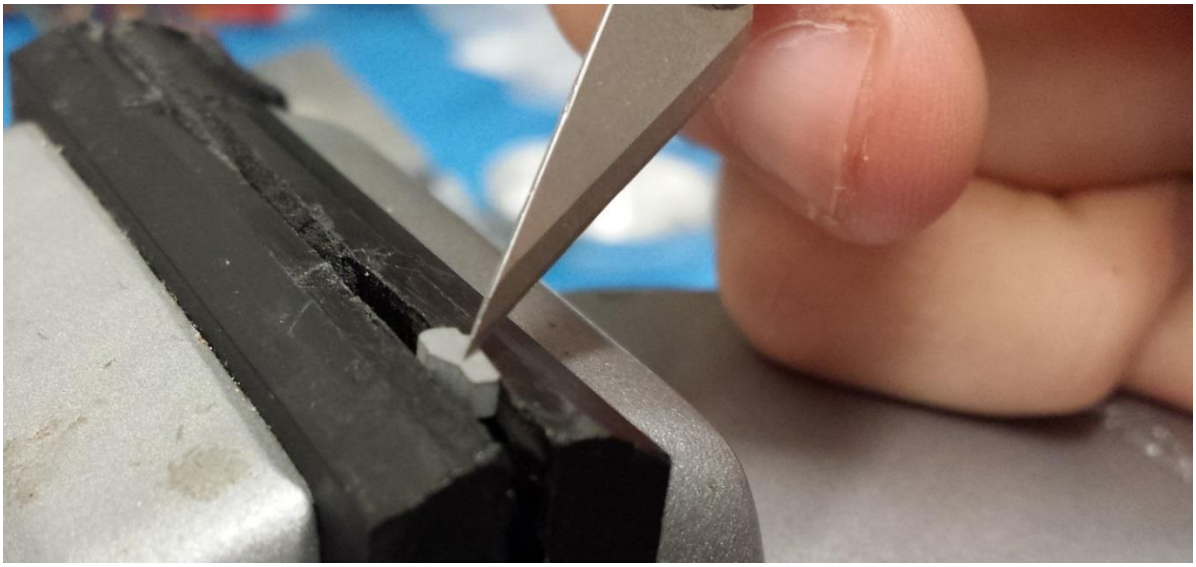
Before Filing	After Filing
 [Neodymium]	
 [Alnico]	



[Pole]



4. Scrape residue off of both of the mating faces. Place each part into a vise with a mating side facing up. Scrape the mating faces with the tip of X-acto knife to remove corrosion and redeposited oxides. The goal is to get the surface clean and rough for gluing without making any major dimensional changes. The knife tip should be fresh and sharp. This is a slow process, similar to mowing a lawn. Work diagonally from on corner to the opposite corner. Once the face is clean and bare metal is exposed, do some scraping in the opposite diagonal direction to roughen the surface with cross-hatch pattern so it will accept glue.



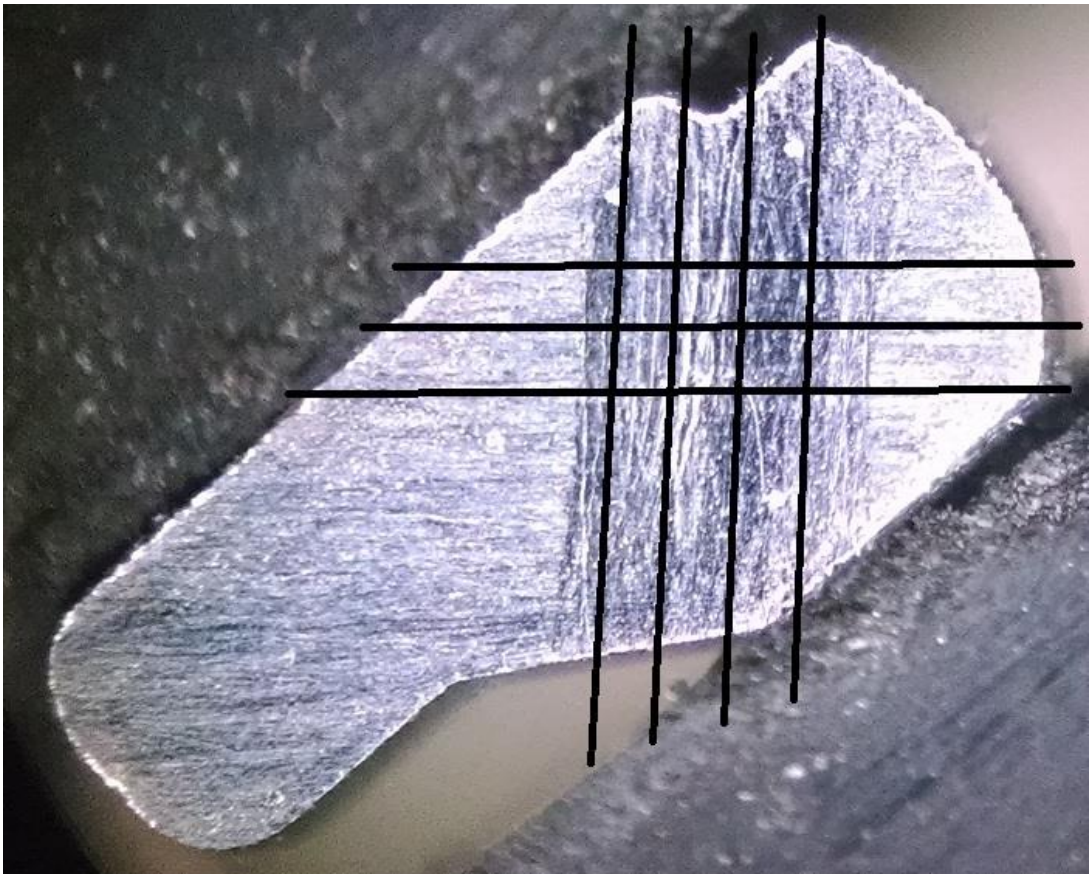
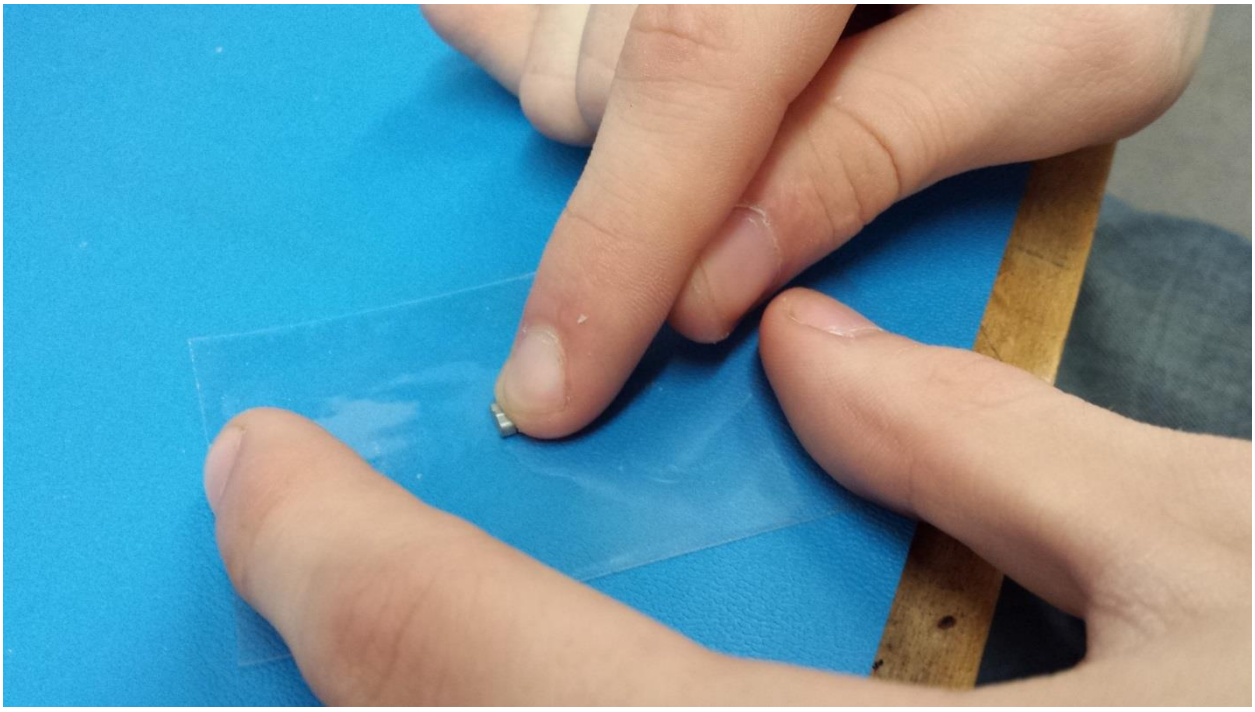


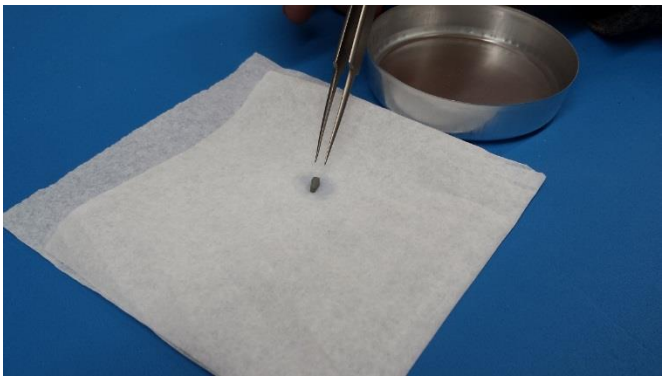
Figure 1: EPM Pole Middle. Lines indicate direction of scraping with the X-acto knife. One side is completed (3 lines) and the other direction is in process (4 lines).

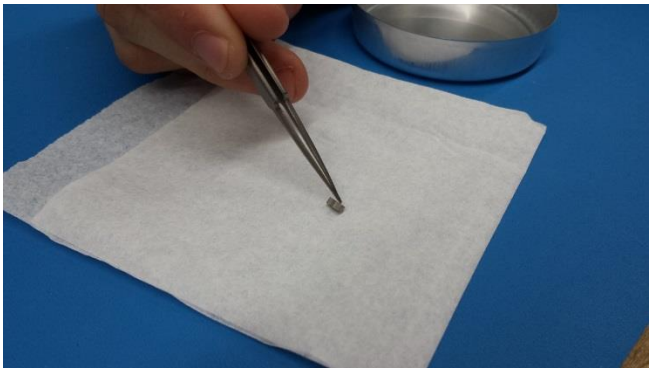
5. Unroll some packing tape and place it face up on the workbench. Roll the part on the packing tape to remove filings, contamination, dust, and rust until no residue is seen when each face is pressed against the tape and pulled straight up.



6. Pour enough isopropanol into a dish to completely cover parts. Swirl the parts in the isopropanol for 20-30 seconds to remove waxy and greasy deposits.

7. Remove parts from isopropanol and place on a fresh Kimwipe. Roll parts on Kimwipe to dry.





8. Inspect the parts. If the mating faces are absolutely clean and free of corrosion and particulates, you are done. Otherwise, repeat steps 4-7.

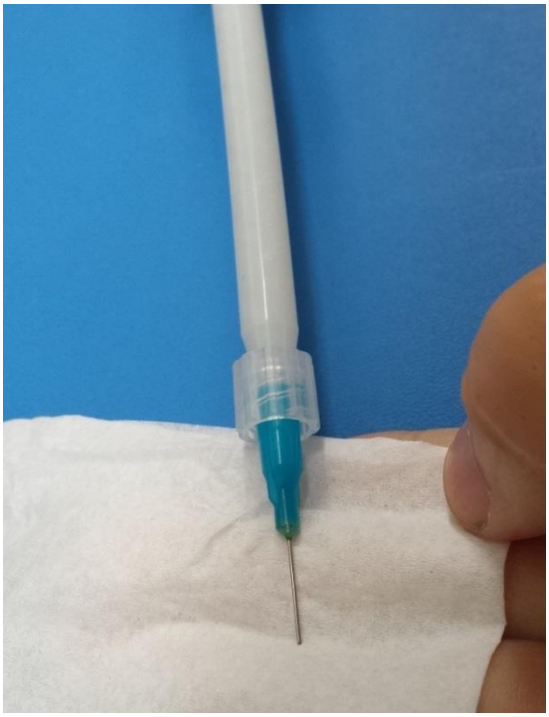
9. Make a fresh, clean dish of isopropanol. Place parts into it when done with inspection. Note: Do not leave parts in isopropanol overnight as the liquid will evaporate and leave deposits on the parts which will have to be cleaned again. Unused parts should be stored in a clean, dry container.

