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Analysis of technical coil realization using various methods

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***Abstract* —The first part introduces the method of technical coil production using a 3D printer and special conductive filament. Liquid metals, a low melting point solder, are listed in next chapters. The last part of the document describes a method for injecting liquid metals into a plastic mold.**

***Keywords* — 3D printer, liquid metals, solder, special conductive filament, technical coil.**

I. Introduction

Today, we encounter a large number of electrical equipment every day. They help us to fulfill our work tasks, satisfy our daily needs and make our lives easier in different ways. One such device is a 3D printer.

In recent decades, 3D printing has evolved from a sophisticated process that requires expensive machines that are used only by larger companies to a significant number of relatively inexpensive open-source projects. This progress, allowing a much wider community to use this 3D printing technology. Today, an ordinary person can buy a 3D printer, create the 3D model of object in CAD software, or download it from an Internet database, and materialize this model in the comfort of his own home with his own and inexpensive 3D printer. With the advent of new print materials, opportunities to print unusual objects increase.

The development in the field of electrically conductive printing materials with admixtures of graphene, carbon or copper opens up a wide range of applications in technology. Not only does it allow the printing of sensors and simpler circuits, it can change the entire standard of electronic devices that are now capable of working in three-dimensional space instead of conventional printed circuit boards. Given that the coil is already an inherent part of any electronic device, this article focuses on the possibility of realizing a technical coil using various methods using also 3D printing.

II. 3D FDM Printer with Electrical Conductive Filament

The first way to make a coil is using an electrically conductive composite material called Electrifi. This composite material consists of a non-conductive material, i.e. a PLA polymer, and electrically conductive material that consist of miniature copper grains (copper powder). More detailed information on this material has already been described in [1] [2]. The use of this material is the easiest of all the methods mentioned here, since it can be purchased directly in the form of a wire wound on a plastic cylinder with a filament diameter of 1.75 mm. Subsequently, the material can be loaded into a suitable 3D FDM printer, set the necessary parameters and print the desired product. In our case it is the production of a technical coil.

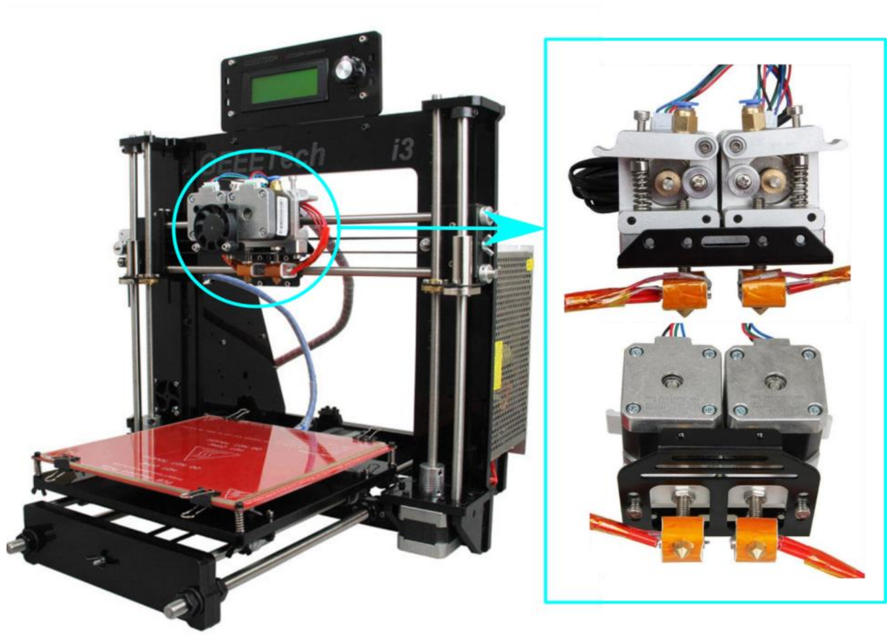

Fig. 1 3D FDM printer with dual extruder

We tested the material and made various measurements of electrical resistance and electrical conductivity [1]. However, after various experiments with this material, we have found that the parameters given by the manufacturer do not approximate those measured by us. Next factors affecting electrical parameters of supplied material:

- Logistics: warehousing and poor quality shipping service
- Manufacturing: poor quality product,
- Custom: unsuitable 3D printer and its components such as nozzle, extruder and others.

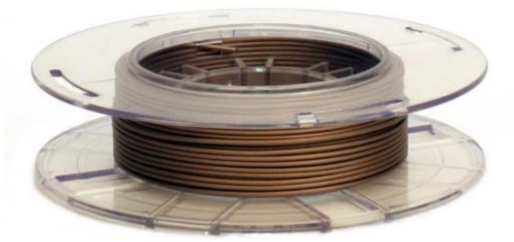

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Fig. 2 Electrifi conductive material from Multi3D [2]

The chance for improving the electrical parameters of a material lies in the application of an electroplating copper coating directly to a printed object from this material. By electroplating of copper layer we could be able to modify the surface of the material and thereby improve its electrical properties such as electrical conductivity. Electrolytic plating will therefore be the subject of further research.

