Micro-3D Inkjet Printing

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Abstract

Based on 2D digital fast and precision inkjet wide-format printing technology and page wide print head technology, we have developed a novel micro 3D stereo digital printing or 3D object accurate and fast production. By using UV curable inkjet technology or IR curable inkjet technology, we can easily and fast solidify the true colorful 3D objects and bring 2D digital technology up to 3D digital printing level. Two types of

3D printers will be addressed to show micro-3D inkjet technology including their various applications on textile, fashion, ceramics, leather, plastics, glass, packaging, personal decorations, detailed stereo sculpture, dental, spine, biotech application, etc..

Keywords: 3D Printing, Additive Manufacture, Micro 3D, Inkjet Printing

Introduction

3D printing has been developed or progressed and pervaded into many industrial areas and even our lives in the past three decades.[1] However, if we look at almost same or very similar technical source of 2D inkjet digital printing, which has been developed over 40 years, we can clearly see that there is a huge difference between 2D plane digital printing market and 3D stereo digital printing market. The former is only about 3 billion and the later has been over 180 billion, almost 60 times of difference. We believe that one reason might be caused by the capability of the computer data processing, which has been solved by recent computer technology progress and development. The another reason could be the old 3D printing industry too limited their technical ideas to a traditional industrial aspect, did not adopt the matured 2D inkjet digital printing technology into the 3D printing in time. i.e., 3D printing did not catch up the pace of 2D inkjet digital printing progress. Therefore, after 30 years long run racing, 3D printing behind the 2D inkjet digital printing far away on the market.[2, 3]

Actually, 2D plane digital printing is the most basic processing of all 3D digital printing, many and many 2D digital printing planes deposited or accumulated layer by layer, over and over again will finally form a stereo 3D object. As 2D plane digital printing technology approaching to a matured level, especially, Multi Inkjet Print Head technology combining UV/IR Curable wide-format flat-bed technology developing and progressing, making a true 3D object become much easier. Therefore, fast and precision 2D inkjet wide-format digital printing has feasibly explored a precision 3D stereo digital printing or making to the reality.

Principle and Methodology

The principle of micro-3D printing is shown as in Figure 1. Ink droplets or forming materials are being jetting out from the multi inkjet print head of a micro-3D inkjet printer, these droplets will be instantly cured by UV or IR cure lamps to form the first layer of 3D object. Then, second layer and third layer, layer by layer, over and over again to form a 3D object what you have designed.

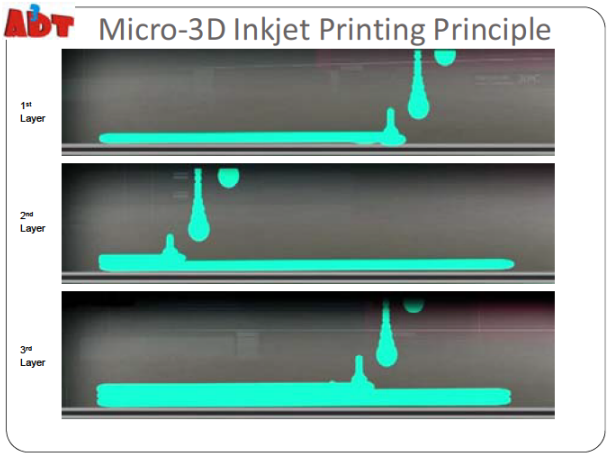

***Fig. 1** Micro-3D Inkjet Printing Principe*

When the upper layer is larger than the under layer, see the Figure 2, if any tilting angle between the larger upper layer and the smaller under layer is larger than 15°, the another ink or supporting materials are needed for a solid structure when 3D object construction. In Figure 2, the yellow part is the forming material, and the white part is the supporting material. When 3D printing, both yellow (forming material) and white (supporting material) are as two different single colors with a clear boundary as the regular single color inkjet digital printing. Therefore, at least, two colors or two different materials are needed for any shape of 3D object making. The supporting materials will be flashed away or washing off after 3D object constructed.