10. Repeat steps 2-10 for EPM Alnico Magnets, EPM Neodymium (North) Magnets, and EPM Neodymium (South) Magnets. <u>Keep the different parts separate in labelled dishes</u>. Be careful with the magnets; they are tiny and can easily get lost if extreme care is not taken in handling. Do not remove them from the workbench, and do not handle with anything except titanium tweezers. Also, note that the 2 types of EPM Neodymium magnets look exactly the same by eye: <u>Do not confuse these parts</u>. If you are unsure of whether an EPM Neodymium magnet is positive or negative, use the Magnetic Field strength meter to check. Do not ultrasonicate, as it is too easy to lose magnets when removing or placing in the ultrasonicator.

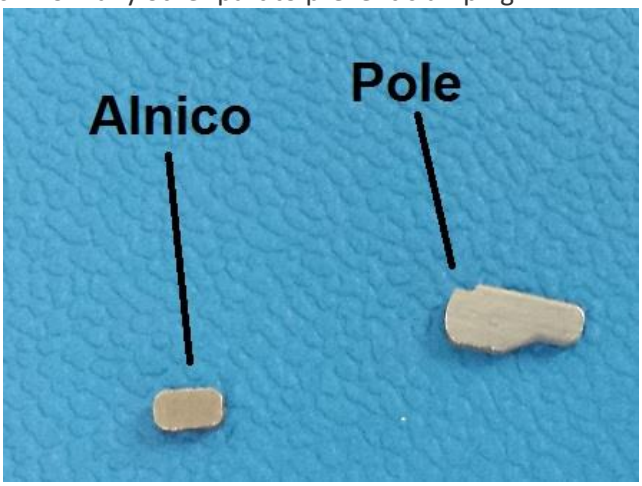
11. This step marks the transition from dirty work to clean work. Clean and put away the file. Discard any dishes of dirty isopropanol. If there is any dried glue residue on the microscope stage, tweezers, or knife, remove it by scraping with a knife. Clean everything by wiping down with isopropanol. Wash your hands with soap and water.

12. As parts are needed in subsequent steps, remove from isopropanol and dry by lightly rolling on Kimwipe (see Step 7).

13. Prepare glue. Place glue cartridge into 2:1 dispenser. Install mixing tube onto glue cartridge. Dispense about 1 cc of waste glue into a Kimwipe to prime the flow of glue through the mixer and ensure that the glue that is used on the parts is well-mixed. Screw the "Ford Blue" needle onto the dispenser and dispense a bead of glue through it into a Kimwipe. Note: Glue has 1 hour work time and will harden. If glue hardens, remove and discard mixing tube and needle, and repeat this step to prepare glue with new mixing tube and needle.

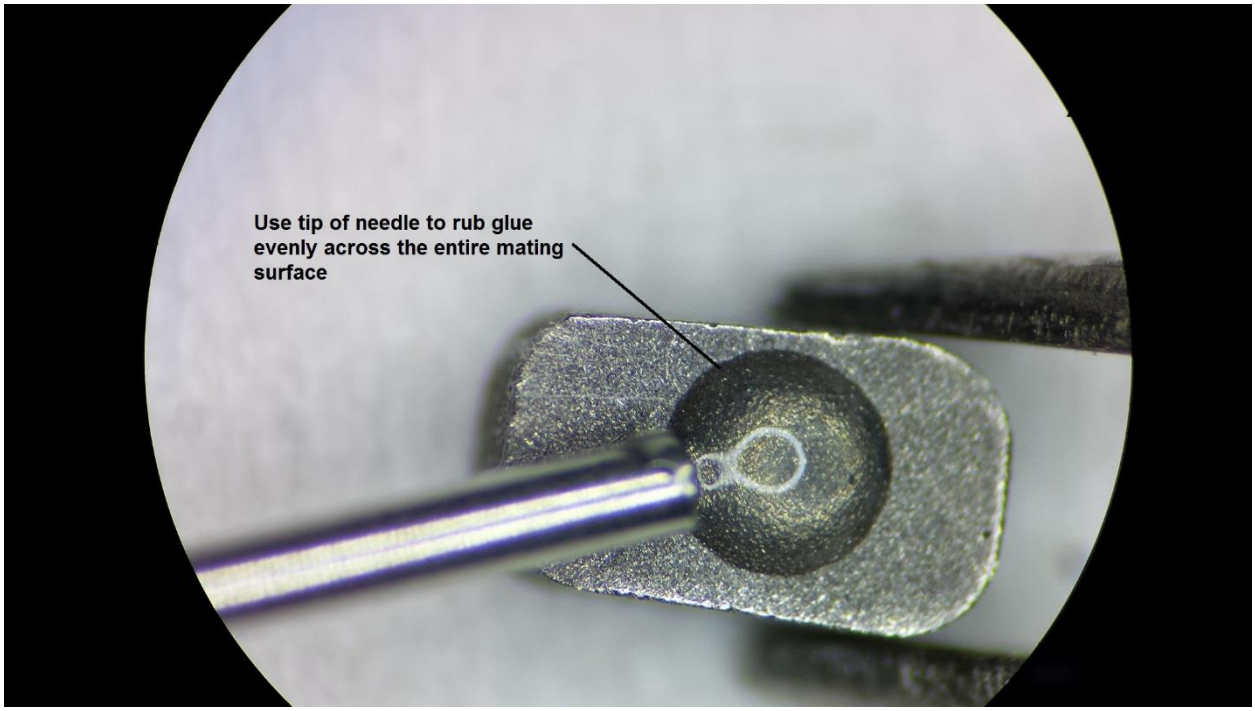


14. Pair a Pole with an Alnico Magnet. Pick one Pole End and one Alnico Magnet and set parts in a dry tray at least one inch from any other part to prevent clumping.

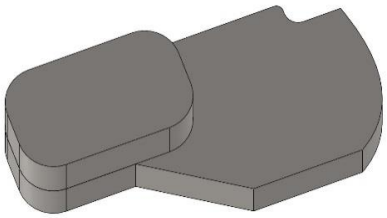


15. Pick the Alnico Magnet and place on microscope stage so that the image below is what you see in the microscope.

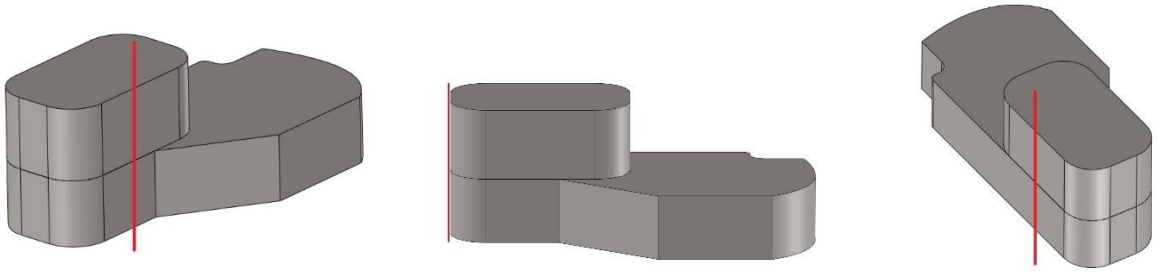
16. Cover the exposed mating side of Alnico Magnet with glue. To do this, hold it with tweezers with one hand, while dispensing a drop of glue with the other hand. Then, rub glue onto surface with needle until entire surface is coated.



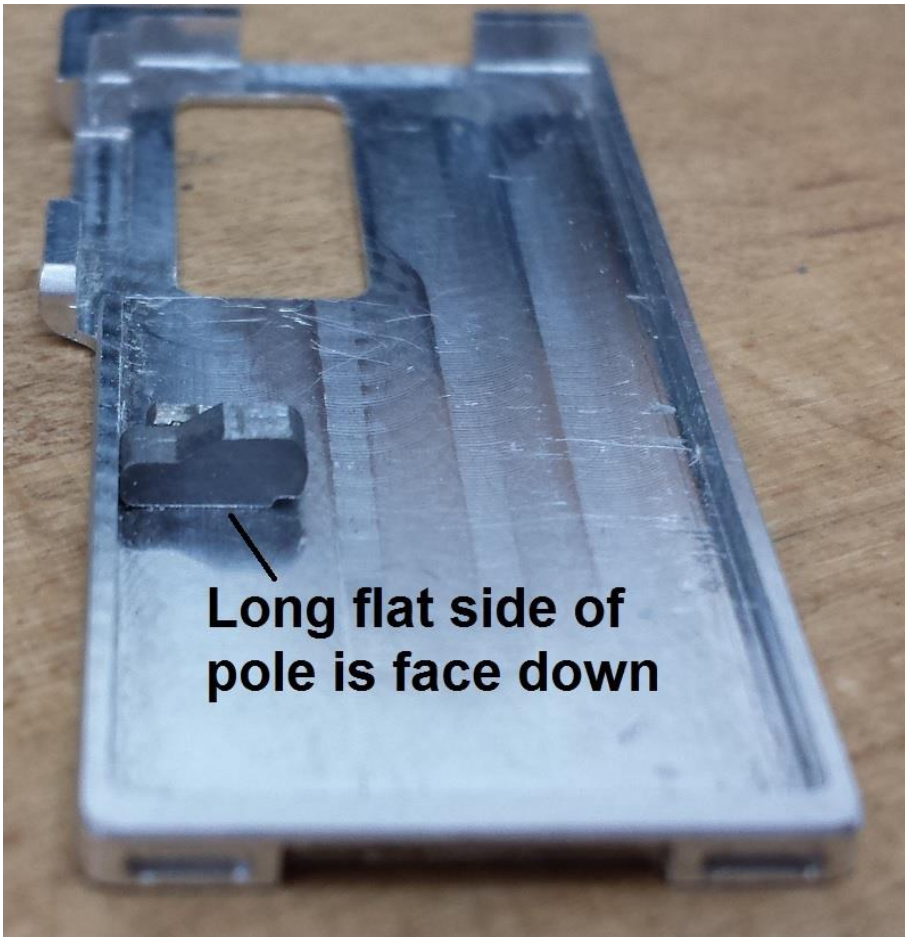
17. Glue the Pole End and Alnico Magnet together. Pick up the Pole End with tweezers and the Alnico Magnet with tweezers. Hold the Pole End down on the microscope stage with tweezers and roughly align the Alnico Magnet on top of it as shown in the image below with the wet glue between the 2 parts.



