Paper-type DIY medical face mask with reusable 3D printed filter housing insert.

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This describes a face mask that can be built of common office materials when a 3D printer and a small amount of medical or HEPA-certified filter material are available. The 3D printing and mask assembly are both fairly quick and easy.

You are responsible for determining the appropriateness of anything made from these plans. I cannot guarantee or assert anything. I welcome any suggestions, experience stories, and especially any professional clinical evaluation.

An effective mask depends on good filter material and proper fitting. A properly-fitting mask depends on a good seal against the face. The paper/Tyvek readily molds to adjust best around your face. Since every face is different and construction is in the hands of the user, I cannot guarantee a given mask will prevent infection.

Clinical-use quality is possible with this design, using careful construction and fitting and proper filter material, but no rigorous evaluation has been done. Community use, using whatever materials are available, is a likely use of this design, but you are responsible for determining the effectiveness of whatever you use and build.

Overview

The pictures below show what the mask looks like. A 55mm (2 1/8”) disk of filter material is housed in a 3D printed holder made of 2 identical parts that snap together over the filter and around the edge of a circular hole in the paper.

The most-critical parts of the assembly are accurate cutting of the round filter circle, and cutting out the circular filter hole and 12 little “snips” around its edge. (A cotton “makeup” disk can be used to backup the filter material if it is thin.) Everything else is easy origami and taping.
The paper (or Tyvek) that the bulk of the mask is made of is essentially impervious to air, so no virus goes through it – if properly fit, all the airflow will go through the mask filter. So the filter itself is a critical issue of how effective the mask will be. Since certified materials are often unavailable, use-at-your-own-risk substitutions are being used.

3D printing notes

Two of the filter holder “clamshells” are needed for each mask. They snap together, and can be pried apart and re-snapped. When snapped together, they simultaneously contain the filter and tightly grab and seal the mask material (paper, Tyvek, etc.) They can be printed in PLA, and a single print of one takes maybe a half hour. I have used 0.2 mm layers with a 0.4mm nozzle, 100% fill, 110% flow, 1.2mm bottom, top, and side wall thickness. Multiple copies can be printed at once, I’ve done up to 7 at a time on my circular-bed Deltaprintr.

There are now 2 different filter housing parts, maskresp40.stl, and the new maskresp40loose.stl, the “loose” file has 0.1 mm more clearance in the clasp part, so it doesn’t grip so tightly. I’m discovering that the fine tolerances differ between printers, thus a 2nd model with looser tolerances would be helpful. You will have to try to see what works best for your printer. In my situation, maskresp40.stl works best for Tyvek, and maskresp40loose.stl works best for paper.

The round hole stencil has the same printing settings, and you should only need one of these per person cutting filter disks.

The Nose Thingy uses TPU or other flexible filament, with similar printer settings, except I use 50% and 120% flow.
Parts list

2 3D printed filter holder parts.
1 55mm diameter disk of filter material, hopefully HEPA-certified.
1 55mm diameter cotton disk “makeup pad” (if needed).
1 Sheet of paper or Tyvek material with mask pattern printed on it. ( Might try surgical gown material.)
Some clear office-type tape for paper. Can also use shipping tape.
1-3 bag ties, the ones with a wire inside, at least 3 inches (8cm)) long. (Optionally, can print, load with wire, and use one of the “Nose Thingy” items described in that section.)
2 rubber bands ~4 inches, or a custom loop from elastic,
or
2 pieces of ribbon/string 36” long. Shoes laces can work.

Tools

Good pair of scissors
Office paper cutter is handy for outside edge
Good small straight edge for creasing folds
Tape Dispenser
3D printed template for 55mm disk
Optional stapler
Optional pliers

Paper Patterns

The paper patterns in MaskPatterns.pdf have 4 sizes plus the instruction diagram on page 1. The 2nd pattern on page 3 ( regular size, longer) seems to be the one that works best for most people.
Filter disk preparation

All of this assumes that you have access to some sort of filter material rated for 0.3 micron particles, and that air passes through it easily enough so that a 55mm disk is big enough for easy breathing. Certified sources of filter material are hard to come by, but I will try to provide a list over time (see appendix).

To cut out a disk, you can 3D print out the stencil (file Disk_stencil.stl), or otherwise provide a 55mm circle. Lightly mark the circle on the material. The cutting needs to be pretty accurate, erring on the big side to ensure a good seal.

Some materials may be quite thin and need something to hold them in place in the filter holder. 55mm cotton “makeup pads” work well for this – put them on the face side of the filter. If the filter is then marginally breathable, just cut out the middle of the cotton pad and let its edge hold the filter in place.

Filter Disk Materials

I have designed this for stopgap clinical use, but it can be used for the general population. There is a lot of discussion about household materials as filters, and more is added each day. Finding something that filters well and allows comfortable airflow through a 55mm disk is a challenge. If you find something documented that works well, let me know. Again, this is at your own risk.