Based on 2D plane textile wide-format flat-bed digital printing, we have developed a novel UV or IR curable micro-3D printer for all stereo digital printings with a true color appearance. The true color of 3D object appears with our specialty designed Gradient 3D Inkjet Inks after many layers accumulations of 3D printing. This technology overcome the technical barrier of all previous 3D printer only can make simple color or single color. Therefore, the oil painting accurate reproduction will become very easy. This micro-3D printer equipped with the white color, so it can be used in all dark background stereo digital printing. See Figure 3, its application is very wide, almost includes all industrial stereo digital printing. There are many different types of 3D inkjet "Inks" (Forming Materials), usually located in the three big categories: hard, medium, soft materials with different gradient of colors.

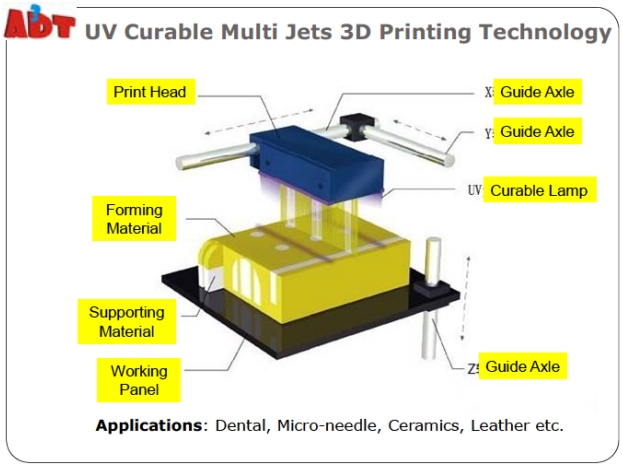

Fig. 2 *UV Curable Multi Jets 3D Printing Technology*

Fig. 3 *UV Curable Wide-Format Flat-Bed Micro-3D Printer*

Results and Discussion

1. Micro-3D printing can be very well applied on a various of stereo industrial digital printings: We have designed and developed a novel PJW-1300 UV curable wide-format flat-bed micro-3D printer for all industrial stereo digital printings. It can be used in oil painting reproduction, which is the true color oil painting reproduction with true 3D effects when equipped with ADT gradient inkjet inks. The 3D stereo digital prints are ecology green products, water-proof, lightfastness, outdoor weather durable to chemical solvents. The gradient inkjet inks are dependent on how many layers 3D printings, usually, 3 - 10 gradients should be fine for most micro-3D printings applications on oil painting. textile garment, fashion design, sport wears, leather case and bag logos, shoes and boots, ceramic tiles, glass and wooden doors, home interior or exterior decorations, stereo ads and labels, concave-convex packaging, etc. Also, there are at least three types of hard, medium, and soft gradient inkjet inks (3D forming materials) to fit different above mentioned applications or customer designs. See Figure 4 for some our micro-3D printers and printing samples. The Z-axial height can be automatically adjusted up to 400 mm, which is controlled by our 3D printing software. The white color ink (3D material) is designed for all black or dark background substrates to provide correct color appearance, especially in fewer layers of micro-3D stereo printing. This technology has solved the problem of all current 3D printers could not make a true color 3D object. Additionally, it brings the original 2D plane digital printing to be easily upgraded to micro-3D printing and explores a brand new stereo digital printing market and new a life for the old 2D plane digital printing industries. Therefore, micro-3D printing technology will have a brighten near future.[4, 5]