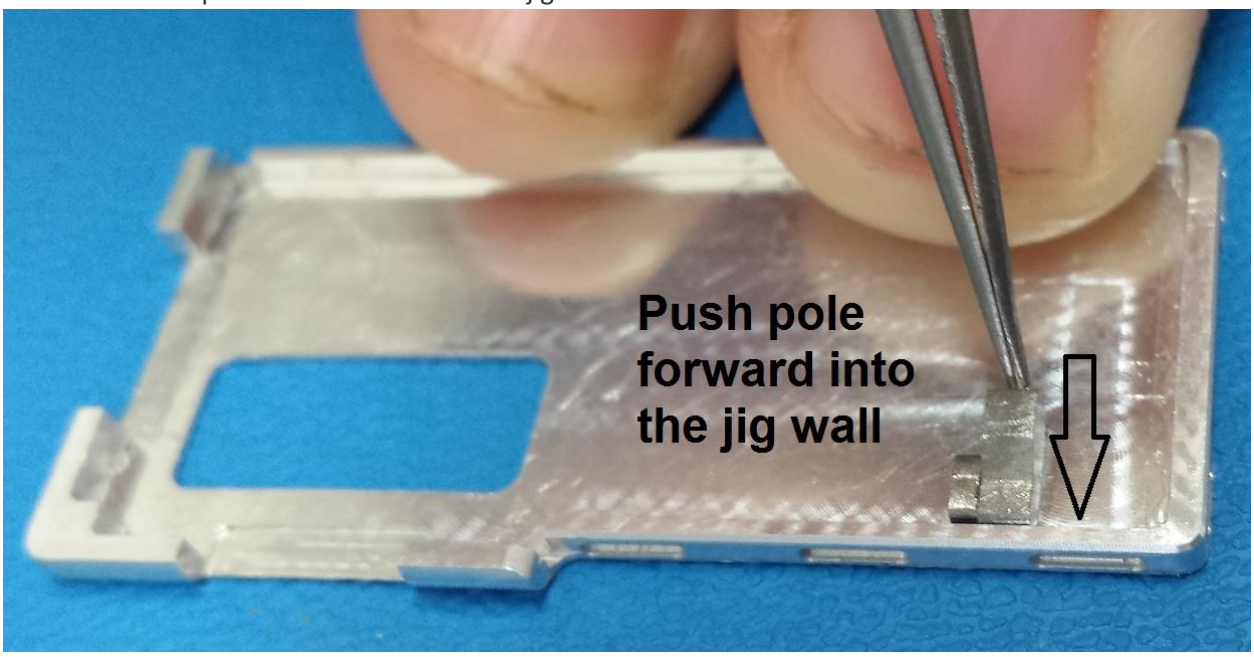
18. Aligning the glued pair. Use the Pair Alignment Jig to align the pair so that the Alnico Magnet is aligned with the Pole End on the three sides indicated with the red line below.



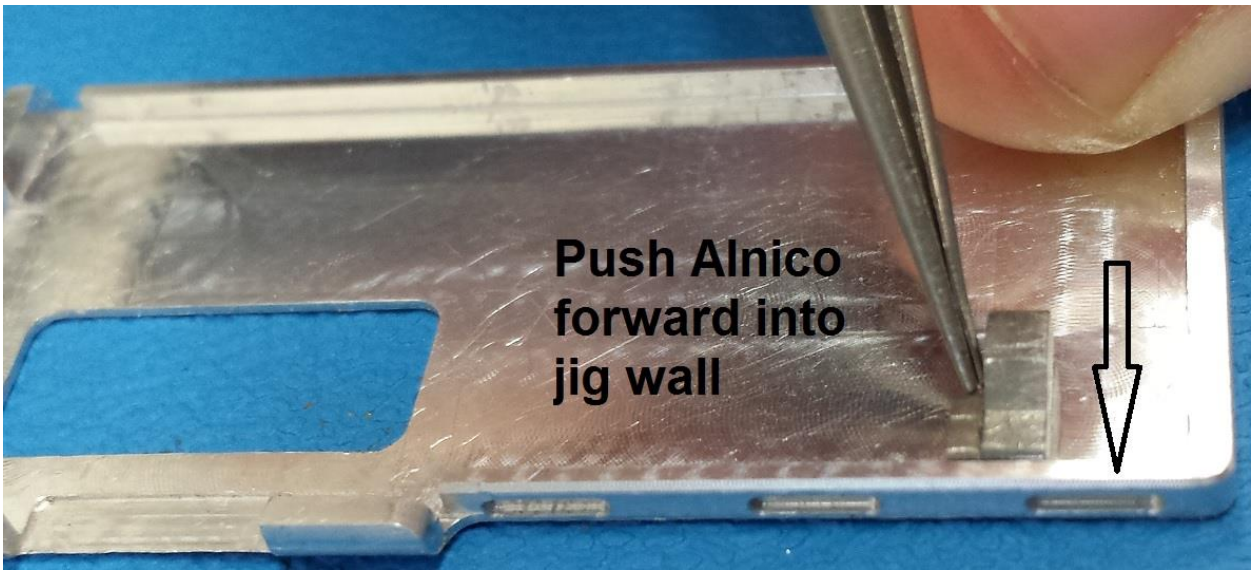
a) Place pair on jig in the orientation shown below.



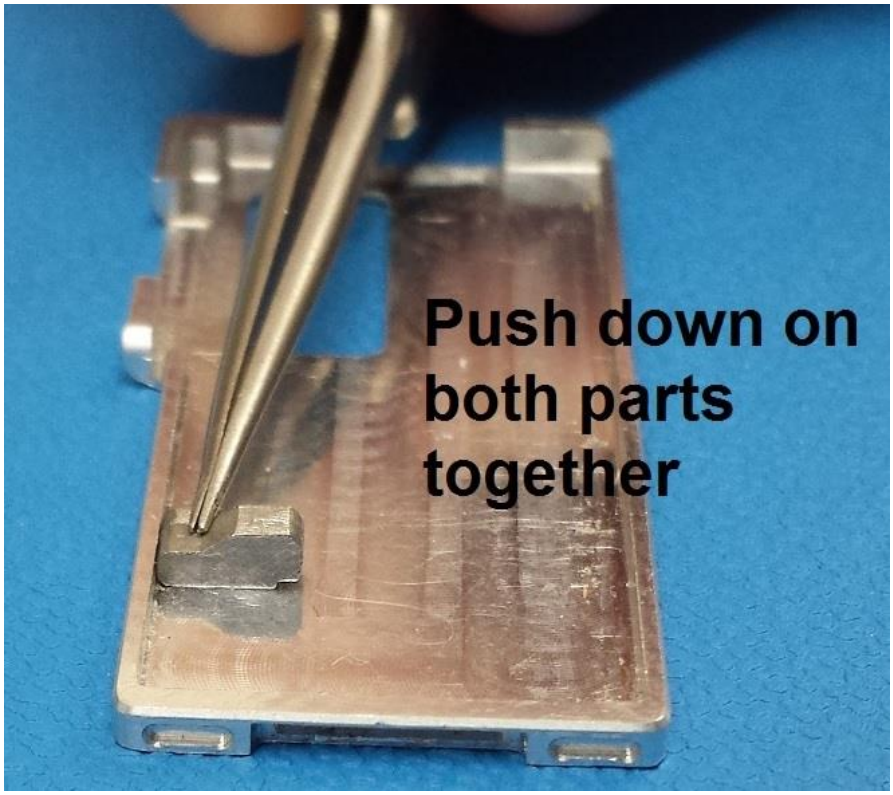
b) Use tweezers to push Pole forward into the jig wall.



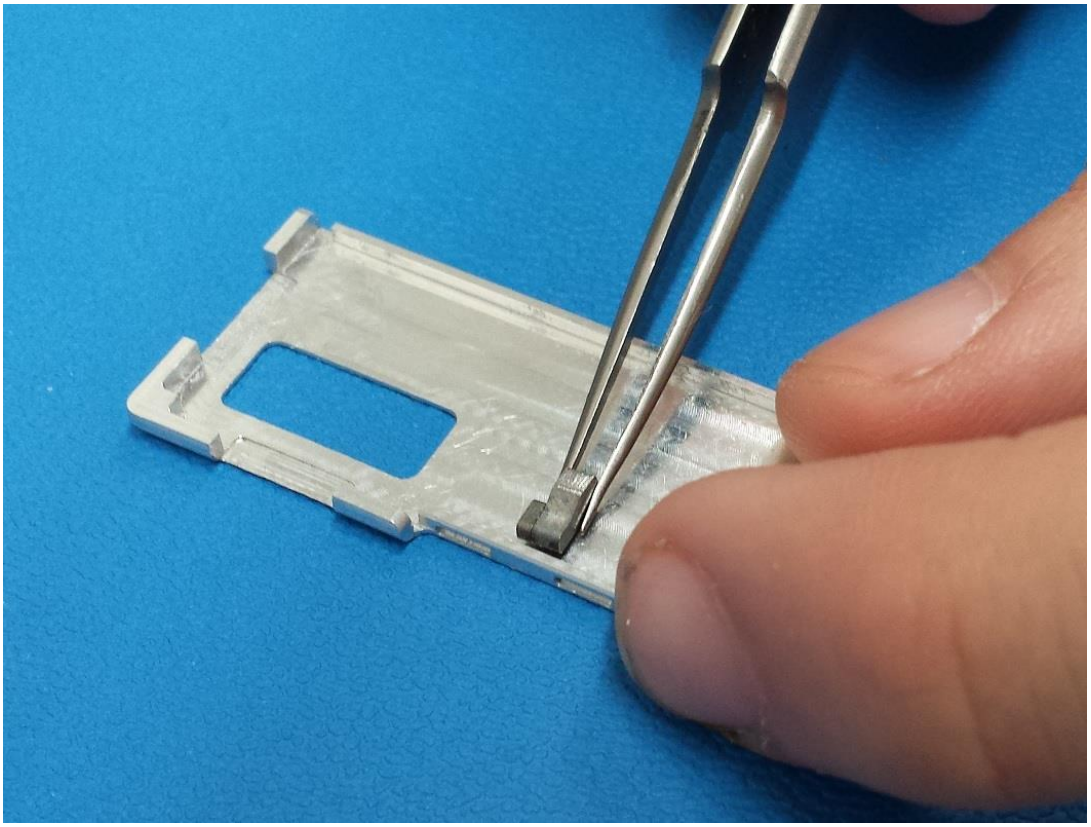
c) Use tweezers to push Alnico forward into the jig wall.



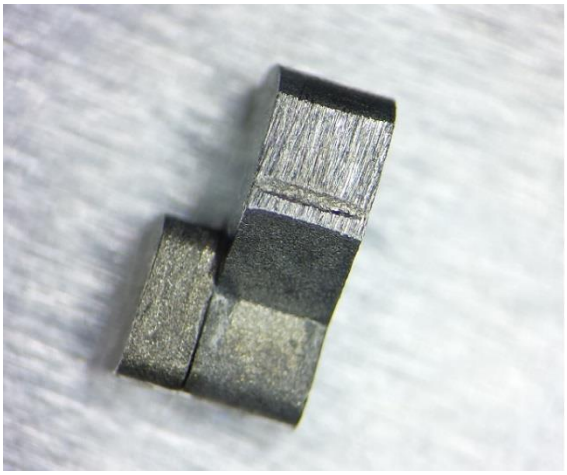
d) Use tweezers to push down on both the Pole and Alnico together to align them vertically.

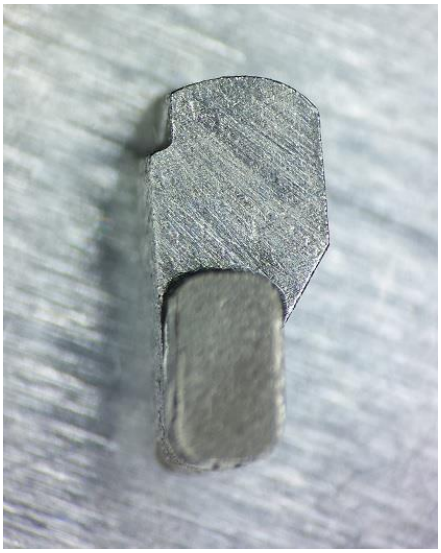


e) Use tweezers to pick up the Pole / Alnico pair. Pick up the pair by the Pole piece only. Use your other hand to hold the jig down while removing the pair.



f) Inspect the parts under the microscope. The parts should be aligned as shown in the beginning of step 18.