III. Liquid Metals

The second option is the use of so-called liquid metals. These are special metal compounds that are liquid at room temperature or even at a negative temperature. However, the use of such material for the production of a spool would require the use of other 3D printing technology. This would probably involve the use of a pneumatic extruder by means of which the liquid metal is gradually extruded from a nozzle. The advantage of using liquid metal is its good formability at a relatively low temperature. However, the choice of a suitable liquid metal remains a problem, since a metal which is already liquid at room temperature will, of course, not be sufficiently solid for subsequent handling and use.

For successful realization of the coil winding it is necessary to look for a metal that can be easily extruded through the nozzle after heated to 100°C and after cooling to room temperature it changes its state to solid. As an example, the liquid metal Galistan also called Galinstan (Gallium, Indium and Stannum) is an eutectic alloy of gallium, indium and tin metals in the composition: 68.5% Ga, 21.5% In, 10% Sn belonging to the group of low-melting alloys [3] [4].

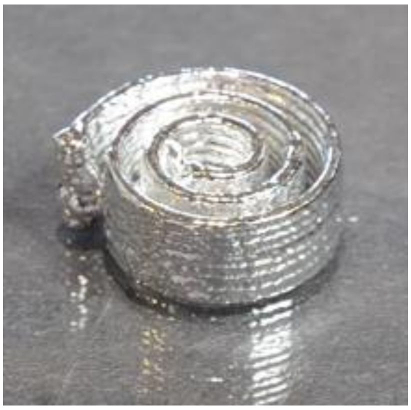

Fig. 3 3D Printed spiral from a material called Galistan [5][4]

IV. LOW MELTING POINT SOLDER

A third possibility is to use solder (tin) as a material for the production of coil winding. Soldering melting temperatures range from 140 °C to 305 °C depending on the type of solder alloy used. Commonly used solder alloy with a higher melting point are not suitable for the production of coil. Because the solder needs to be continuously heated to the desired temperature during the application to become fluid and be able to be continuously applied to the printing pad. Another problem that arises when using a solder in the form of tin is the flux content. Almost every solder available contains some amount of flux that facilitates melting of the tin itself and exact application. Since the solder is primarily intended to solder components to the PCB, the presence of flux is justified. In this case, the content of flux in solder causes clogging of the nozzle and prevents continuous solder extrusion from the nozzle. This results in imperfect resp. no connection to the previous printed layer. Another problem is the market absence of solder without the addition of flux with a suitable composition of the individual alloy elements. To choose a low melting point solder, it is necessary to select a solder containing metals having a low melting point, such as bismuth, cadmium, lead and others. However, another problem is the toxicity of such solder, since it is an alloy containing, in addition to tin, other metals such as bismuth, cadmium and lead. These added metals have toxic effects on the organism, accumulating in the liver, kidneys, bones and nerve tissue. Another problem is adhesion of solder to the metals, thereby creating the need to form a nozzle of a material to which the solder does not adhere, yet sufficiently resistant to handle the higher temperature needed to melt the solder itself.

