Conductive Paint on Polylactic Acid 3D Printed Parts

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This article is about the shelf life of Polylactic Acid (PLA) 3d printed parts, such as antenna prototypes for the microwave bands, after metallizing with conductive spray paint. Does the process of metallizing a 3d printed antenna reduce its shelf life? What can be done to mitigate any deterioration from the painting process?

Introduction

PLA is a monomer thermoplastic derived from organic sources such as corn starch or sugar cane. It is commonly used in 3D printing because it is easy to work with and dimensionally stable.

3d printing of microwave band antennas is a very useful technology for experimenting with antenna designs. As nearly all 3d printing filaments are plastic and therefore non-conductive, metallizing the 3d printed surface is required in order for it to operate as an antenna. Conductive paint is a very common approach.

The paint used in this experiment was 843AR-340G - Super Shield Silver Coated Copper Conductive Paint.

843AR is "An EMC spray coating in convenient aerosol packaging. It is a solvent-based acrylic lacquer, pigmented with a highly conductive silver-coated copper flake. It is smooth, hard, and abrasion resistant. It adheres strongly to most injection-molded plastics, such as ABS, PVC, nylon and polycarbonate."

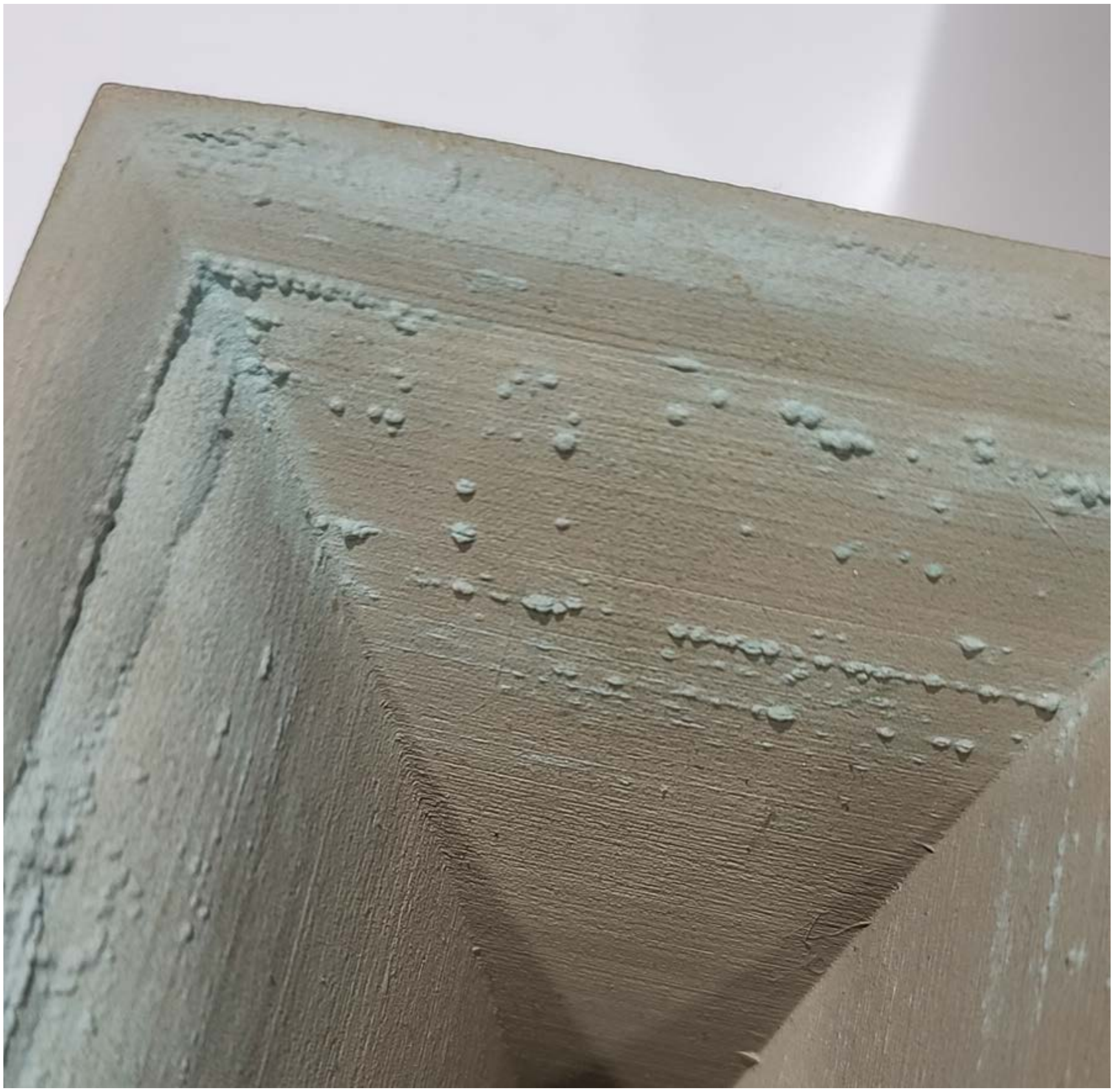
https://www.mgchemicals.com/products/conductive-paint/conductive-spray-paint/emc-spray-coating/