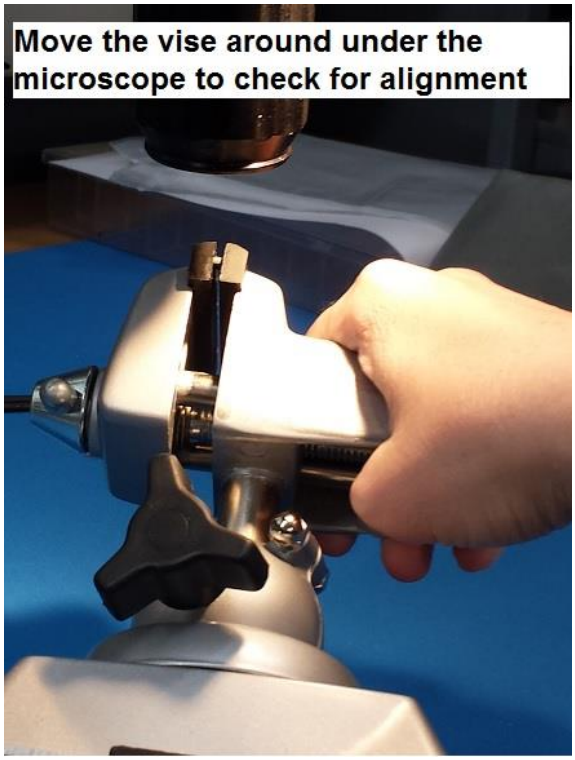


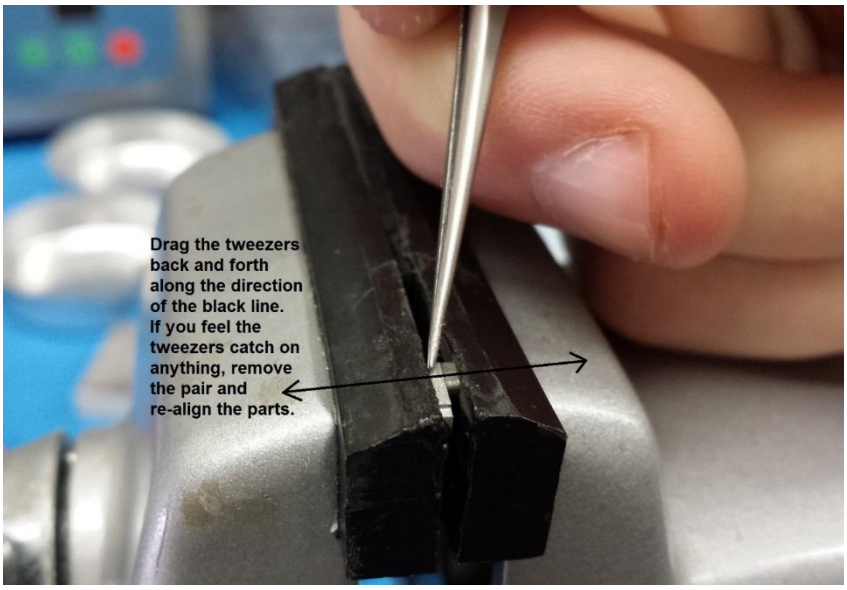


g) If parts do not look aligned under the microscope, repeat step 18 from the beginning.

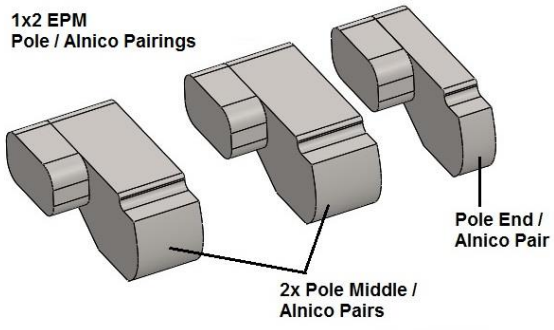
19. Gently place assembly into a vise and clamp. Place the pair in an upper corner of the vise so that three sides of the pair will be viewable under a microscope while in the vise.

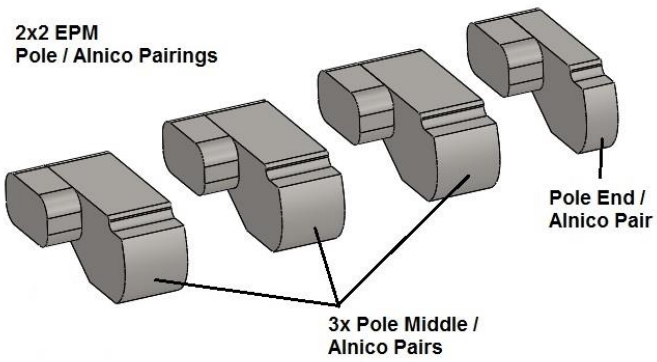
20. Wipe off any excess glue. Visually inspect the parts under a microscope. If it appears that there has been any movement from perfect alignment while clamping, remove and repeat steps 18-19. [OPTIONAL: In addition to a visual inspection, you can use tweezers to ensure that the parts are aligned. Drag the tweezers back and forth across the 2 parts and see if you feel the tweezers catch on any misaligned edge. If you feel the tweezers catch, repeat steps 18-19.]





21. To make enough pairs for a 1x2 EPM Assembly, repeat steps 14-20 two more times using Pole Middles instead of a Pole End. To make enough pairs for a 2x2 EPM Assembly, repeat steps 14-20 three more times using Pole Middles instead of a Pole End. When completed, you should have the following pairs created and curing in vises:

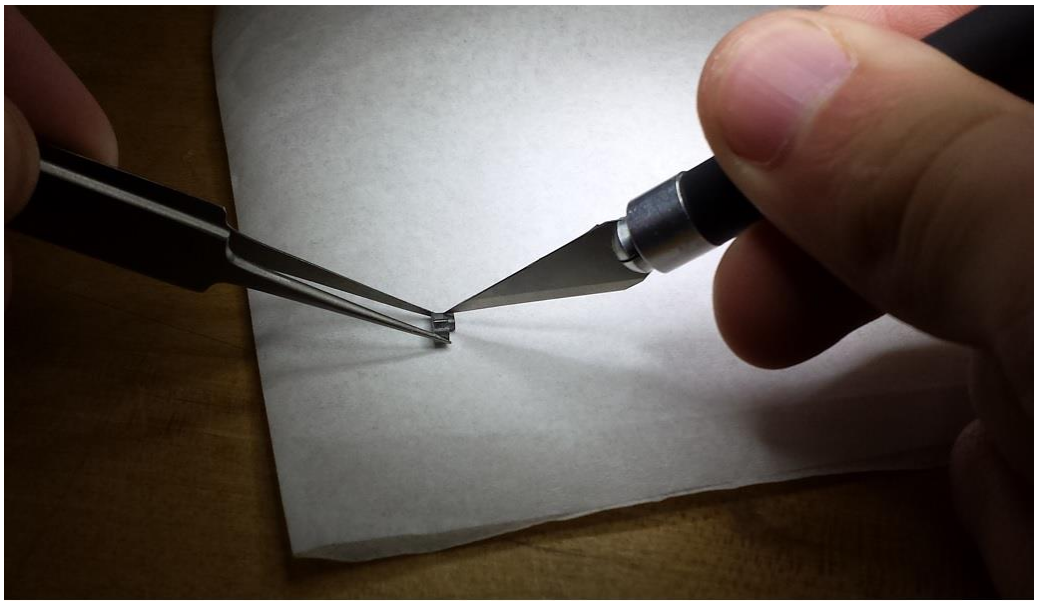




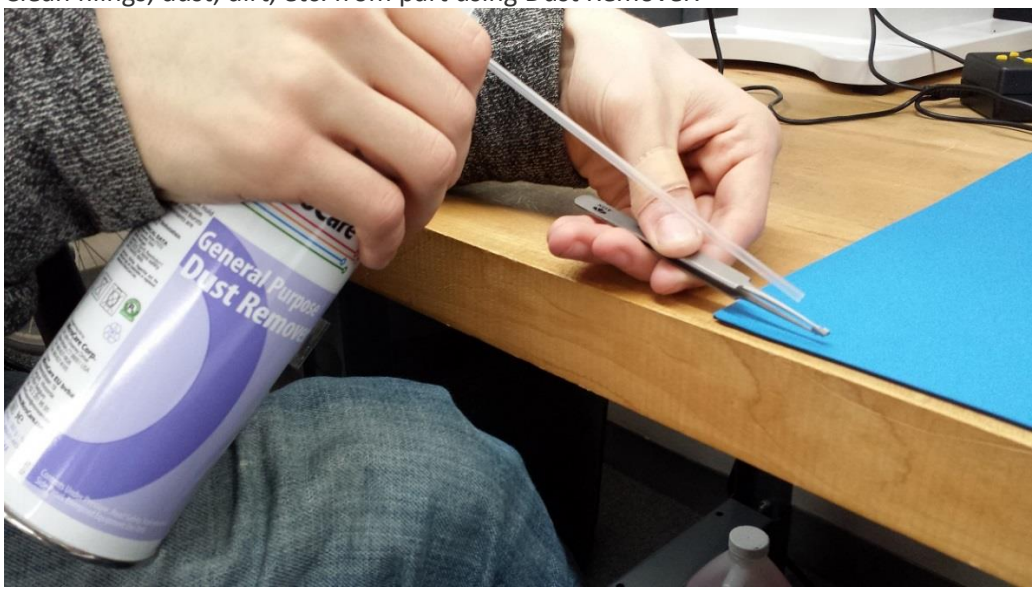
22. OPTIONAL: Place vise and part into oven, preheated to 50 C. Allow glue to cure in oven for 2 hours. Place vise and part into oven, preheated to 50 C. Allow glue to cure in oven for 2 hours. Remove part from oven and allow to air cool for a few minutes. [Preferred: Cure for 24 hours at room temperature].

23. Remove parts from vises. After 24 hours (room temperature curing) or 2 hours (oven curing), remove the pairs from the vises.

24. Scrape excess dried glue from Alnico / Pole pair. Hold the pair down with tweezers on the microscope stage. Use an X-acto knife and/or file to remove glue residue. Too much glue residue may interfere with the coil fitting around the Alnico. Warning: Do not push the X-acto knife between the two parts or you might wedge them apart.