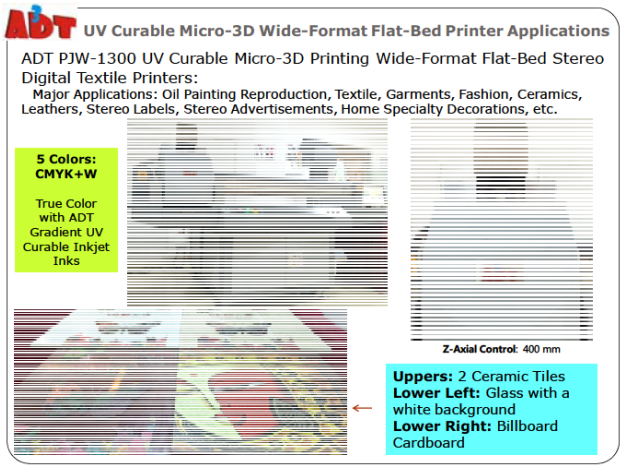

Fig. 4 PJW-1300 Applications

2. Micro-3D printing on biological applications is shown in Figure 5. We can see there are several different applications on the micro-needles electrodes and dental currently in our labs.

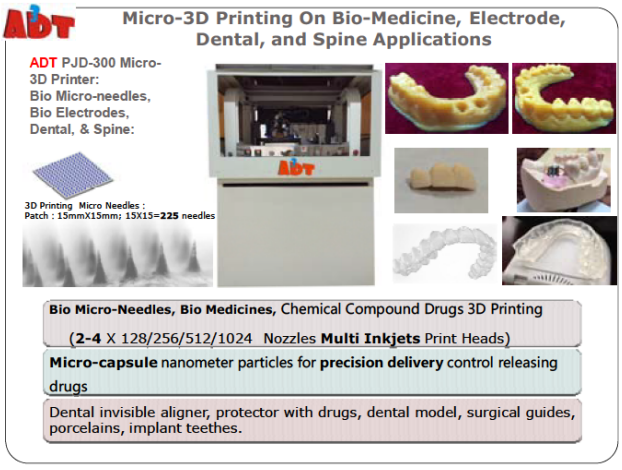

Fig. 5 PJD-300 on Bio Applications

By using PJD-300 micro-3D printer, we have made polymeric dental models and micro-needle patches. The printer is equipped with two Spectra 128 print heads, one is for 3D forming material, another is for supporting material when it needed in the 3D object printing. It is also a UV curable inkjet micro-3D smaller flat-bed

printer equipped with LED UV lamps. 20 pairs of different dental models can be made at same time which save many hours in traditional CNC processing. Also a series of clear or invisible dental correction aligner set with mechanical strength can be directly made by this printer.[6] With healing and making up functions of teeth protectors can be directly printed by silicone elastomeric polymeric materials as well.[7]

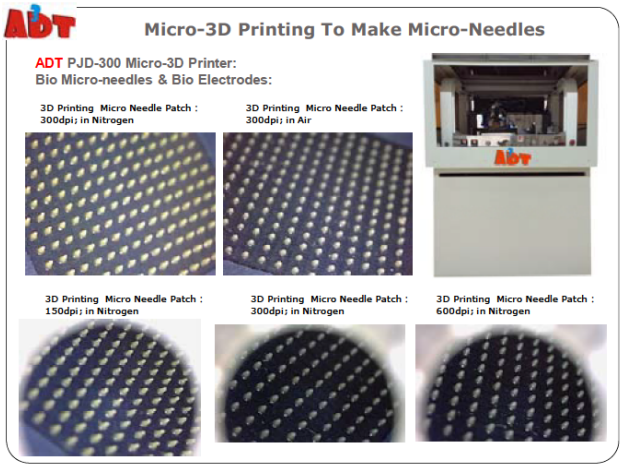

Fig. 6 *Micro-Needles Under Different Conditions*

We have found that the oxygen in air will largely effect the making micro-needles, especially on the needle tip part. As we known, the oxygen is an inhibitor for polymerization.[8] Micro-needle is very small or very tiny, ambient atmosphere is always around micro-needles when 3D inkjet printing, even though the initiators in the system (monomers and oligomers) were initialized by UV light, due to the oxygen in air around the surface of the printed, the polymerization would be partly quenched to form the object structure somehow collapsed. From Figure 6, we can obviously see this phenomenon. The upper two pictures from the snap image captures of eheV1-200USBPlus Microscope Borescope clearly show the 3D printed difference between in nitrogen and in air. When 3D printing exposed to air, the micro-needle tip are round and shorter, which means the micro-needle was collapsed when printing, i. e., the ink was not instantly cured or solidified by UV lamps. When the micro-3D printing under a nitrogen ambient, the initiators of ink system will be much better initialized by UV lamps and the liquid ink will be instantly cured or solidified to form the shape and structure what we designed. So, we can obtain a sharper micro-needles with nitrogen protection.

