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Super Cub: Making Carbon Fiber Door/Window Frames

A “looks cool” project to learn more about composites and implement yet another carbon fiber based set of components for my experimental Super Cub.

Above: Right side door/window frames completed using carbon fiber

Total weight saving thus far on the two right-side door/window frames: Close to three pounds. Not dramatic, but nearing the critical weight of a six pack of beer!

With a bit of time (ok a lot of time) and materials, this PDF walks one thru the steps to achieve similar results. Throughout this document, I list sources to purchase every material and tool I used. I also will try to remember and mention every trick that I learned the hard way.

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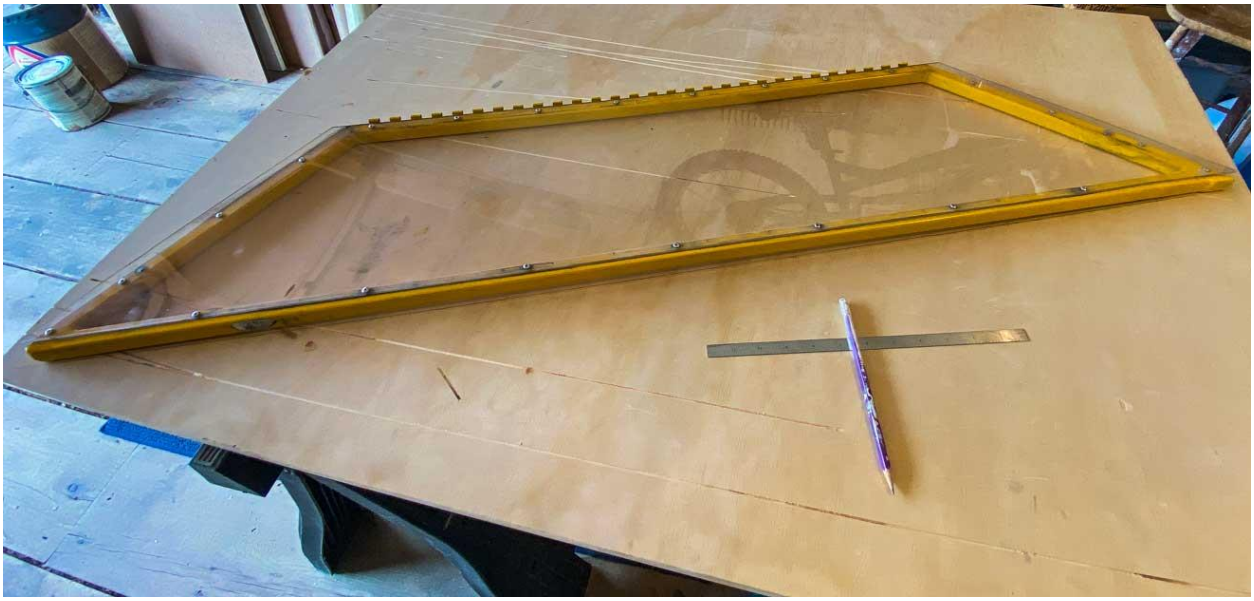
I do enjoy making things. More so than I thought I would years ago. If someone wants to purchase carbon fiber square tube there are numerous sources.[i] I could have likely saved money by buying the tubes pre-made. But now I have another skill set and can proudly point and say, "I made that."

Above: Final carbon fiber sticks after *many* iterations

There are three door/window frames on my experimental Super Cub. The longest dimension is just over 50". Each frame in the kit is ¾" x ¾" square 6061 T6 aluminum, with a wall thickness of perhaps 0.063".



Above: One of the original kit door/window frames

The original kit door/window frames are non-structural parts. Hence I did not need to consider any structural design issues with the carbon fiber. I merely needed the CF parts to ultimately be stiff enough to hold up to everyday use and standard window/door flight loads. The beauty of making these frames myself is I can later redo any particular part that cosmetically or otherwise needs to be replaced.

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Note: In case you didn't read my CF Floor panel PDF, I'll cover some composite basics at the end of this document. Refer to near the end of this PDF where you'll find a heading entitled: Background Methods, Tools & Materials Discussion.

Looking at the aluminum kit frames, the key factor is how to achieve a nice, square corner. I realized that a mold to form the CF around would be essential.

First Prototype Effort

I first found 8' wood trim[ii], which I cut into a 54" section for the longest needed piece. Using a hand layup, I figured I could tightly hand wrap CF to achieve square corners. This process might work on say a 2" piece, but it does *not* work on 10" or worse 54" pieces. No matter how hard you try, even with a helper, you just cannot wrap a wet layup of CF tight enough to achieve any sort of a corner. Not even close. Or at least I couldn't.

Note that for all my frame pieces I used 3 layers of 5.9 ounce 2x2 twill weave carbon fiber[iii]. Available from a local source in the Denver area or on-line.