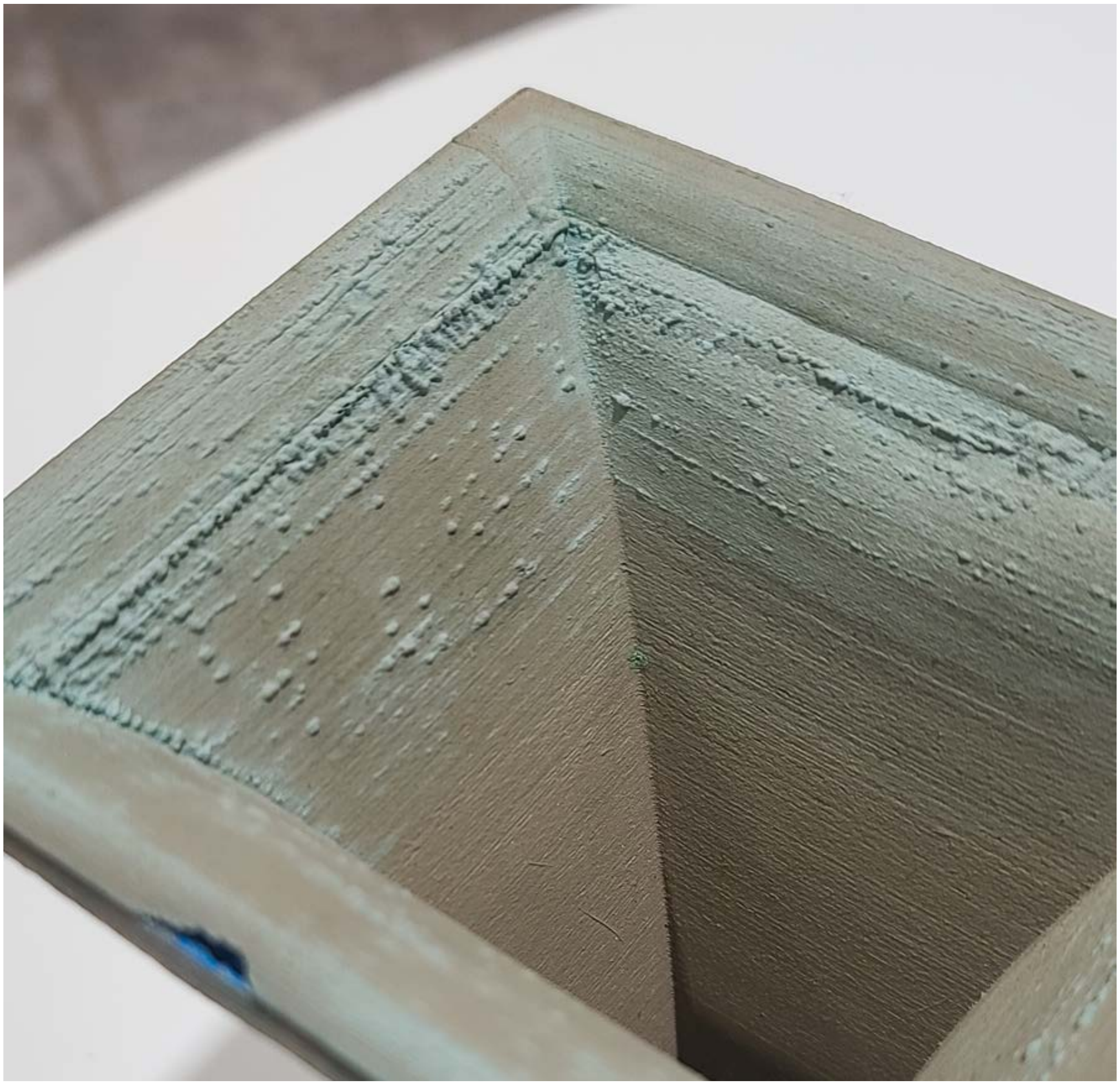
The 3d printed design was a 10 GHz horn with elliptical taper. An article about the antenna design and build was published in September 2016 QEX (PG. 16) "3-D Printed Horn Antennas" by Michelle Thompson W5NYV and Kerry Banke N6IZW