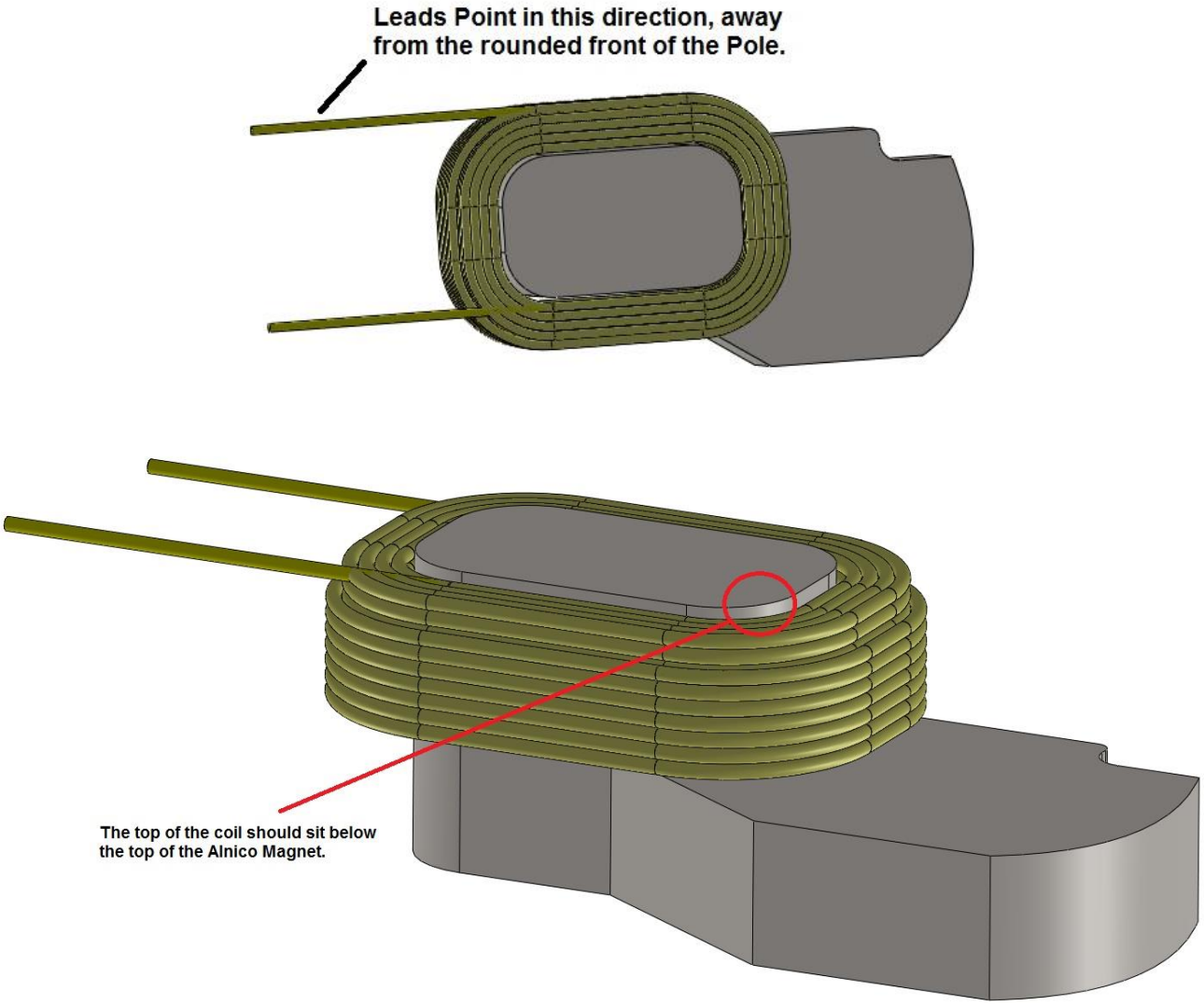


25. Clean filings, dust, dirt, etc. from part using Dust Remover.



Process: Completing the Assembly of a 1x2 or 2x2 EPM

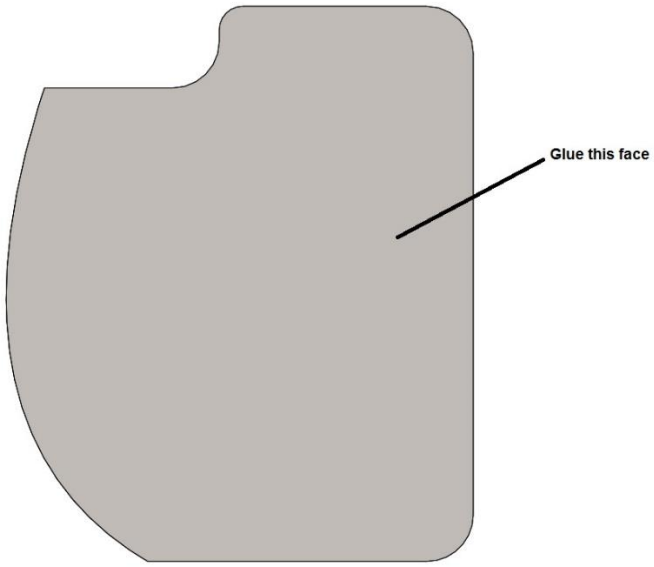
26. Attach a coil to Pole / Alnico Pair. Pick up a Pole End / Alnico pair with tweezers and hold it down on the microscope stage.
    a. Inspect the coil. If you see any tears in the coil wire, discard the coil, select a new one, and repeat step 26a.
    b. With your fingers, pick up a coil and place it around the Alnico magnet. The coil should smoothly fit over the Alnico without having to use force. The leads of the coil should face in the direction shown below and the coil should not protrude above the top of the Alnico. The coil wire is very delicate, so handle gently and avoid grabbing it with tweezers. .



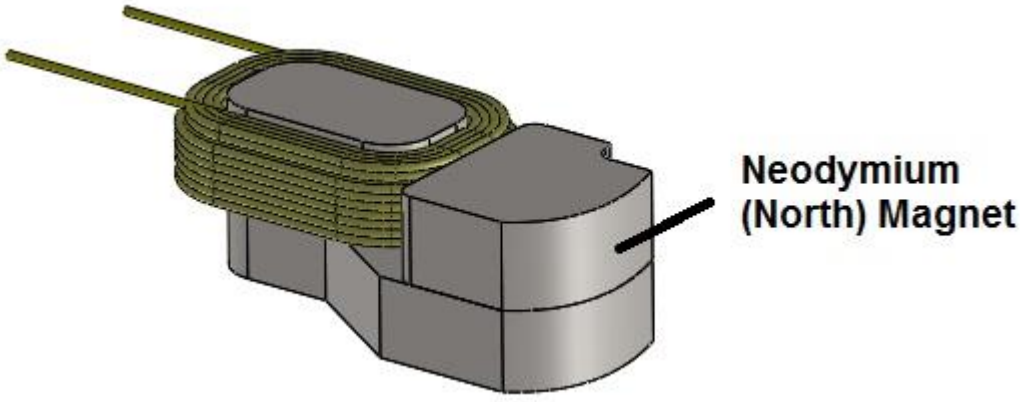
27. Repeat step 28 using Pole Middle / Alnico pairs. For a 1x2 EPM you will need two Pole Middle / Alnico pairs. For a 2x2 EPM you will need three Pole Middle / Alnico pairs.

28. Place your 3 or 4 pairs with coils into a dry dish and set aside.

29. Select a Neodymium (North) Magnet. All of the Neodymium magnets look exactly the same, and it is very important that the North and South Neodymium magnets do not get mixed up. If you are unsure which type you have selected, test it with your Magnetic field strength meter to confirm that you have a Neodymium (North) Magnet.
30. Cover one mating side of Neodymium (North) Magnet with glue. To do this, hold it with tweezers in one hand, while dispensing a drop of glue with the other hand. Then, rub glue onto surface with needle until entire surface is coated. Be sure that you apply glue on the correct side of the magnet.

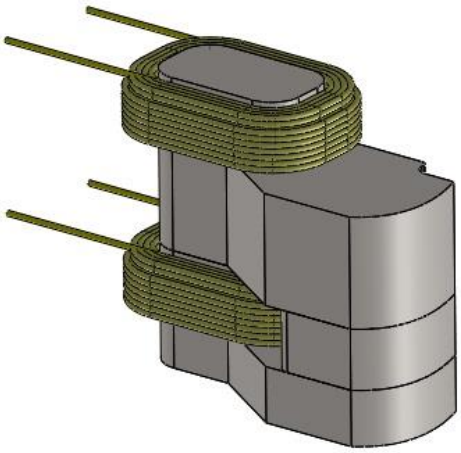


31. Glue the Neodymium (North) Magnet to the Pole End / Alnico Pair. Use tweezers to select the Pole End / Alnico pair and place it on the microscope stage, coil side up. Hold it with tweezers in one hand. In your other hand, hold the Neodymium (North) Magnet with tweezers and place it onto the exposed mating face of the Pole End so that the rounded edges are roughly aligned. Note that the Neodymium magnet will be magnetically attracted to the Pole End.

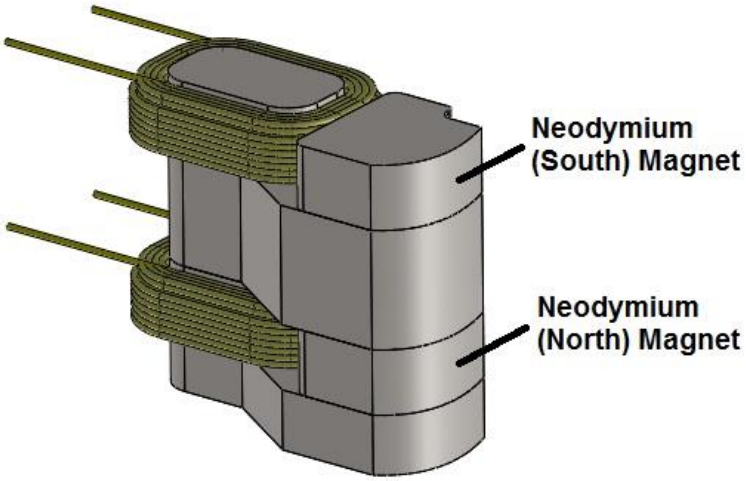


32. Cover the exposed sides of the Alnico and Neodymium Magnets with glue. To do this, hold the assembly on the microscope stage with tweezers in one hand, while dispensing a drop of glue with the other hand on the Alnico Magnet and a second drop of glue onto the Neodymium Magnet. Then, rub glue onto surface with needle until entire surface is coated. Note that the glue tip will be attracted to the Neodymium Magnet.

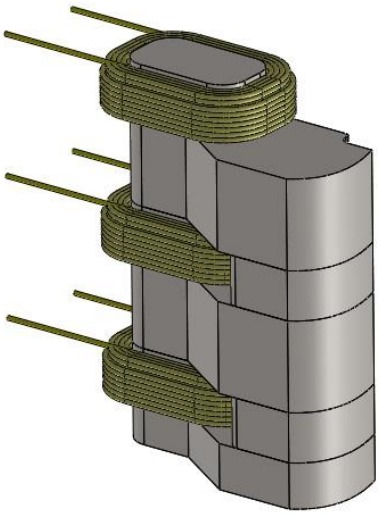
33. Glue a Pole Middle / Alnico Pair to the current assembly. Hold the current assembly on the microscope stage and select one of the Pole Middle / Alnico Pairs. Attach the pair to the current assembly, coil side up. Roughly align the front rounded edges together.



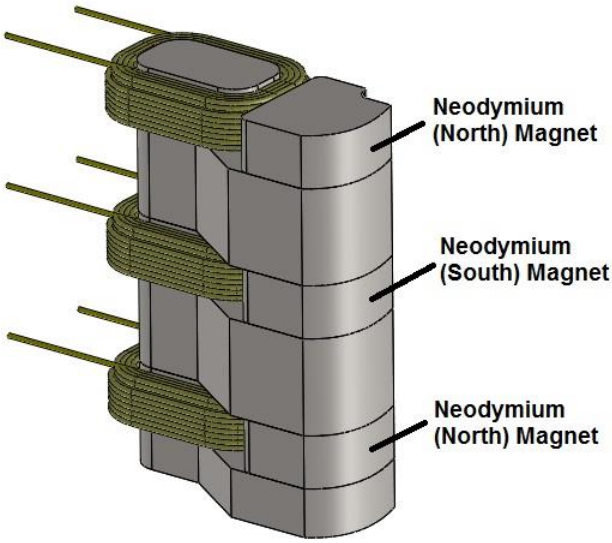
34. Repeat steps 29-31 but with a Neodymium (South) Magnet.



35. Repeat steps 32-33.

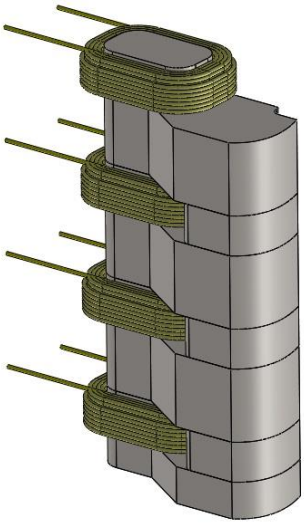


36. Repeat steps 29-31 with a Neodymium (North) Magnet.

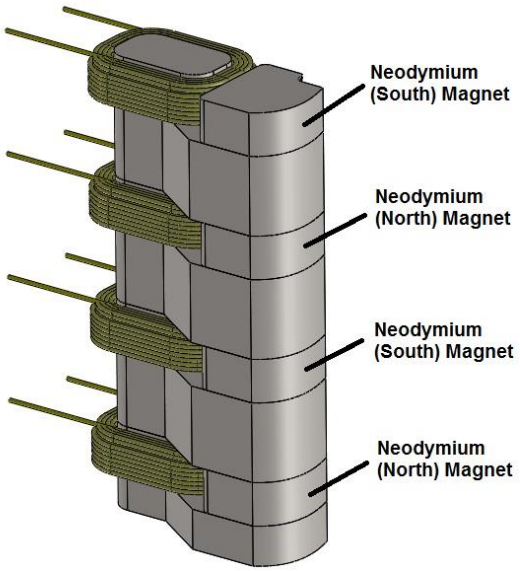


37. If you are building a 1x2 EPM, skip to step 40.

38. If you are building a 2x2 EPM, repeat steps 32-33.

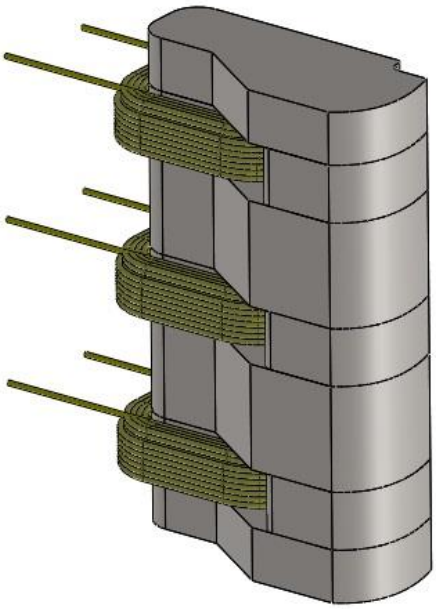


39. If you are building a 2x2 EPM, repeat steps 19-31 but with a Neodymium (South) Magnet.

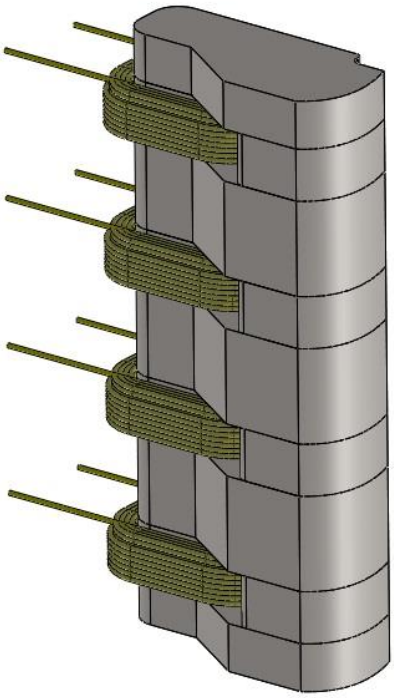


40. For the final time, cover the exposed sides of the Alnico and Neodymium Magnets with glue. To do this, hold the assembly on the microscope state with tweezers in one hand, while dispensing a drop of glue with the other hand on the Alnico Magnet and a second drop of glue onto the Neodymium Magnet. Then, rub glue onto surface with needle until entire surface is coated. Note that the glue tip will be attracted to the Neodymium Magnet.