Above: Hand-wrapped initial prototype pieces

The above hand-wrapped sections looked individually good, but the further along I got in the process the more I realized there had to be a better way. I wanted a square edge! First set is hanging in my garage. I'm was many (!) hours into the effort by now. But what a great learning experience!

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Second Prototype Effort

I decided to try vacuum bagging parts. On my second iteration, I found 36" ½" x ½" wood trim pieces at Home Depot. These would be long enough for the two sides, but not for the top or bottom. I figured I could simply splice the resulting CF together (more on this later). I primed, epoxied and sanded the wood pieces so they'd be smooth; Ready to apply release wax and use as molds.

When vacuum bagging parts, I could only make one "U" shaped part at a time. I would need quite a few "U" parts to make up enough parts to form one window frame.

The challenge with vacuum bagging turned out to be that I could not consistently get a good, square, edge that I was happy with.

Above: After vacuum bagging using wood 36" mold pieces

The process worked well enough that I continued with cutting these "U" parts out using a Dremel cutoff wheel[iv].

To join two "U" parts into a single square frame I first sanded the edges smooth using 80, then 220 grit sandpaper with a sanding block. These Dura-Block[v] sanding "tools" work great! For sanding paper, I much prefer the Eagle[vi] brand of abrasives. I always wet-sand. Wet sanding helps prevent the sandpaper from loading up.

Once sanded, I joined to two halves using West Systems Epoxy resin. There are other products one can use[vii], but with the epoxy already handy I simply used it. To hold the parts together I simply wrapped them with peel-ply and taped the end with duct-tape.

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Above: "Glued" carbon fiber pieces held together with peel-ply & duct tape

Later, I found that I could use light-weight clamps[viii] at perhaps 4" to 6" intervals to achieve the same "holding" effect during the curing process. Easier; Less messy.

After the typical over-night cure, I started sanding the parts using 80, then 220, 400, 600, 800 and eventually 1000 grit sandpaper. I later found that there didn't seem to be a significant difference in final surface finish with these frame parts going past 800 grit.

After sanding, I applied two coats of clear-coat finish. I've tried several products. I prefer the Dupli-Color Acrylic Lacquer Clear Coat[ix].

Now I had a set of individual carbon fiber finished "sticks." I laid the original window frame out on my work table and traced its outer dimensions. Then I measured the original frame in place on the aircraft. I wanted a better fit—perhaps 1/16" on one side; Maybe up to 3/32" on another. So I drew precise lines on my work table and built a jig.

Using the jig parts and cut and laid out the carbon fiber frame pieces.

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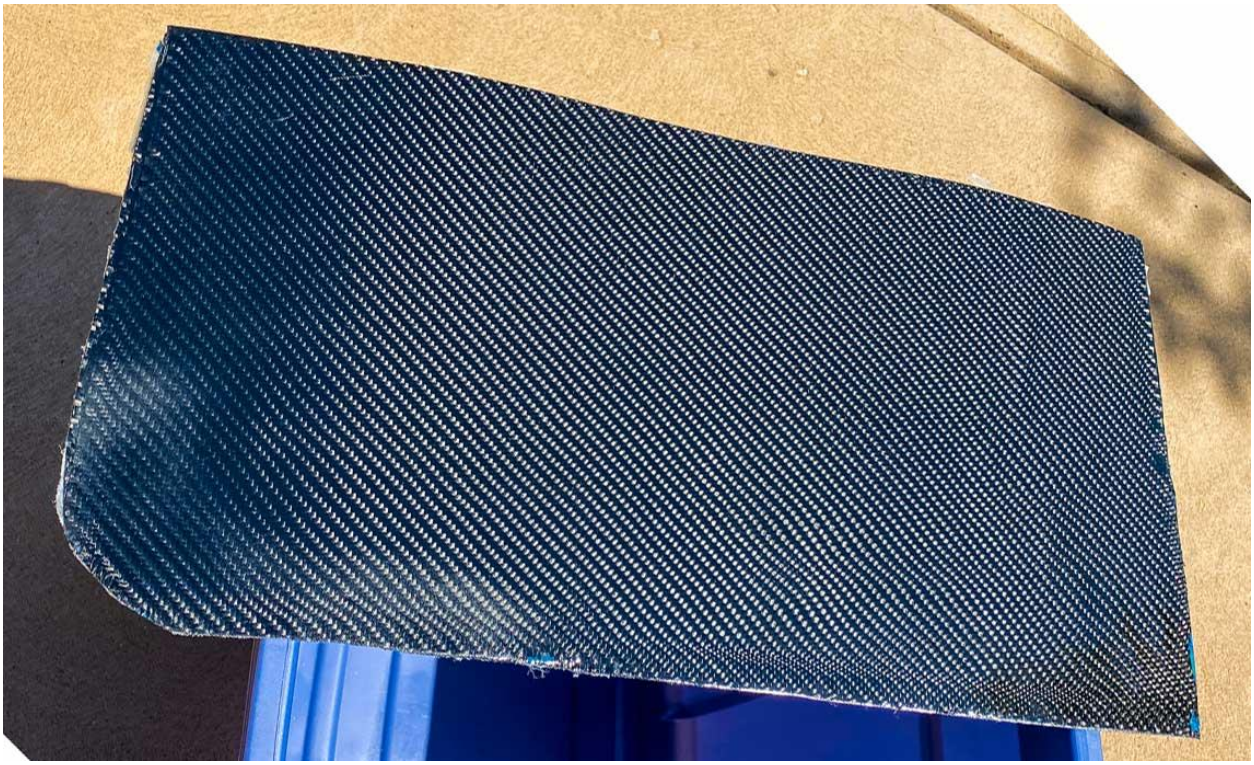
To join them together, I chose to fabricate a flat sheet of carbon fiber (2-layers). From that I cut out gussets. Of course, sanded up to 1,000 grit and clear coated as noted above.