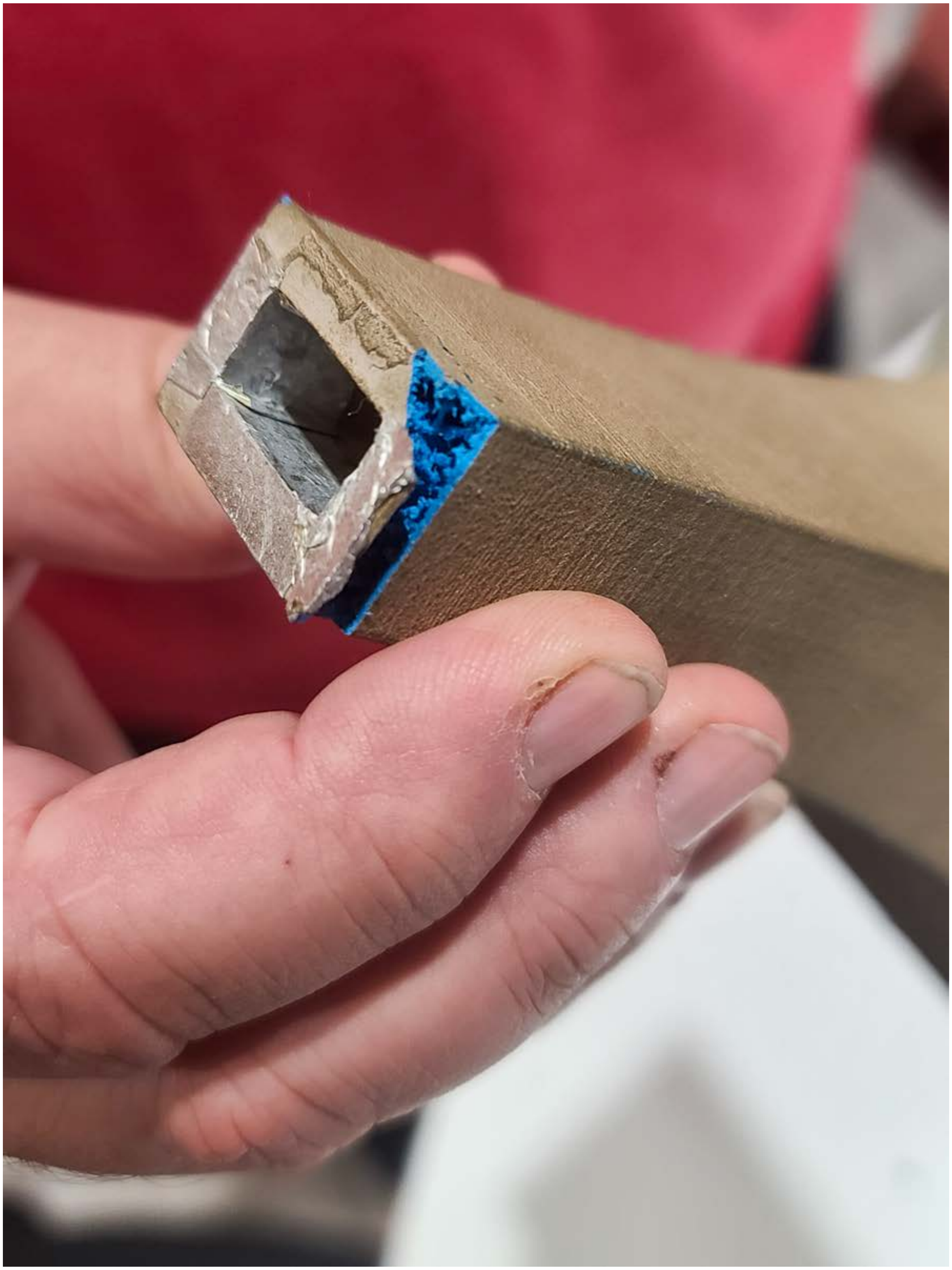
The horn from the article has deteriorated much more rapidly than expected.

The Damage

The horn has been kept inside out of direct sunlight since it was printed in 2016. These photographs clearly show some damage.







What is this damage from?

PLA part degradation has been studied, and degradation can occur within months or weeks when prints are exposed to heat, moisture, and chemicals such as acetone.

We know that PLA is hydrophilic and more sensitive to ultraviolet damage than other plastics. It's biodegradable and compostable. The degradation products are non-toxic.

The damage to the conductive paint looks like bubbling, which is when paint doesn't adhere to the surface. Common factors in paint bubbling are 1) not using a primer and 2) moisture building up in the surface and having no where to go.