Certified Filter Materials

One certified source of material is listed in the appendix. They provide pre-cut 55mm disks. They now only ship to healthcare organizations, however. Something in this category would be needed for clinicians.
Furnace, Vaccum Cleaner, etc. Filter Materials

If you are going to try to use furnace/vacuum etc. filter material, try to make sure it is HEPA-certified, but be aware that these filters often contain fiberglass and/or chemicals that might prove hazardous to breathe. The ones I have tried thus far had a chemical smell. Plan to back it up with the cotton pad (face side) in the filter holder, especially if it has fiberglass.

Other Medical Materials

Surgical mask material has been suggested, perhaps salvaging 55mm disk from damaged/worn-out masks. Other medical fabrics, like “Halyard” might also work. I have been usable to obtain and test these yet.

Household Materials

Household materials tried so far:
• Just a cotton makeup disk.
• Single layer of blue mechanic paper towel.

Sewing Interface Materials

It seems that some folks are testing and using masks in clinical settings using sewing “interface” material, which is made up of spun-not-woven polyester, and is of similar fineness to approved viral filters. The question of filtering effectiveness versus breathability for this design, with 55mm diameter filter area, remains to be seen, but there is optimism about their properties. See Appendix for a list of these products.

I obtained some of the 810 Tru-Grid Pellon material, and it is quite thin. Stacking 3 55mm disks of it in the filter holder in my design seems to be about right for "breathability". I used a makeup pad with the center cut out for backing in the filter holder.
Assembly/cut/fold order

This expands upon the terse instructions in the MaskPatterns.PDF file. Have that instruction page on hand while building. This all is not as hard as it appears. Think “Origami”, use straight edge to pre-crease folds. It may seem complex, but after making one or two it should take less than 15 minutes to make each one.

The step numbers below correspond to the diagram in the pattern document. (Print out the pattern size you wish.)

1. Cut outside (can use paper cutter).
2. Cut out filter hole and nip hole edge tabs. This needs to be pretty accurate. The 12 “snips” around the edge need to not go beyond the little circles. See picture below. These swips allow the filter holder to clamp without tearing.
3. Crease, fold over, and tape top/bottom seams. Use straight edge to crease. Ignore extra wrinkling at nose and chin points.
4. Pre-crease the tuck folds for #6, #10. See picture below. For the folds that go away from you, first fold towards you, then turn the mask over, locate the crease on the other side, carefully place your straight edge, then fold it towards you.
5. Position bottom filter holder under shell, insert filter (and pad if needed), then position top shell over it, aligning. Snap close, press around shell. See pictures below. If your “snips’ weren’t quite right, you might need a lot of pressure.
6. Fold and tape side tucks. Do one side at a time, work from top. The lines for steps #8 and #9 should now line up. See pictures below
7. [Changed]Turn the mask over, and place the end you are working on atop a small container upon which it sits close to flat. Tape or place the middle of the two tie strings, elastic bands, or ribbons along and between the #8 fold lines on each end, but on the OUTSIDE of the mask. For elastic loops/rubber bands, just place them, don’t tape them. For ribbon/string, that is to be tied, they need to be taped into place here. See picture below.
8. Crease both #8 fold lines, but on the outside of the mask.
9. Fold each end over the ribbon/tie to where its line #9 would be on the other side and tape. (Having the #8 lines show on the very end of the mask is another way to gauge. Add extra tape just inside where tie comes out of mask. See pictures below.
10. Fold and tape nose and chin tucks. Tape both inside and outside
11. Affix nose shaper (bag wire tie, paper clip, NoseThingy, etc.). Note that the center of the mask at the nose is the seam on the inside (face side) of the mask, line up the center of the nose shaper with it. Pre-bend the shaper a bit before taping.
Step 2, cutting the “snips”.

Step 4, pre-crease folds.

Step 5, line up and install the filter housing and filter.

Step 6, fold and tape side tucks.
Step 7, the #8 lines, we want to put the tie band/ribbon here, but on the OTHER side.

Step 8, pre-creasing the #8 lines toward mask front, mask propped up, position tie.

Step 9, fold end over tie so you can just see #8 line, and tape.

Step 9, extra tape at corners.

Step 11, pre-bend nose shaper before taping.
and you are done!

**Construction Tips**

Note that the recommendation for folding the ends of the mask over the tie/band has changed – now the preferred way is to fold AWAY from the face, and tape onto the outside of the mask. This makes a better seal over the face and thus makes the mask more effective.

Note that one or more “plastic bag wire ties” or similar will work for shaping the mask around the bridge of the nose. Tape it onto the outward-facing side of the mask at position 11. If you have some wire, but no wire ties, you can make your own “Nose Thingy”, see section below.

Also, note that 36” for string/ribbon for each end is about right for tying the mask around the head. Alternately, 4” rubber bands or hair tie bands work for hooking around the ears.

When inserting the filter and snapping the 2 halves of the holder together, it might be helpful to temporarily lightly tape the lower filter holder half into place under the mask (the “away from the face” side). This will help accurate placement.

The filter housing can be opened with a fingernail or small blade – just pop them apart. When re-assembling, just line up with the existing paper wrinkles and press.