Above: 2 layers of 5.9oz 2x2 Twill CF for gussets

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Above: Carbon fiber gussets in place

Here's the first window in place:

Above: First door/window in place (lots of reflections from new Lexan)

By the way, with new carbon fiber frames, I decided that I should cut out new Lexan. Couple of hours effort but worth it in the end. Here's the scratch-resistant Lexan that I used:

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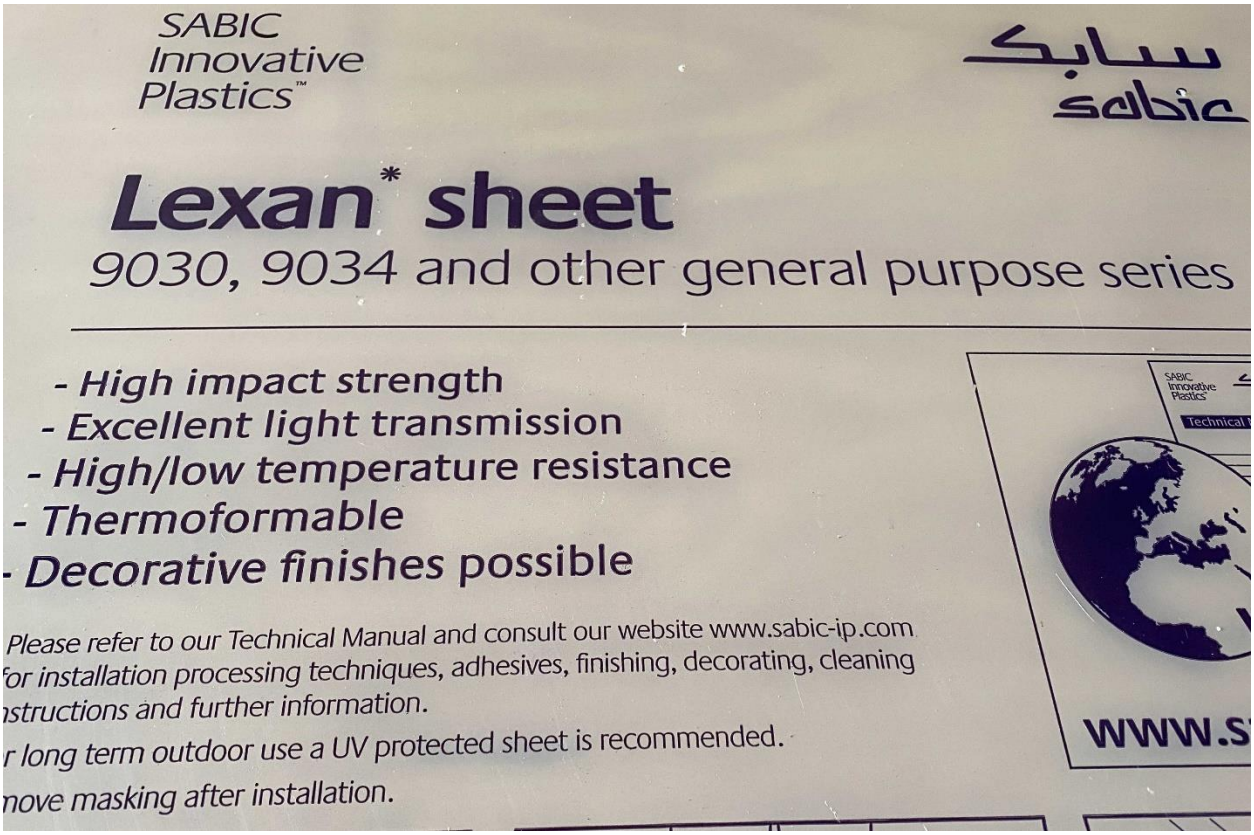

Above: Scratch-resistant Lexan used for my doors/windows

Third Prototype Effort

At this point in the overall process I still wasn't totally pleased with the quality of the corners on my CF frame parts. A friend stumbled upon a YouTube video by a gentleman building a Bearhawk which gave me a new idea for the overall process. I traded a couple of emails with the builder—super great gentleman!