41. Glue final Pole End to the current assembly. Hold the current assembly on the microscope stage and select one of the Pole Ends. Attach the Pole End to the current assembly roughly align the front rounded edges together.

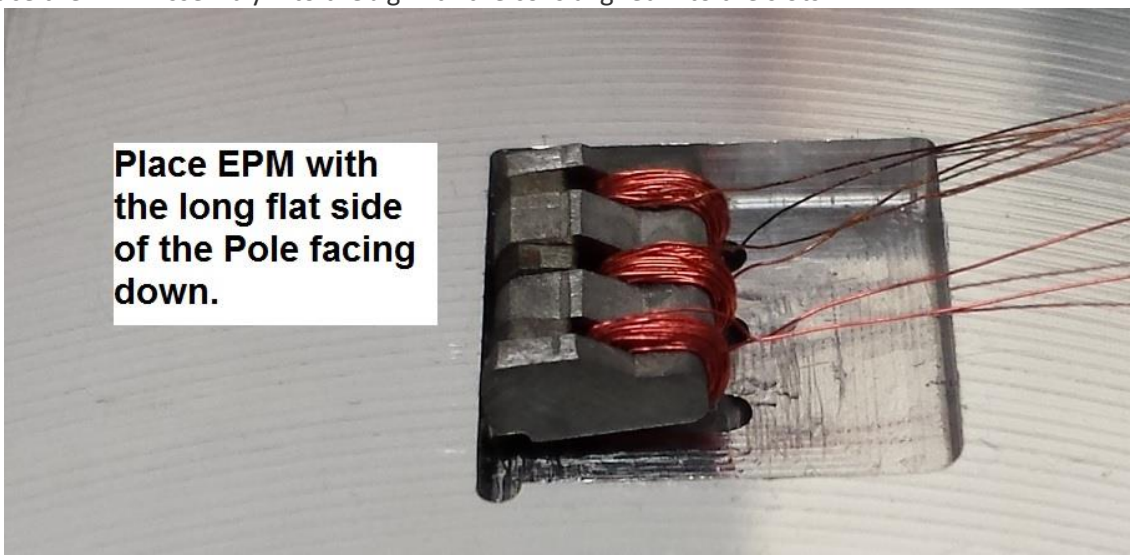


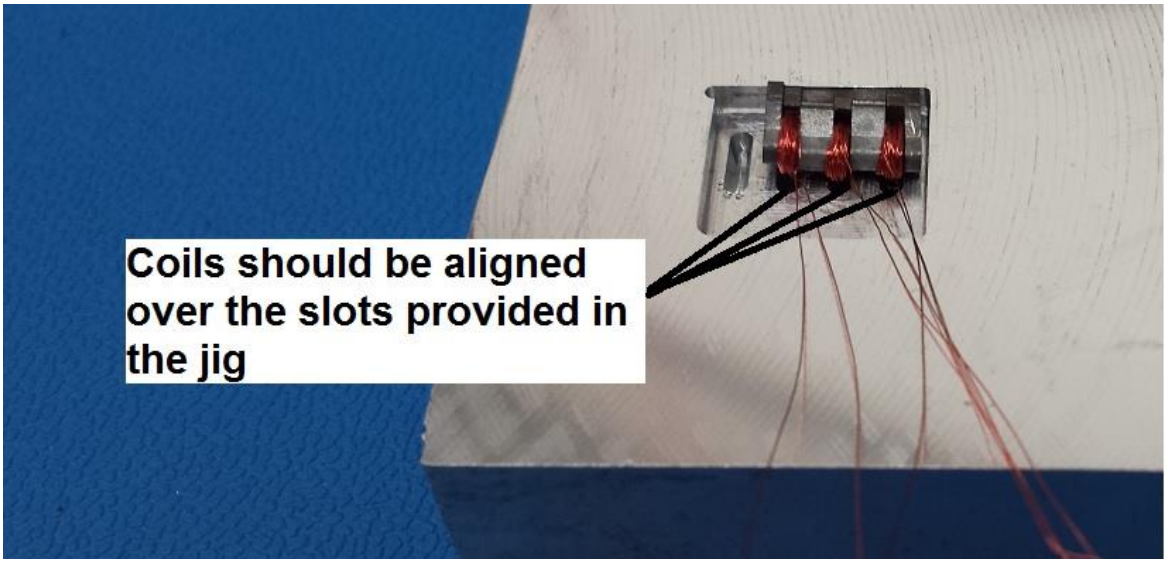
1x2 EPM



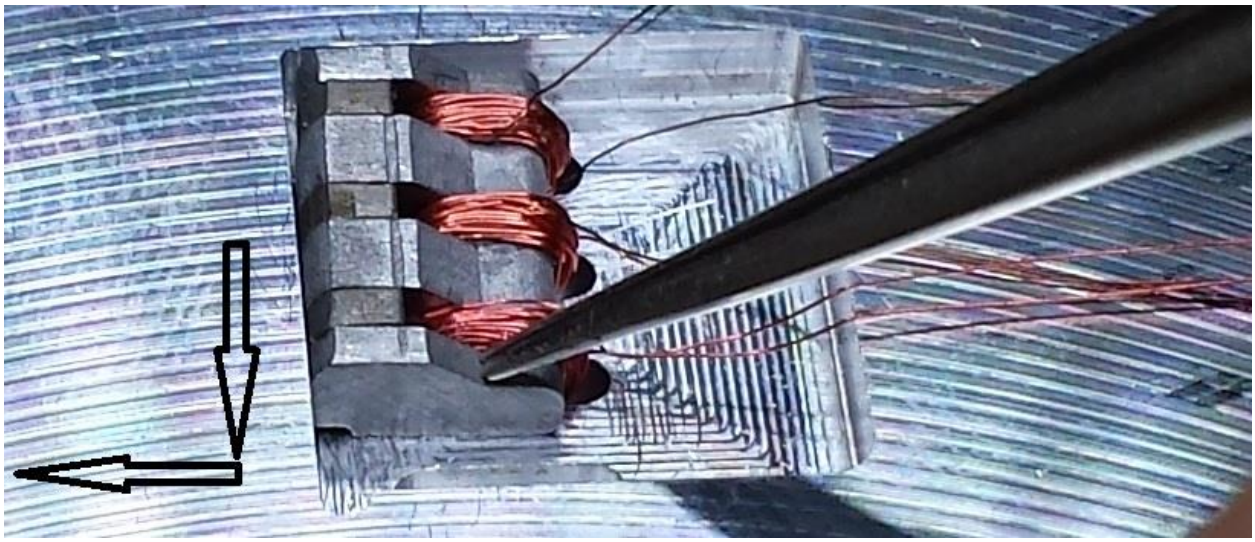
2x2 EPM

42. Align the final assembly using the EPM Alignment Jig. Place the EPM Alignment Jig onto the microscope stage. Place the EPM Assembly into the Jig with the coils aligned into the slots.



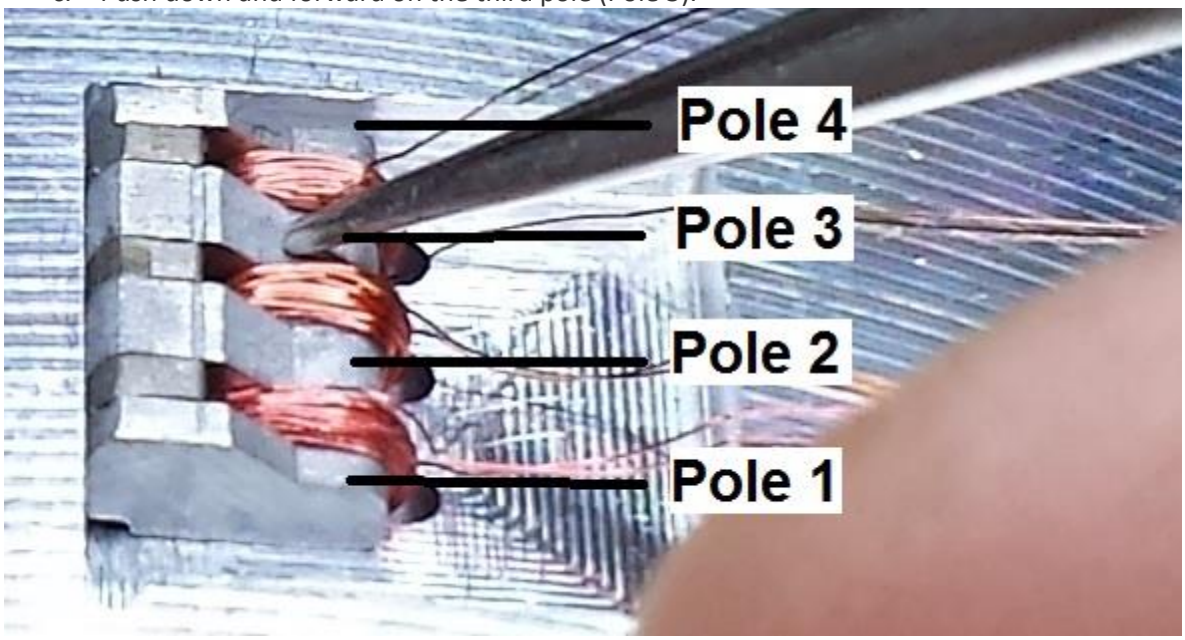


43. Use tweezers to gently push the Poles into alignment. Use the tips of the tweezers to push down and forward into the wall of the jig on the Poles. Pushing down will align all of the tops while pushing forward will align all of the rounded front ends.
    a. Push down and forward on the pole nearest to you (Pole 1).