Some 3D printers may print slightly out-of-round, so it might be helpful to try to click together a pair of shells, rotating them until you get a good fit, and then marking the orientation with a pencil, before you use them in a mask.
Stapling

One can add strength to the connection of the tie-band/ribbon using a stapler. Staple from the inside (face side), avoiding going through the tie band unless it is a taped-in ribbon. Also, after stapling, you may want to squeeze down the staple ends on the outside to ensure no snagging.

Using Tyvek

I have had success with Tyvek, using mailing envelopes (Tyvek paper is also available, as is large rolls used for house wrapping in building construction). I happen to have a large format inkjet printer, so I was able to print directly onto the envelope material, but not everyone has that.

**Warning!** Do NOT try to print onto Tyvek with a laser printer, the high temperatures inside will melt the Tyvek and muck up the works!

Tyvek is available as regular letter-sized pages (see Appendix for example), so you can print directly onto those pages with an inkjet printer.

But if you can’t get a hold of that, or are using bulk tyvek rolls...

There are 2 ways to deal with the pattern for bulk/envelope Tyvek...

One is to print the pattern on paper, cut out and tape a piece of Tyvek big enough to cover the pattern on the paper, tape it into position, and send that through the inkjet printer again.

Another alternative when you are unable to print on the Tyvek is to...

- print and cut out a printed pattern on regular paper
- tape it temporarily onto a Tyvek sheet
- mark the edges and circle cut
- untape (leave tape on paper)
- cut Tyvek to shape (you can save the center circle cut for later)
- retape paper pattern to Tyvek sheet
- do all of the pre-creases (see picture below)
- remove the paper pattern, but keep it around to guide (see picture below)
- then repeat the pre-creases, using existing crease marks
- then cut out the middle and snips
- proceed with assembly
Also, the envelope-seal strip on Tyvek envelopes may be useful for securing the “NoseThingy”.

Note that one can usually unsnap and then re-snap the filter holder only a couple times on a paper mask before the center paper with the snips falls apart, but Tyvek does much better, multiple snaps works fine.

**Nose Thingy**

If you cannot find suitable tie wire strips, but have access to small wire, you can print out NoseThingy.stl or Nose Thingy2.stl (requires flexible filament like TPU), and insert 2 lengths of the wire into the 2 channels. Cut the wire a little shorter than the NoseThingy, and push the wire in so that both ends of each wire are well inside the NoseThingy, so no poking.

NoseThingy.stl is 80mm long, and the new NoseThingy2 is 100mm long.

I use aviation safety wire, but small wire paper clips (straightened out) work fine as well – NoseThingy2 is sized to take the wire from a small paper clip without cutting, but still cushioning the ends.

I have had better results using a half-width of common clear packing tape, instead of office clear tape, to secure the Nose Thingy atop the mask, probably because of the width.

**Fitting the mask**
Everyone’s head is a little different, so to make a good seal and be comfortable, there are some adjustments. First of all, picking the right pattern helps.

Shaping the nose area properly helps.

Some folks with smaller chins may get a better fit by adding a couple small tucks to the bottom (one each side of center).

If your tie-band or ribbon is too loose, you may get leakage as well. There are many examples of

**Salvage, Re-use, and Disinfecting**

If a mask wears or tears, or gets contaminated, it is easy to salvage and potentially sanitize and reuse the filter holder, the filter, the tie bands/ribbons, and the nose shaper.

The 3D printed parts won’t handle autoclave heat (they are thermoplastics, after all), but chemical/detergent disinfecting should work. Give it time to soak and dry, 3D printed stuff has lots of small crevices throughout. PLA will be broken down by extended exposure to UV, but probably not a factor here.

[more coming]

**Quality Control – Check before use**

Checklist: Before each use of one of these masks, you should…

- Hold the mask up in front of a bright light and make sure that you don’t see any light leaks coming through, especially around the edge of the filter holder.
- Check the taping points, especially at the ends holding the ties or bands, and also the nose shaper. You can always add more tape.
- Make sure the filter holder halves are still snapped firmly together, and the filter material is still centered properly in the holder.
- Make sure the nose shaper is adjusted to fit your nose.

Think through any protocols for donning, adjusting, and removing the mask in the presence of contagion.
Appendix

So far, I have one commercial source of filter material…
https://www.flowmarkhightech.com/3d-face-mask-filters
They are not certified per se, but physicians are using the material in other mask designs. If you order, specify 55mm diameter round disks. These won’t need the cotton disk backing.

Type of usable non-woven Interfacings:
• 910 Sew-in Featherweight by Pellon
• 911FF Fusible Featherweight by Pellon
• 930 Sew-in Mid-weight by Pellon
• 931TD Fusible Mid-weight by Pellon
• 880F Sof-Shape by Pellon
• 950F Shir-Tailor by Pellon
• 830 Easy Pattern by Pellon
• 380 Soft -N- Stay by Pellon
• 810 Tru-Grid by Pellon
• 808 Craft-Fuse by Pellon
• Oly-Fun by Fairfield
These are commonly available in fabric stores – if they have stock.

Tyvek is available as regular letter-sized pages (example: https://www.amazon.com/JAM-PAPER-Tyvek-Tear-Proof-Paper/dp/B00B1B1MGS/), so you can print directly onto those pages with an inkjet printer. It runs about $.50 a sheet.

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