First, I wandered around the hardware store looking for something else to use as a mold. I thought I'd use a long piece of aluminum "U" material (if I could find such). But, I stumbled on long PVS molding which worked I believe worked much better than aluminum would have. The PVC already had a smooth surface ready to apply release wax[x].

I tried two methods with the PVC molds (after waxing them of course). First, I suspended one of the pieces a few inches off of my work surface and did the hand-layup. Next to that, I tried an inverted approach (over a piece of 4-mil release waxed drop-cloth plastic mylar), where I first put down a 4"x54" piece of peel ply, then 3 layers of carbon fiber. Then I sandwiched these with inexpensive metal trim[xi] pieces that I found wandering again in the hardware store (can you tell I wander a lot in Home Depot?).

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Above: Two prototype pieces as noted

A critical tip is that using peel ply is essential (I believe). The peel ply allows one to aggressively pull on the lay-up, ensuring flat sides and a good, flat bottom (using this upside-down method).

Without the peel ply one would be pulling/manipulating the carbon fiber itself, resulting in stretched or distorted weave patterns in the final product.

I thought about trying to simply set up the lay-up using stiffer metal clamped right to the carbon fiber, as did the gentleman in the above YouTube Bearhawk project. However, since I'm making pieces that are 54" long, I'm not sure how well of a final product I'd get. Given the cost of materials and time involved, I just didn't feel like experimenting again on another prototype process!

Above: After layup—the 3rd prototype

I was finally satisfied with the square edges!

I used a silver sharpie[xii] pen to mark a straight edge which would give me about a 5/8" high "U" piece.

I first tried cutting the marked edge using a Dremel oscillating tool[xiii]. Didn't work well in my opinion.

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Above: Trying a Dremel Oscillating tool to trim carbon fiber frame piece

I then tried to rough cut the edge with the Dremel Saw-Max. MUCH better process. Smoother and good results (as long as you have a steady hand).

Trimming would be easier and more precise using a router table (as did the gentleman in the above YouTube Bearhawk video) or maybe a planer. But I don't have those tools.

Note: Eye, ear and breathing protection mandatory! And—wear good work gloves to minimize the number of carbon fiber slivers you get! Even with good work gloves, I have had endless slivers.

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Above: Rough Cutting a frame piece

After the rough cut, I sanded to a good, flat edge using a standard table sander. Of course then I joined two halves using epoxy as noted previously. Once joined, sanding and clear coat as noted previously.

I was far more confident at this stage in the repeatability and quality of the final result. Hence I went into mass production and made 8 pieces, yielding 4 frame pieces once joined.

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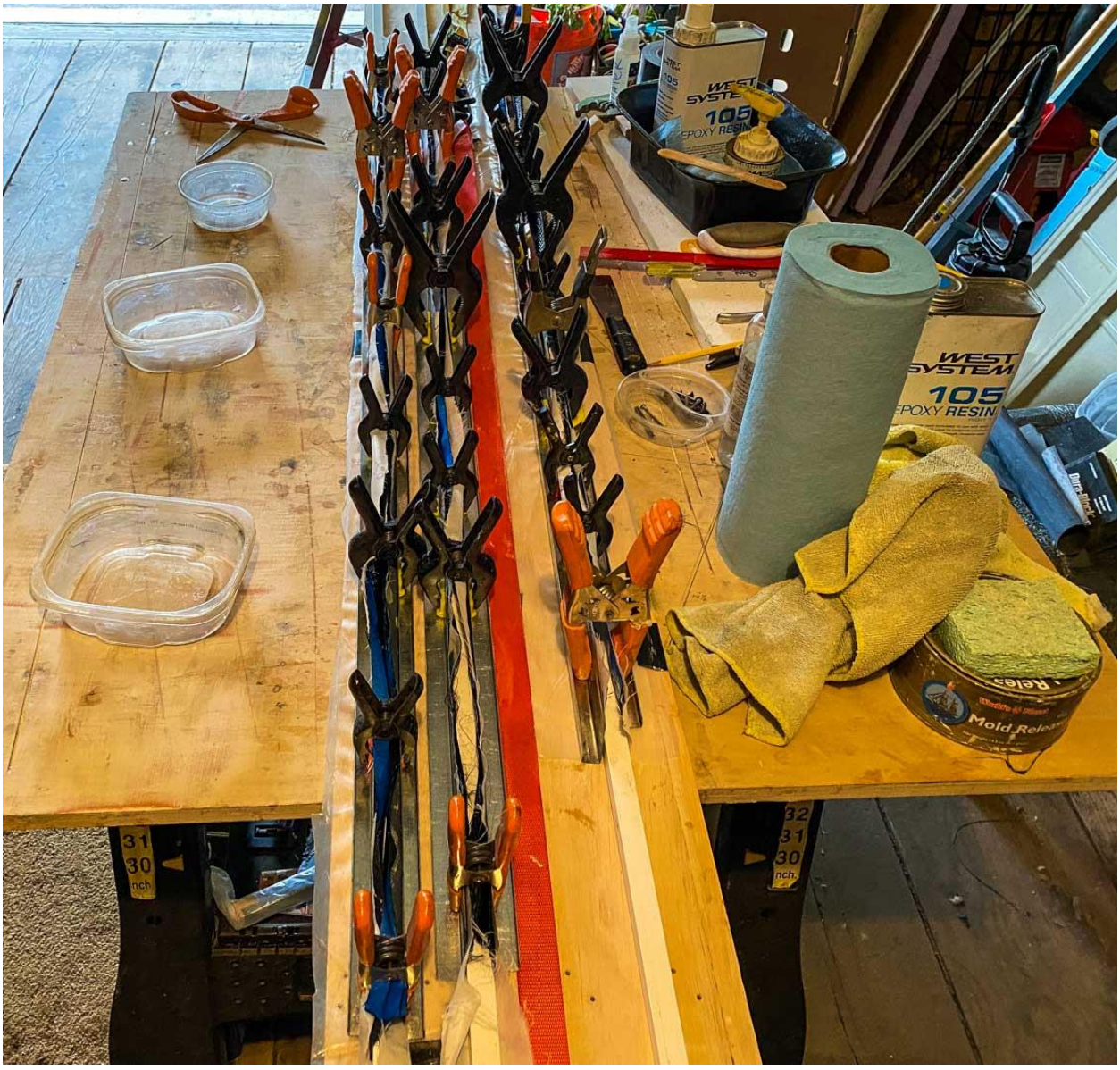