The green color could be caused by corrosion of the silver-coated copper particles in the paint. The PLA could have absorbed enough moisture to cause the paint to fail.

Is it the PLA deteriorating normally?

"PLA prints are expected to last anywhere between 10 to 15 years without suffering any significant deterioration in indoor conditions." (https://3dinsider.com/pla-prints-expiration-date/)

Is the damage an interaction between the paint and the PLA?

Using composite filaments and coating the print with waterproof epoxy are some of the recommendations for increasing the lifespan of a 3d printed PLA part. The horn antenna was not primered and was not sealed with waterproof epoxy. There were no additives in the PLA. The horn was printed and then painted with conductive spray paint (843AR). It was tested and and performed as expected, and then stored.

Primer filler (such as Rust-Oleum) is recommended for PLA prints, and then acrylic or enamel paints, followed by a top coat (https://www.makerbot.com/professional/post-processing/painting/).

From the information sheet for 843AR,

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843AR is a conductive paint that consists of a
1-part, solvent-based acrylic lacquer, pigmented
with a highly conductive silver-coated copper
flake. It is smooth, hard, and abrasion resistant.
It is a ready-to-spray system, with no let down
necessary. It has a quick dry time, with no heat
cure necessary. It adheres strongly to most
injection-molded plastics, such as ABS, PBT,
PVA and ABS/PC blend. It provides excellent
shielding levels at high frequencies.
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843AR is designed to provide a conductive
coating for the interior of plastic electronic
enclosures that suppresses EMI/RFI emissions. It
excels when higher levels of shielding are required.
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This is a solvent-based acrylic lacquer. ABS, PBT, PVA and ABS/PC plastics are mentioned, but PLA is not.

From the ingredients list on the material data sheet below, we can see that we've used at least one chemical directly on the surface that studies have shown weaken 3d printed objects. Namely, acetone.

See: Ali Nahran, S., Saharudin, M.S., Mohd Jani, J., Wan Muhammad, W.M. (2022). The Degradation of Mechanical Properties Caused by Acetone Chemical Treatment on 3D-Printed PLA-Carbon Fibre Composites. In: Ismail, A., Dahalan, W.M., Öchsner, A. (eds) Design in Maritime Engineering. Advanced Structured Materials, vol 167. Springer, Cham. https://doi.org/10.1007/978-3-030-89988-2_16

Section 3: Composition/Information on Ingredients

CAS #	Chemical Name	% (weight)
67-64-1	acetone	31%
7440-50-8	copper	20%
616-38-6	dimethyl carbonate	17%
110-43-0	heptan-2-one [a)]	13%
68410-97-9	distillates (petroleum), light distillate hydrotreating process, low-boiling	5%
108-65-6	1-methoxy-2-propanol acetate	4%
7440-22-4	silver	2%

a) Also known as methyl amyl ketone (MAK)

Conclusion

3d printed antennas are extremely useful for prototyping and testing. However, the process of metallizing PLA prints directly with conductive spray paint will limit shelf life. Using a primer, then applying the conductive paint, then a waterproof epoxy sealant, can extend the shelf life of a 3d printed experimental antennas.

There are reasons that one might want to keep a 3d printed antenna for longer than a few years. One might want to use it as a reference design. One might not have thoroughly tested every aspect. One might want to use it in education as a laboratory teaching tool.

Even with proper painting, 3d printed antennas, from the type of printers generally available to experimenters and hobbyists, are generally not durable enough to withstand deployment "in the field".

3d printing is an unparalleled prototyping technique. With free open source 3d modeling software (https://openscad.org/) and at least one open source electromagnetic modeling design suite (https://www.openems.de), the barriers to entry for doing innovative microwave engineering work have never been lower. One will still, in all likelihood, for the foreseeable future, have to build a permanent or production antenna out of metal, in order to get reasonable durability. The power of 3d modeling and design is that the production part can be much higher performance because 3d printed prototypes can be iterated for the cost of filament. Printers can be found at maker places and many libraries and schools. Purchasing a printer has never been more affordable. Many consumer printers are fully capable of resolutions in excess of the surface requirements for 122 GHz.

Metallized 3d prints may not have a long shelf life, especially if one shortcuts the painting process, but they are an important part of the process of producing the perfect part.

Future Work

Will a waterproof epoxy top coat interfere with the electromagnetic performance of a metallized 3d printed antenna? What sealants are best to use for testing 3d printed microwave antenna surfaces? One could primer and metallize, test, and then seal a 3d printed experimental antenna for storage. However, one may need to re-test the printed antenna in the future. If there is any degradation from the sealant, it would be good to know how much can be expected.

Credits

Thank you to Paul Williamson KB5MU for noticing the degradation of the printed horn design and providing photography support for this article.