We also have investigated the difference of printing dpi used. The lower 2D printing dpi means need more and thinner layers. Because the 3D printing using a concept of Voxel (a cubic unit), not a Pixel (a plane unit). The layer height is 1.25 μm in the 150 dpi, however the layer height is 5 μm in the 300 dpi, and the layer height is 20 μm in 600 dpi. That means the 150 dpi needs printing 4 times more layers than that of the 300 dpi, of course, it will take longer time to finish the 3D printing job but with more precision results and more accuracy structures. If using 600 dpi, also compared with 300 dpi, the faster printing and shorter time will take, but, the results and structure will be rougher and inaccurate. See Figure 6 the bottom 3 captured images for this analysis. For the micro-needles, we believe the 150 dpi has provided the best result so far, even though it would take a longer time to finish the 3D printing. If we want to increase the speed of 3D printing, we could add more print heads to reduce the manufacturing time and raise up the efficiency. Adding one more print head, the printing speed will increase 90% at least. The processing efficiency will increase almost double.

Based on the above results, we can make a bio electrode for the non-drug dosed micro-needles with conducting materials. These biological electrodes can be used in healing medical instruments, like an induced electric field could be applied onto the cerebral palsy.[9] This research and development project is undergoing with our customers. By using the micro-needle electrodes, it will benefit the cerebral palsy patient to recover from a deeper biological-electric stimulation on the nerve system with a safer method, it will be better than acupuncture.

Conclusion

We have made two types of micro-3D printers: PJW-1300 and PJD-300 based on Multi Inkjet flat-bed digital printing principle. Wide-format PJW-1300 has solved true color 3D object digital printing via a series of Gradient Inkjet Inks cured by UV or IR lamps. We have brought the original 2D plane digital printing into a new 3D stereo digital printing era.

We have explored the micro-3D printing technology to make the sharp and tiny micro-needles. The initial application will be on medical treating instruments as a bio-electrode. To make qualified micro-needles, the micro-3D printing process should be under nitrogen protection and with a lower dpi model printing.

We have successfully used the micro-3D printing technology to make personalized dental models at a scale up level. It could permeated into dental processing center as a major tool for the real production.

Other two new models (LIJ and CNDP) of novel regarding micro-3D printing technologies are under developing.[10, 11] It will cover all micro-3D inkjet printing with nano-particles materials.

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Biography

Dr. Jie Wang currently is CEO president of ADT, Advanced 3D Printing Technology (Zhuhai) Co., Ltd. since 2013 and president of ND, Nano Digital Technology (Zhuhai) Co., Ltd. since 2007. He was president of JCD Digital Inkjet Tech (Shanghai) Co. Ltd. from 2005 to 2007 and general manager of Graphic Digital (Portland, Oregon) from 2001 to 2005. In the past 18 years, he has contributed numerous papers, presentations, publications and patents to address his research and development team on micro-3D printing and inkjet printing invention and innovation. After graduated from SUNY- ESF, Syracuse University with the Ph.D. degree in polymer science, Syracuse, New York in 1996, He worked as a postdoctoral researcher in Ames Laboratory of USDOE and Iowa State University from 1997 to 1998, then worked for PolymTech, Inc., Ames, Iowa as a senior scientist and technical manager from 1998 to 2000. He started working with Graphic Sciences, Inc. as an associate director of R&D, Portland, Oregon in 2000.