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Again, I made a jig for the 2nd window/door frame similar to what I previously illustrated above. Again, used CF gussets to join the pieces. Another new piece of Lexan.

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Time spent thus far? A LOT. Maybe upwards of 100+ hours. I haven't logged my time—I'm having fun, learning and keeping myself busy with a super cool airplane project.

Materials cost? If I had to guess, by now I'm into everything for maybe $600+. Not counting tools which I already had, including the vacuum machine and Dremel tools.

I'm happy to answer any questions. Feel free to email me at ted@fly2ak.com or call me anytime 303-378-4987.

Again, there are endnote references throughout this PDF that point you to where to purchase every tool/item mentioned. If I missed something—please let me know!

Good luck!

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Background Methods, Tools & Materials Discussion

This section is an abbreviated learning section on basic composite techniques.

As mentioned in my PDF on making carbon fiber floor panels (link here), there are a host of YouTube videos that demonstrate various aspects of the composite processes. Like anything, getting a good finished product takes practice. You may have a few "do-over" steps as you learn, but I can assure you if I can do this anyone can. I'm no home hobby, handyman expert. Give it a try!

There are several ways to "lay up" CF. The easiest is what is called a "hand" lay-up. This is where you are brushing or using a plastic squeegee (a complete parts list is at the end of this PDF).[xiv] Ultimately, this process proved the best in terms of the quality of the final product for the CF door frames.

Next most efficient—but yielding a much stronger final product—is Vacuum Bag. Since I already have a bit of experience in the vacuum bag process (e.g. starting with my CF floor panels, and other parts) I started to use this process to create my initial door frame prototypes.

One needs a vacuum pump[xv] You'll also need a two piece vacuum valve.[xvi] The primary advantage of vacuum bagging your products (e.g. floor panels) is that it yields a more optimal resin-to-material ratio, leading to a sturdier product. Further efficiencies can be achieved through what is called Resin Infusion, or Vacuum Infusion. I'll leave it up to the reader to Google and compare these various methods[xvii].

FYI, I've haven't done resin infusion yet. Infusion is a whole other layer of complexity with new tricks to learn and a few more tools to purchase.

You'll need some type of release wax. There are many types on the market.[xviii] There are other release agents available as well, but wax works and it is inexpensive.

A smooth, flat surface for the layup (whether hand or vacuum bagging) is required. Glass is ideal. Smooth lexan or plexiglass works. The firm nature of Melamine board from your local hardware store works well too.[xix] Ultimately I used 4-mil plastic over a smoothly sanded 1"x6"x96" scrap lumber board that I had laying around.