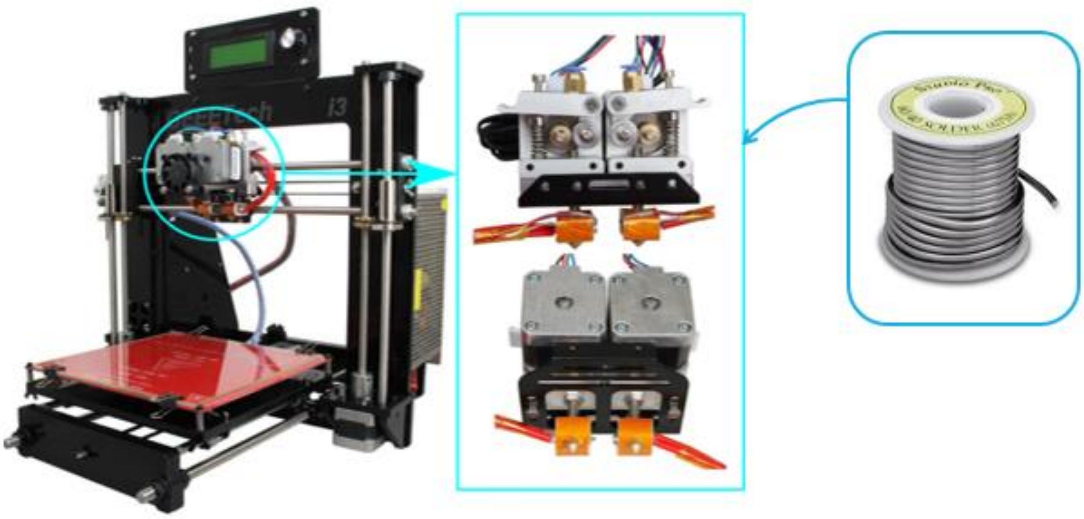

Fig. 4 3D printers with dual extruder and tin as printing material

V. Injecting Liquid Metals to the Plastic Forms

Another solution of the technical coil implementation is the possibility of injecting liquid metal into a plastic mold. With this possibility, a suitable hollow mold in the form of a coil of plastic material would be produced by 3D printing. Liquid or molten metal would be injected into such a hollow mold by a suitable technology. The metal would, upon cooling and solidification, form a conductive connection of the coil winding. As with the options already mentioned, this brings a large number of unexplored cases that need to be tested. For example, which liquid or molten metal can and should be used. This also applies to materials for producing a plastic mold with respect to temperature conditions [6].

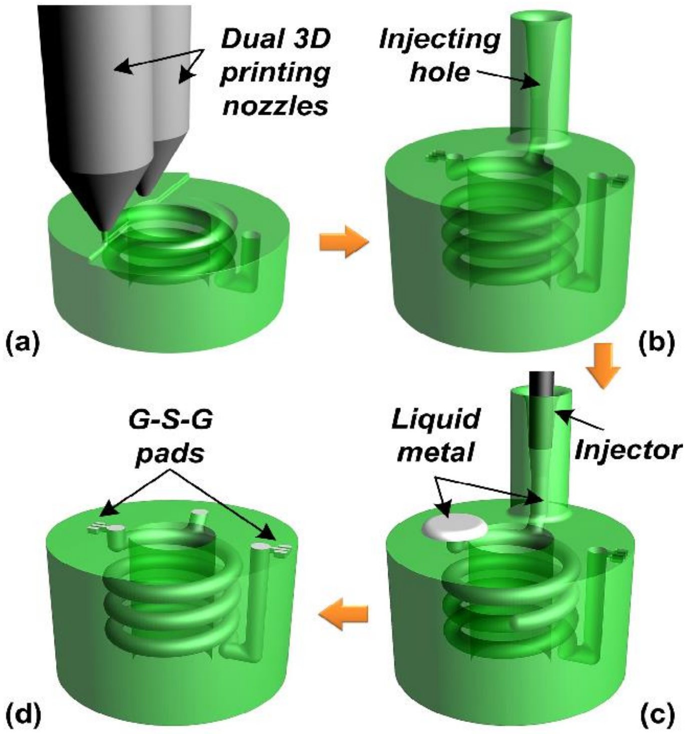

Fig. 5 Process of the proposed 3D fabrication method including the liquid metal filling technique. [6]

On the Fig. 5 you can see the process of the proposed 3D fabrication method including the liquid metal filling technique. (a) 3D printing to form structures with hollow channels (a solenoid-type inductor as an example); (b) a finished 3D structure with the injection hole; (c) liquid metal filling; (d) surface planarization to remove the injection hole and extra metal [6].

VI. Conclusion

Various methods for realizing of technical coil using 3D printing technology were described in the paper. To verify these methods, it is necessary to test them. Consequently, it will be possible to select the most suitable method for realizing the technical coil. The idea of looking for other ways to realize the technical coil also opens up. Individual testing of these options will be subject to our further research in the near future.

References

[1] HRABOVSKÝ, P., MOLNÁR, J. Measuring the electrical resistance of a conductive material for a 3D printer. In: Journal of Industrial Electrical Engineering [online]. 2019, vol. 3, no. 1, p. 52-58.
[2] MULTI3DLLC.COM. Electrifi Conductive 3D Printing Filament [online]. Available online at: <https://www.multi3dllc.com/faqs/>.
[3] WANG, Xuelin; LIU, Jing. Recent advancements in liquid metal flexible printed electronics: Properties, technologies, and applications. *Micromachines*, 2016, 7.12: 206.
[4] DAALKHAIJAV, Uranbileg, et al. Rheological modification of liquid metal for additive manufacturing of stretchable electronics. *Advanced Materials Technologies*, 2018, 3.4: 1700351.
[5] 3DPRINT.COM. Advancing the Field of Flexible Electronics with 3D Printable Liquid Metal Alloy [online]. Available online at: <https://3dprint.com/205872/osu-3d-liquid-metal-printing/>.
[6] YANG, Chen, et al. 3D printed RF passive components by liquid metal filling. In: 2015 28th IEEE International Conference on Micro Electro Mechanical Systems (MEMS). IEEE, 2015. p. 261-264