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1. Introduction

Many inkjet printed antenna are thermally treated by processes such as sintering to ensure the nano-particle ink reaches optimum electrical conductivity. This treatment process uses high temperatures and is therefore expensive to power and limits the types of materials that can be used as substrates.

Instead, researchers have realized the benefits of particle-free inks, where a solvated metal salt is reduced in-situ to produce a metal. Since the metal is formed in-situ and the proportion of binder materials is very low, the conductivity of particle-free inks can be as high as 80% of the bulk metal. This is beneficial because less ink needs to be used for layers during printing and there is less solvent to evaporate so curing time is reduced. Particle-free inks also have a low viscosity, and their lack of particles means that nozzle clogging is less frequent, and the coffee ring effect is suppressed.

For particle-free inks the selection of metal precursor will determine the thermal and electrical properties of the ink. Metal aliphatic carboxylates, unsaturated, branched and substituted with a hydroxyl group are preferred precursors because they provided good conductivity and are easily transformed into metal atoms at low temperatures via a decarboxylation reaction. The low sintering temperature of such inks enable a wider range of substrates to be used, expanding the applications for inkjet printed antenna.

In this work two particle-free inks have been manufactured for inkjet printing of antenna, one with a silver carbonate precursor and another with a silver citrate precursor.

2. Ink properties

As shown in Table 1, both manufactured inks marginally failed to meet the printer surface tension recommendation, but both are within that given for density. The key differentiation between the two inks is the dynamic viscosity, both of which are below the printer specifications. However, the printer recommended values are not strict limits, for the Fujifilm Dimatix Inkjet Printer that was used, fluids within a range of 2 – 30cP are jet-able. The Z number of both inks was within the recommended range for the inkjet printer and so it was expected that the inks would be jettable.

Table 1: Table listing the surface tension, density, nozzle, dynamic viscosity and Z number for the silver carbonate and silver citrate inks compared to the printer recommendations.

Precursor	Surface Tension (mN/m)	Density (g/cm^3)	Dynamic Viscosity (cP)	Z Number
Silver carbonate	27.15	1.0402	4.6293	5.32
Silver citrate	27.92	1.0912	2.6159	9.78
Printer recommendations	28-42	>1	10-12	$1 < Z < 10$

3. Jetting of silver carbonate ink

The jetting waveform was optimised and tailored for the silver carbonate ink to ensure droplet velocity was between 6 m/s and 9 m/s and the droplet had a good shape. As shown in Figure 1 the silver carbonate ink was jetted from nozzle 1 to 4 at 22V and a temperature of 22.4ºC. All four nozzles had a similar droplet speed which was a between 7 and 8 m/s and all droplets had a good shape, with no satellite or tails.

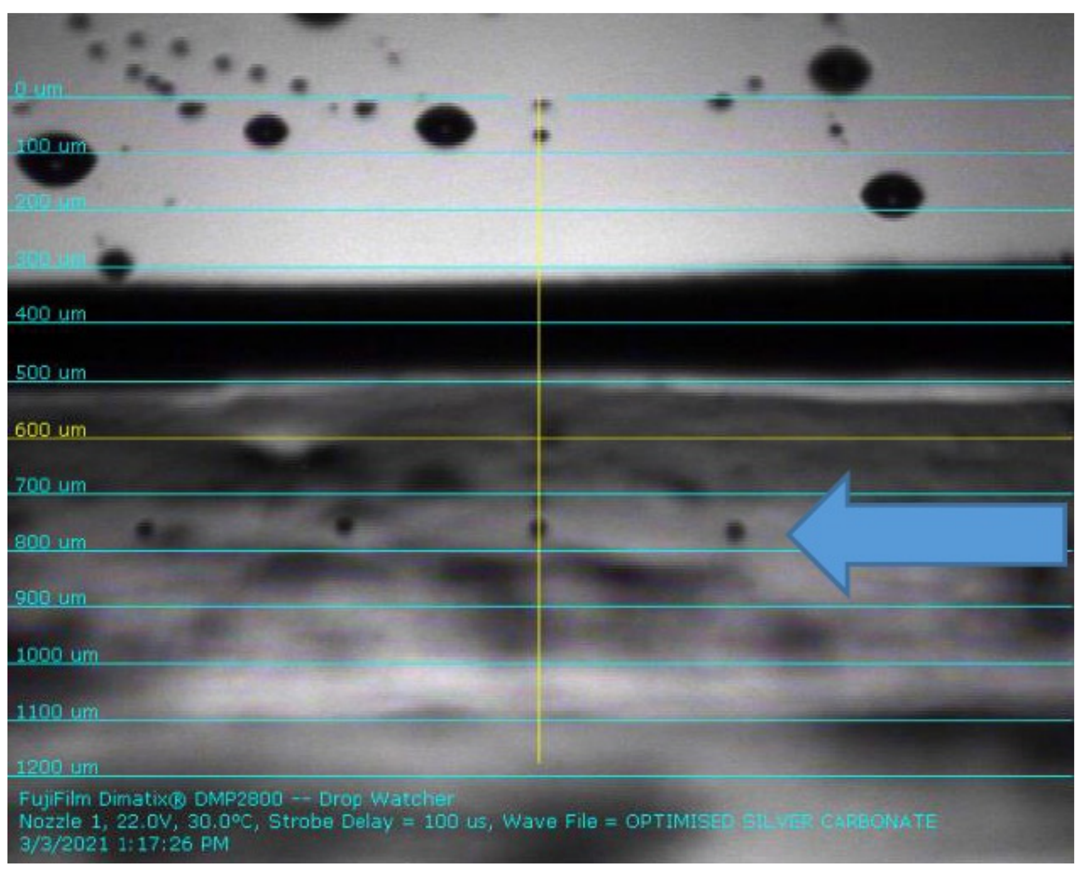

Figure 2: Dropwatcher image of the silver carbonate ink droplets from nozzles 1 to 4.