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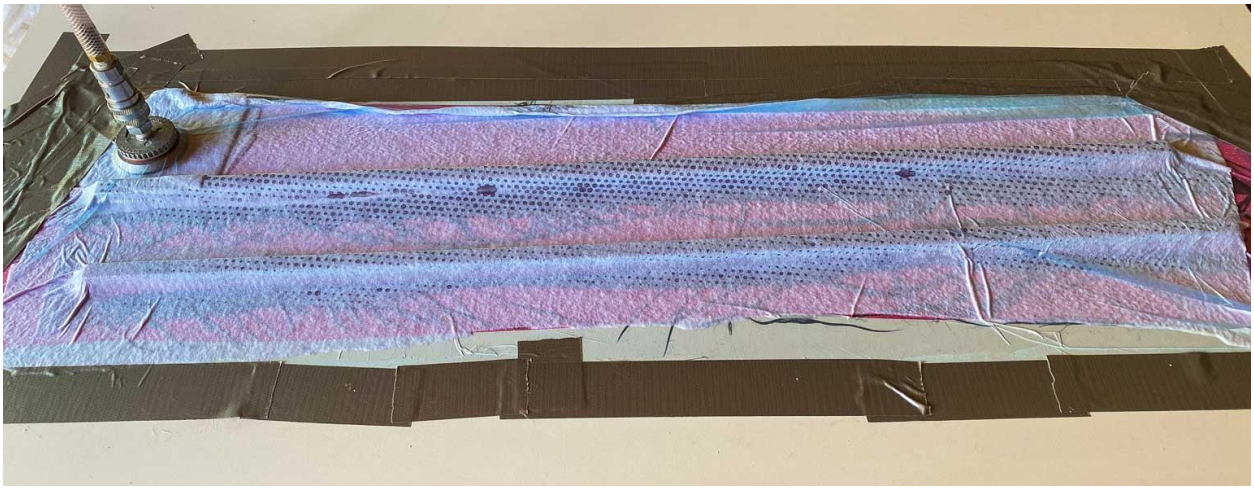

Again, there are a ton of "How to" vacuum bag videos on YouTube.[xx] Many of you have likely seen the hugely popular Draco and now Snappy video series by Mike Patey—he uses vacuum bagging almost exclusively for his many carbon fiber projects.

Materials you'll need include Carbon Fiber[xxi], peel ply[xxii], low temp perforated material[xxiii], breather cloth[xxiv], vacuum bag material[xxv] and sealant tape[xxvi]. Again, materials lists and sources at end of the PDF.[xxvii] You'll also need gloves—these work well and are available.[xxviii] Of course resin is needed. I personally like to use West Systems epoxy resin[xxix]. There are other resin types available.[xxx]

You can save some money on materials by substituting 3+ mil painters plastic drop cloth from your local hardware store for the vacuum bag film. You can also use Duct Tape in lieu of the sealant tape (Mike Patey shows these savings in his video series).

What I find works well is to use a separate, flat surface for the material preparation.

Lay your sealant tape around the perimeter of the glass (or melamine) surface. You can see the tape around the edges in the previous picture. Prepare the remainder of the surface by applying several coats of release wax.

Cut out and lay a measured portion of say .5 mil or other thin plastic drop cloth out. Lay your CF down. Mix your resin and pour on the CF. Sample picture below. Use your plastic squeegee to insure all the CF of well "wetted out" (you can see the color change). Then you can move the now resin infused CF to your glass or other prepared surface.

In the below picture you'll note the use of blue painters tape on the carbon fiber. When measuring out your desired material size, it helps to mark the edges with such tape. Cut the material through the center of your marked tape. This prevents the edges from unravelling while you're working on and moving the material around.

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Next cut out similar sizes of peel ply, perf film, and breather cloth.

The size you cut out of the vacuum bag material will need to be larger, as initially before applying the vacuum you need to allow for the increased required distance of the materials. Several inches wider is usually sufficient.

In order, lay the peel ply, perf material and breather cloth down. Use two layers of breather cloth for the small square where you'll place the base of the Vacuum valve assembly.

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Don't forget to put the base of the vacuum valve assembly in place before you tape the vacuum bag film down! Been there done that!

Secure the vacuum bag film in place. Using scissors or a razor blade, cut tiny slots where the (above picture) vacuum base (the orange piece) will fit into the metal base. "Screw" the vacuum fitting onto the base thru the vacuum bag film material.

Attach your vacuum motor to the assembly and start sucking a vacuum. If you have an air leak you'll be able to both hear it (probably) and see that you have less than say 20 atmospheres pulling on your vacuum motor. Diligently seal all leaks. Spray with soapy water if necessary.