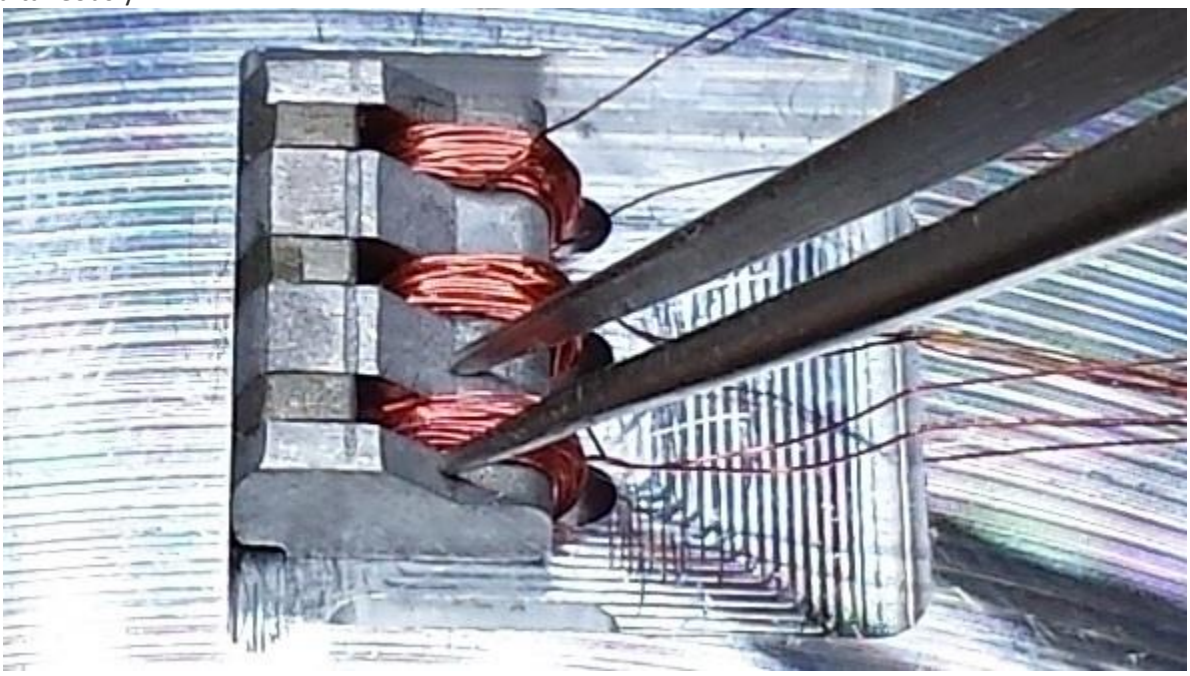
b. Push down and forward on the second pole (Pole 2).

c. Push down and forward on the third pole (Pole 3).

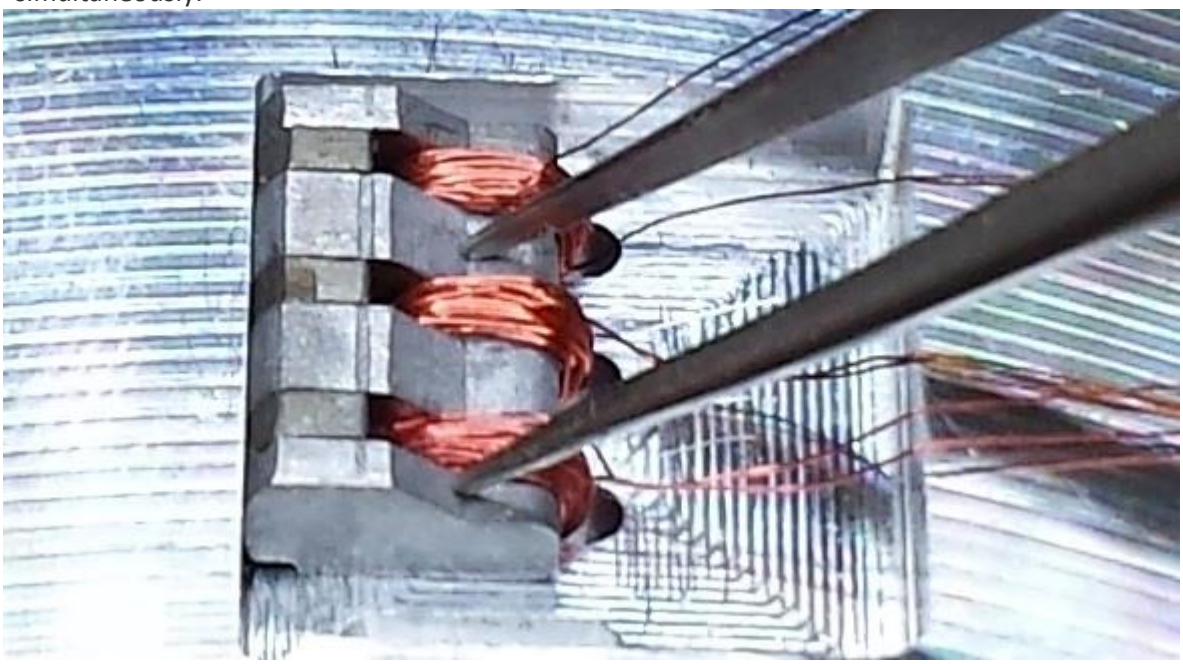


d. Push down and forward on the fourth pole (Pole 4). For 2x2 EPMs, also push on down and forward on the last pole (Pole 5).

e. Push down and forward on two poles at one. Start by pushing down on Pole 1 and Pole 2 simultaneously.

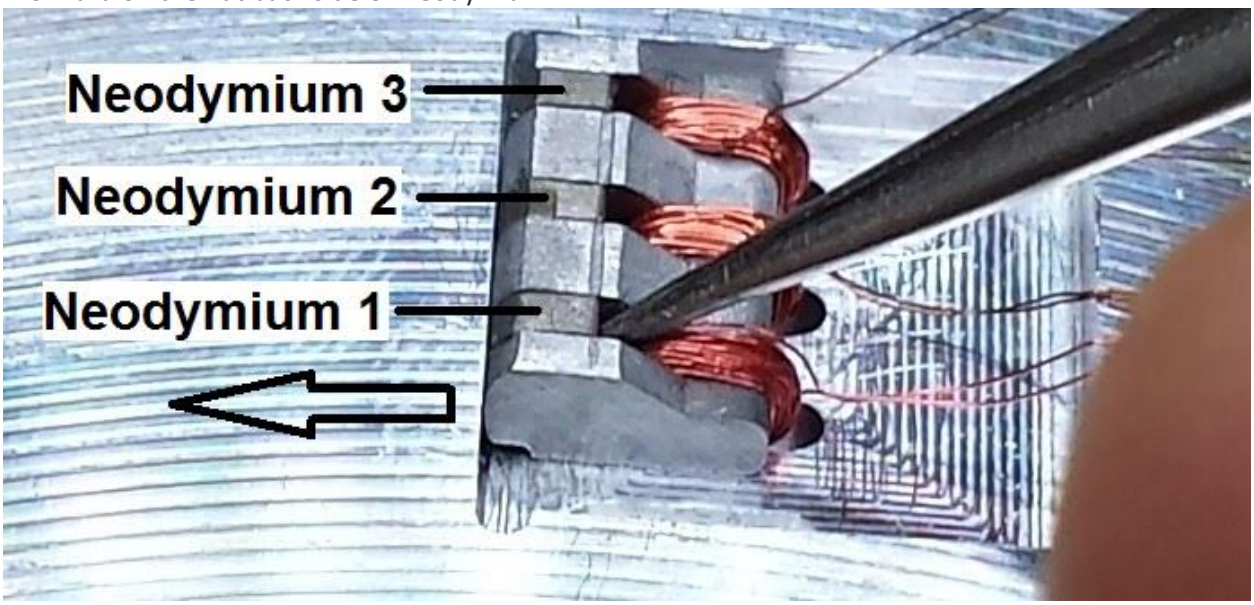


f. Push down and forward on two poles at one. Start by pushing down on Pole 1 and Pole 3 simultaneously.



g. Continue Pushing Down and Forward on 2 poles simultaneously in the following order
   i. Pole 2 and Pole 3
   ii. Pole 2 and Pole 4
   iii. Pole 3 and Pole 4
   iv. (2x2 EPMs only) Pole 3 and Pole 5
   v. (2x2 EPMs only) Pole 4 and Pole 5

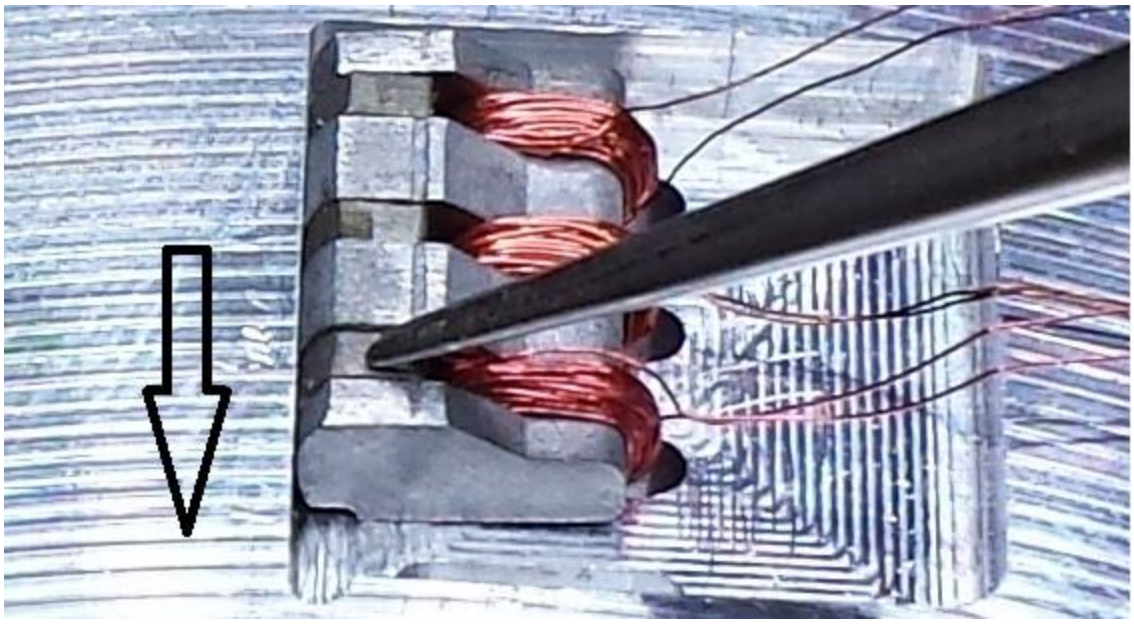
44. Use tweezers to gently push the Neodymium Magnets into alignment.
    a. Push forward on the flat back side of Neodymium 1.



    b. Push forward on the flat back sides of Neodymium 2 and Neodymium 3. For 2x2 EPMs, also push forward on Neodymium 4.

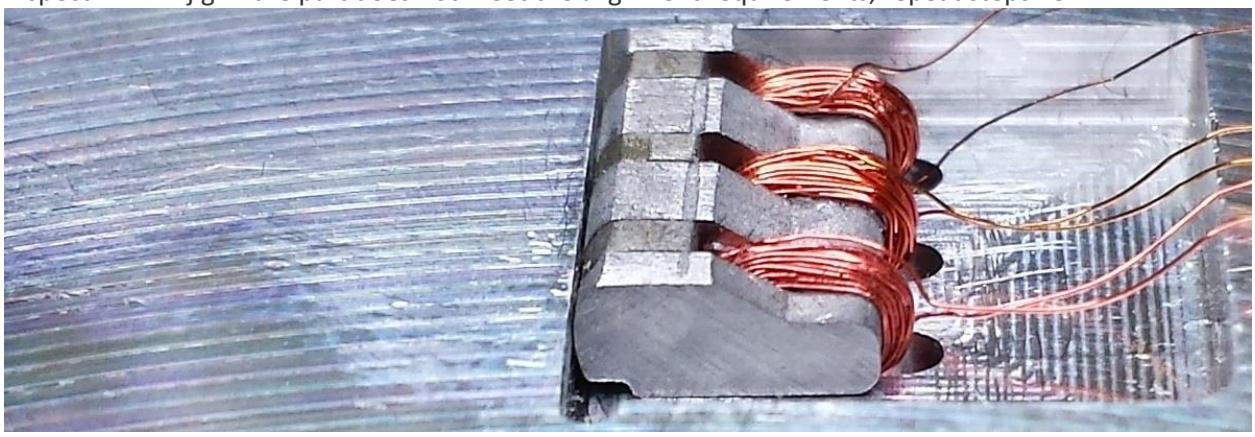
    c. Caution: If you push too much on the upper edge of the Neodymium pieces, they may tilt forward:

    d. Push down on the top flat side of Neodymium 1.