4. Jetting of silver citrate ink

The jetting waveform was then altered and optimised for the silver citrate ink to ensure the droplet velocity was also between 6 m/s and 9 m/s with good droplet shape. As shown in Figure 2 the silver citrate ink was jetted from nozzle 1 at 19V and a temperature of 22.4ºC. It was optimised to print between 6 and 7m/s and had a good droplet shape with no satellite or tails.

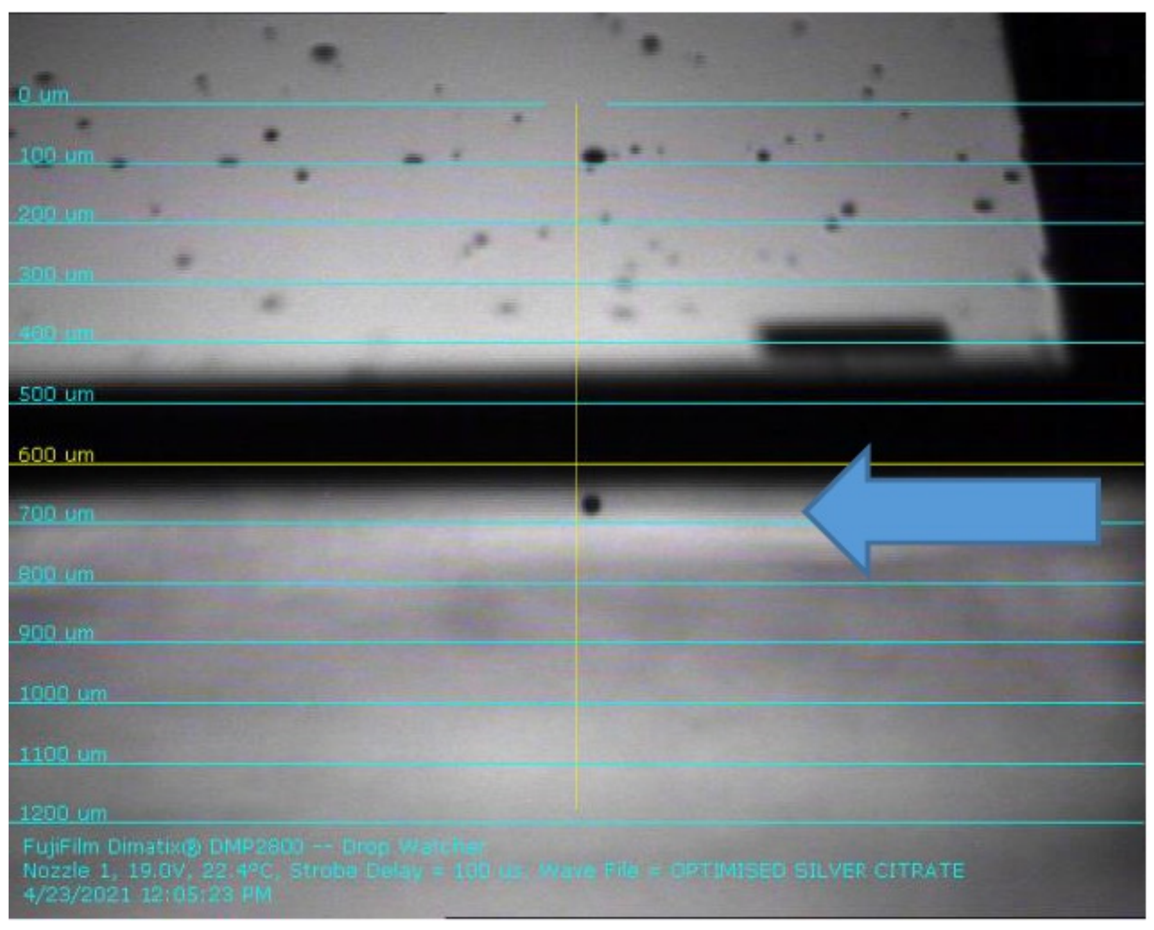

Figure 1: Dropwatcher image of the silver citrate ink droplet from nozzle 1.

5. Conclusions

- The silver carbonate and silver citrate inks both had good jettability.
- The silver carbonate and silver citrate inks should both be processable at low temperatures.
- The silver carbonate ink began to degrade after just two months of jetting, so it does not have a good shelf life.
- The silver citrate ink had a slightly longer shelf life of seven months.

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