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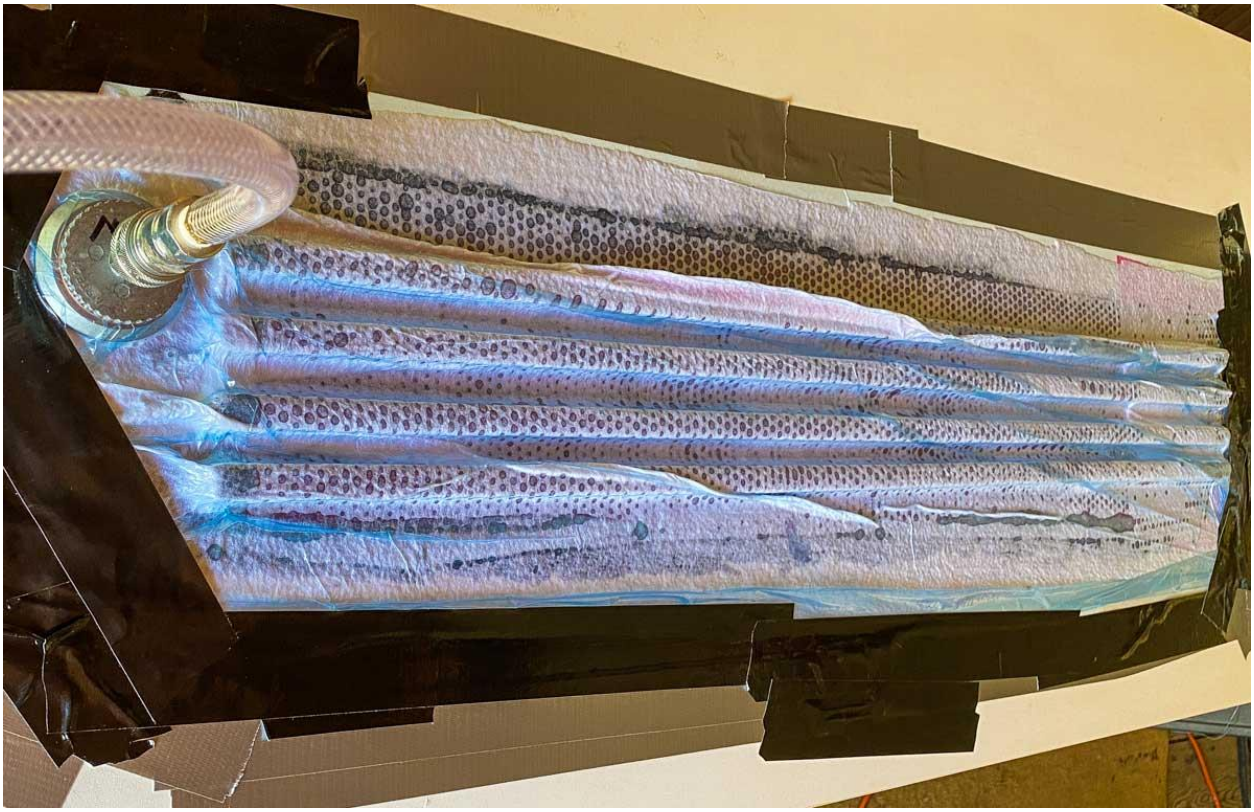

Once you apply a vacuum, you'll see excess resin being absorbed by the breather cloth. This is of course the excess resin that would otherwise be present in a hand lay-up process. This excess resin detracts from the strength and durability of the final product. Though more complicated and expensive (for materials), this is a good reason to use vacuum bagging if able.

The final product after about a 12 hour cure under vacuum:

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Remove the vacuum bag material and peel off all the layers of other materials. This is often a bit of a challenge. Persevere and the lowest peel ply later will release/pull away from the Carbon Fiber.

You'll then need to cut out the carbon fiber pieces from the overall matrix. NOTE: Carbon Fiber dust is likely worse then asbestos for your lungs. You must use a respirator and ideally a good filtration system when cutting cured carbon fiber!

Use a die grinder, oscillating cutter, jig-saw cutter or other suitable device. We used a die grinder with a metal cut-off wheel in this case. Wear gloves throughout this process!

The cut out edges of the final product will be VERY sharp. Use a sanding block with perhaps 220-grit sandpaper along the edges. Again, wear gloves throughout this process! I gained innumerable CF slivers over the course of this project!

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[i] Sources to purchase carbon fiber square tube: a) https://dragonplate.com/braided-carbon-fiber-square-tubes and b) https://www.rockwestcomposites.com/shop/shaped-tubing/square-tubing/standard-modulus-carbon?p=4#content5

[ii] Wood ¾" trim to use as mold: https://www.lowes.com/pd/3-4-in-x-8-ft-Pine-Wood-Lattice-Moulding-Actual-0-75-in-x-8-ft/1000444725

[iii] Carbon fiber material: Carbon Fiber: https://www.fibreglast.com/product/3K_2_x_2_Twill_Weave_Carbon_Fiber_Fabric_01069/carbon-fiber-fabric-classic-styles

[iv] Dremel "Saw-Max" tool: https://www.homedepot.com/p/Dremel-Saw-Max-6-Amp-Variable-Speed-Corded-Tool-Kit-for-Wood-Plastic-and-Metal-with-2-Blades-SM20-03/204331723