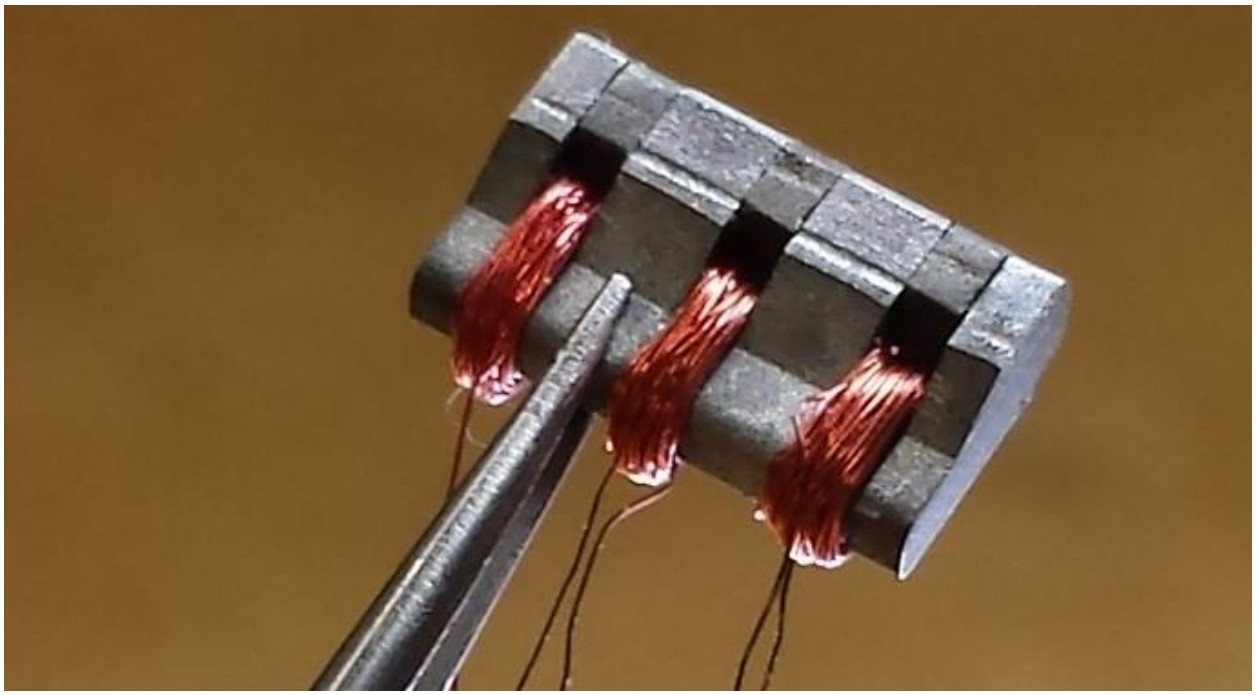


e. Push down on the flat top sides of Neodymium 2 and Neodymium 3. For 2x2 EPMs, also push forward on Neodymium 4.

45. Repeat steps 43-44 as needed until all the parts are no longer moving when you push on them with the tweezers.
46. Inspect EPM in jig. If the part does not meet the alignment requirements, repeat steps 43-44.

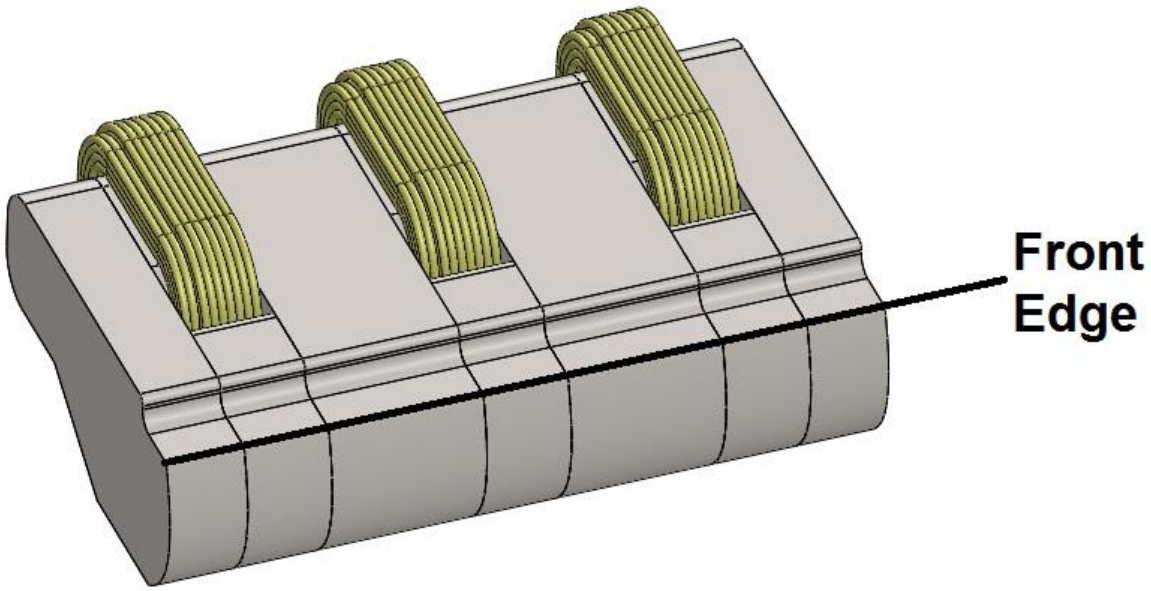


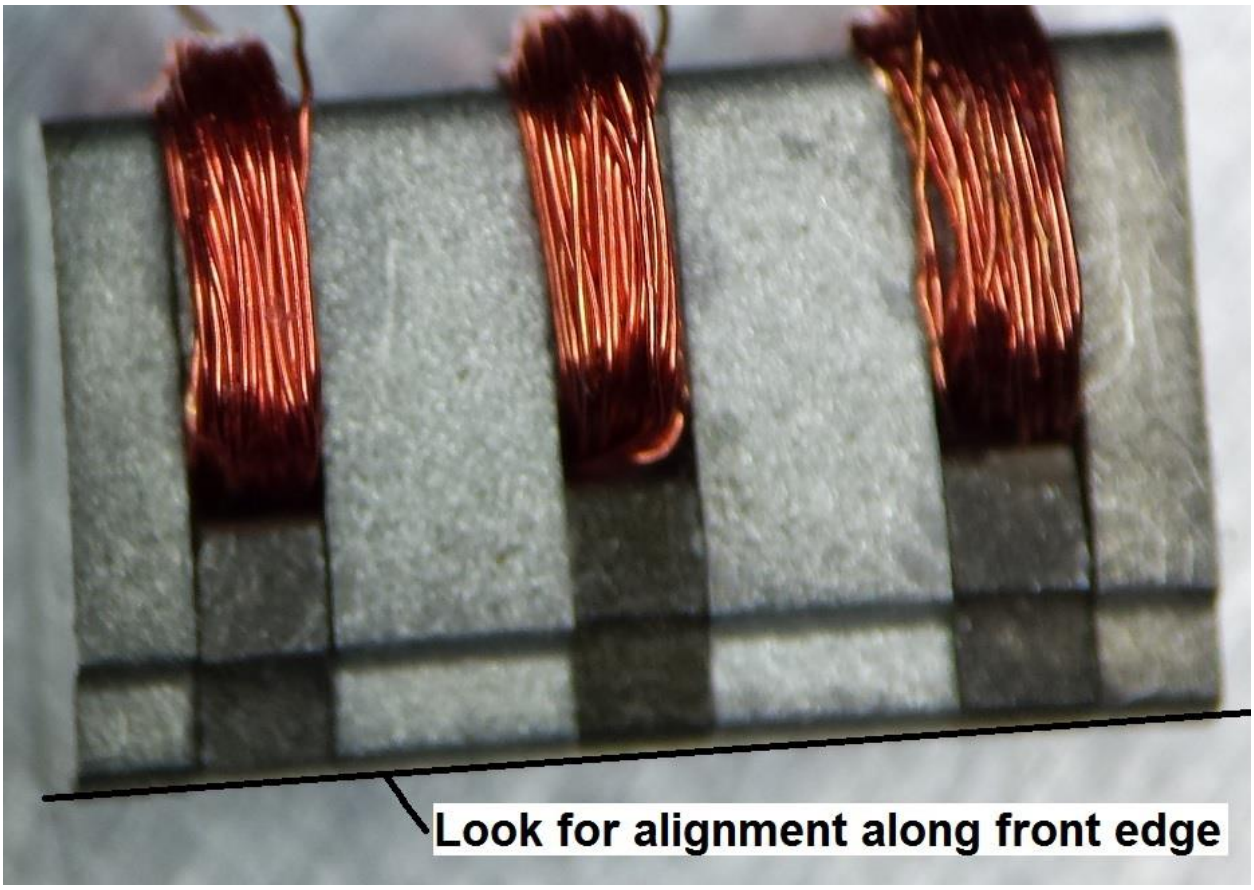
47. Carefully remove the EPM Assembly from the jig and inspect under the microscope.
    a. Use tweezers to lift the EPM up by one of the Middle Poles. **Do not** lift by the coil wires because the wires break easily. Hold the EPM by one of the Middle Poles only.



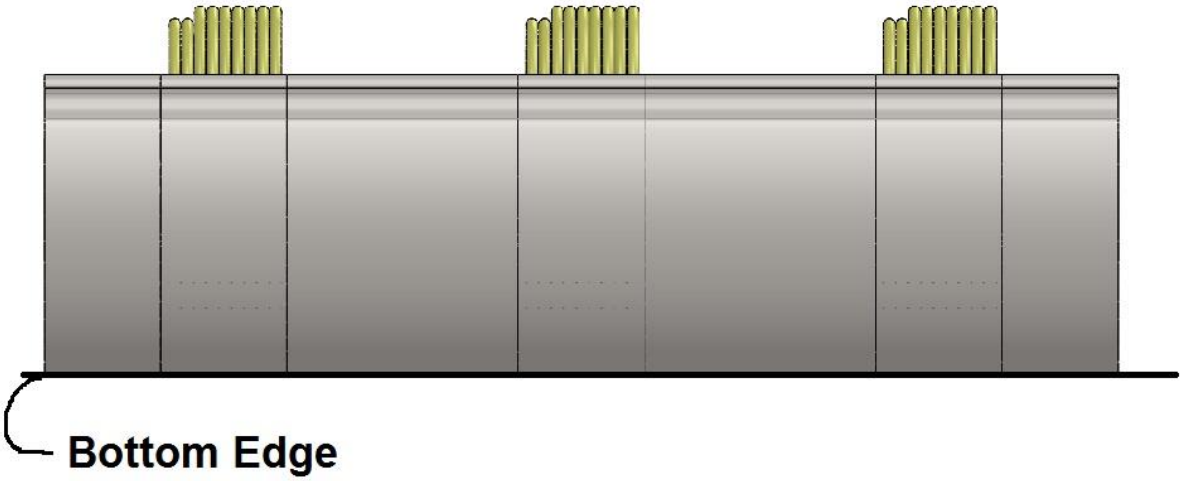
b. Inspect the coils to ensure that there are no breaks.

c. Inspect the EPM alignment on the microscope stage. Look at the front edge alignment. All front edges of Poles should be within +/-.05mm of the Front Edge reference line. Front edge of Neodymium pieces must not extend forward of any of its adjacent Pole pieces. Front edge of Neodymium pieces may be up to 0.1mm behind the front edge of its adjacent Pole pieces.





d. Inspect front view of EPM for alignment. Turn the front of the EPM towards you under the microscope. All Neodymium and Poles Bottom Edges should be within +/- 0.05mm of the Bottom Edge reference line.



e. If there is any Front Edge or Bottom Edge misalignment, go back and repeat steps 42 – 47.

48. Gently place assembly into vise and clamp.

49. Wipe off any excess glue. Visually inspect the parts. If it appears that there has been any movement from perfect alignment while clamping, remove and repeat steps 43-48.

Process: Final Inspection and Testing

50. After 24 hours at room temperature curing, remove the pairs from the vises.

51. Inspect under microscope. Use an X-acto knife and/or file to remove glue residue on the bottom mating faces (where the EPM Assembly will be glued to a Module Base).

52. Clean filings, dust, dirt, etc. from part using packing tape on the small mating area only.

53. Dip a Kimwipe in isopropanol and wipe small bottom mating area only. Pat area with a clean, dry Kimwipe.

54. Final inspection of part under microscope. Check that all coil leads are visible and no coil has any tears. Check that the assembly retained the tolerances laid out in steps 47c and 47d.

55. Place completed EPM Assembly in packing container.