[v] Dura-Block sanding pads: https://tinyurl.com/y92umdzz

[vi] Eagle brand abrasives (sandpaper): https://tinyurl.com/yaybrdf3

[vii] Other product to "glue" carbon fiber pieces together: Loctite 9340 Hysol: https://www.amazon.com/gp/product/B00VFP1LAM/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1

[viii] Inexpensive clamps to hold parts: https://www.homedepot.com/p/ANVIL-Spring-Clamp-Set-22-Piece-TGS0199A/302755768

[ix] Dupi-Color clear coat: https://www.amazon.com/Dupli-Color-EDAL16957-General-Purpose-Acrylic/dp/B001DKNSE6/ref=sr_1_2?dchild=1&keywords=duplicolor+acrylic+lacquer&qid=1594764506&sr=8-2

[x] PVC square tube to use as a mold: https://www.lowes.com/pd/EverTrue-5-8-in-x-8-ft-PVC-Stop-Actual-0-625-in-x-8-ft/1000443661

[xi] Metal trim to secure edges of curing carbon fiber frame: https://www.homedepot.com/p/Alexandria-Moulding-1-4-in-x-3-4-in-x-96-in-Metal-Mira-Lustre-Cap-Trim-Moulding-AT024-AM096C03/205576710

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[xii] Silver Sharpie to mark black carbon fiber: https://www.officedepot.com/a/products/584057/Sharpie-Extra-Fine-Oil-Based-Paint/

[xiii] Dremel oscillating tool: https://www.homedepot.com/p/Dremel-Multi-Max-MM50-01-5-Amp-Variable-Speed-Corded-Oscillating-Multi-Tool-Kit-with-30-Accessories-and-Storage-Bag-MM50-01/308443441

[xiv] 3M Hand Applicator https://www.amazon.com/gp/product/B00657SFPE/ref=ox_sc_mini_detail?ie=UTF8&psc=1&smid=A1UMBRA5ZTBCX8 and Inexpensive resin applicator brushes: https://www.harborfreight.com/1-in-industrial-grade-chip-brushes-36-pc-61491.html or https://www.harborfreight.com/12-in-horsehair-bristle-acid-shop-brushes-36-pc-61880.html

[xv] Excel 5 Continuous Run Vacuum Press System https://www.veneersupplies.com/products/Excel-5-Continuous-Run-Vacuum-Press-System.html . This is an great product that I have. There are others for sale here https://www.fibreglast.com/category/Vacuum_Bagging_Pumps

[xvi] Vacuum Valve assembly: https://www.aircraftspruce.com/catalog/cmpages/vbvacvalve2.php?clickkey=31724

[xvii] One reference on hand layup vs other composite techniques https://www.compositesworld.com/articles/fabrication-methods

[xviii] Release wax https://www.fibreglast.com/product/Meguiars_Mold_Polish_Conditioner_and_Release_Wax_118/Mold_Releases

[xix] Melamine board https://www.homedepot.com/p/Veranda-Melamine-White-Panel-Common-3-4-in-x-4-ft-x-8-ft-Actual-750-in-x-49-in-x-97-in-461877/100070209

[xx] Vacuum bagging overview: https://www.youtube.com/watch?v=URGXbpib1dY

[xxi] Carbon Fiber: https://www.fibreglast.com/product/3K_2_x_2_Twill_Weave_Carbon_Fiber_Fabric_01069/carbon-fiber-fabric-classic-styles

[xxii] Peel Ply https://www.fibreglast.com/product/Polyester_Peel_Ply_583/Vacuum_Bagging_Films_Peel_Ply_Tapes

[xxiii] Low temp Perf https://www.fibreglast.com/product/low-temperature-release-film-1580/Vacuum_Bagging_Films_Peel_Ply_Tapes

[xxiv] Breather cloth https://www.fibreglast.com/product/Breather_and_Bleeder_579

[xxv] Vacuum Bag material https://www.fibreglast.com/product/1783-1785-nylon-bagging-film-below-300/Vacuum_Bagging_Films_Peel_Ply_Tapes

[xxvi] Sealant tape https://www.fibreglast.com/product/yellow-sealant-tape-00580/Tapes

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[xxviii] Gloves
https://www.amazon.com/gp/product/B07FW4YSSW/ref=ppx_yo_dt_b_asin_title_o08_s01?ie=UTF8&psc=1

[xxix] West Systems Epoxy Resin https://www.westmarine.com/buy/west-system---105-a-epoxy-resin--323733?cm_mmc=PS-_-Google-_-GSC%3ENonB%3EProduct%2520Type-_-323733&product_id=323733&creative=108421551244&device=c&matchtype=&network=g&gclid=Cj0KCQjwoub3BRC6ARIsABGhnybSquPukXa0k07I2n18BhpPZwnotlWRZEUia964XIfUXmwqZcpJf4kaAivKEALw_wcB

[xxx] Resin overview & other types: https://www.fibreglast.com/category/Epoxy_Resins