Inkjet Printing Toluene using the Dimatix Materials Printer

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Application Note

Introduction

With the miniaturization of packaging in areas such as electronics, optics, medical devices, sensors, coatings and wafer fabrication, the spatially controlled and precise deposition of particles into increasingly smaller spaces or as patterned films has become critically important. These thin films are material layers having a thickness of less than 1 μm and are generated using a variety of techniques including chemical vapor deposition (CVD) and spin coating.

CVD relies on using a gas phase and high temperatures to produce a thin film[1] The thickness of the film is controlled by the internal pressure of the deposition chamber, and the volume and temperature of the gas such that the number of moles of material deposited is equal to the pressure times the volume divided by the universal gas constant times the absolute temperature (ideal gas law):

$$n = PV/RT$$

Additionally, only a uniform coating is possible unless some areas are masked during the deposition process or thin film areas are removed chemically after thin film production. Taken together, these outcomes suggest that in order to produce a patterned thin film, subtractive processing is required thereby driving up the cost of processing.

In producing thin films, an alternative to CVD is spin coating. In this technique, the material is dissolved in an easily evaporated solvent, and the substrate is rotated with a specific centrifugal force in order to obtain a thin film.[2] In this technique, the number of moles of deposited material is determined by the concentration of the starting material, the evaporation rate of the solvent (or air flow above the substrate), the time, speed and force of the centrifuge and fluid viscous forces. Generally, films of less than 10 nm can be produced, but this thickness is manipulated by changing operating parameters. This technique has at least two technical obstacles; first, the film coating is being driven to the outside of the substrate edge during processing meaning there can be a gradient thickness of the film from the inner substrate core to the outer substrate core and secondly, any small changes in centrifugal force or composition can lead to radically different thin film characteristics. However, from a processing standpoint, it is an easy process to establish and once tuned, reliable films can be produced.

While it is possible to yield uniform thin films with both of these processes, in general, often the desired outcome is to produce a patterned thin film. Considerable attention has been directed towards producing patterned thin films of materials, and new techniques need to be developed to address this important requirement. Many researchers are taking their existing techniques in CVD and spin coating and adopting them to techniques that allow patterning. Ink jet printing is an obvious technique to adopt, and the Fujifilm Dimatix Materials Printer is an ideal research and development tool that will easily allow the deposition of patterned thin films. However, in general, ink jet printing jettability is determined for the printer by using fluids in the viscosity range of 10-12 centipoise (cps) and 28-32 dynes/cm^2. In contrast, the viscosity for toluene is 0.590 cps at 20ºC. The surface tension is 28.5 dynes/cm^2. Some of the work in our lab has been overcoming this obstacle to ink jet print nanoparticle- or polymer-containing fluids containing toluene as the base component. In order to successfully jet this material, we have produced a unique waveform for ink jet printing toluene.

MSDS[3]

Common synonyms: Methylbenzene, phenylmethane

Formula: C_7H_8

Physical properties: Form: colorless liquid. Stability: Stable, but very flammable. Melting point: -93ºC. Boiling point: 111ºC. Triple point: -93º. Critical temperature: 320ºC. Critical pressure: 41 bar. Enthalpy of vaporization: 38 kJ mol^{-1}. Enthalpy of sublimation: 43.1 kJ mol^{-1}. Water solubility: negligible. Specific gravity: 0.865

Principal hazards: Toluene is toxic if swallowed or inhaled. It is also harmful in contact with the skin. Toluene is very flammable, so presents a significant fire risk. There is some evidence that repeated exposure to toluene may cause reproductive harm.

Safe handling: Wear safety glasses. The working area must be well ventilated to prevent the build-up of toluene vapor. Make sure that any sources of ignition, such as Bunsen burners, hot plates and hot air guns, are removed before you start work.

Emergency: Eye contact: Immediately flush the eye with plenty of water. Continue for at least ten minutes and call for medical help.
Skin contact: Wash off with soap and water. Remove any contaminated clothing. If the skin reddens or appears damaged, call for medical aid. Note that clothes soaked in toluene will be very flammable, so should be removed in an area in which there is no risk that they might catch fire.
If swallowed: Call for immediate medical help.

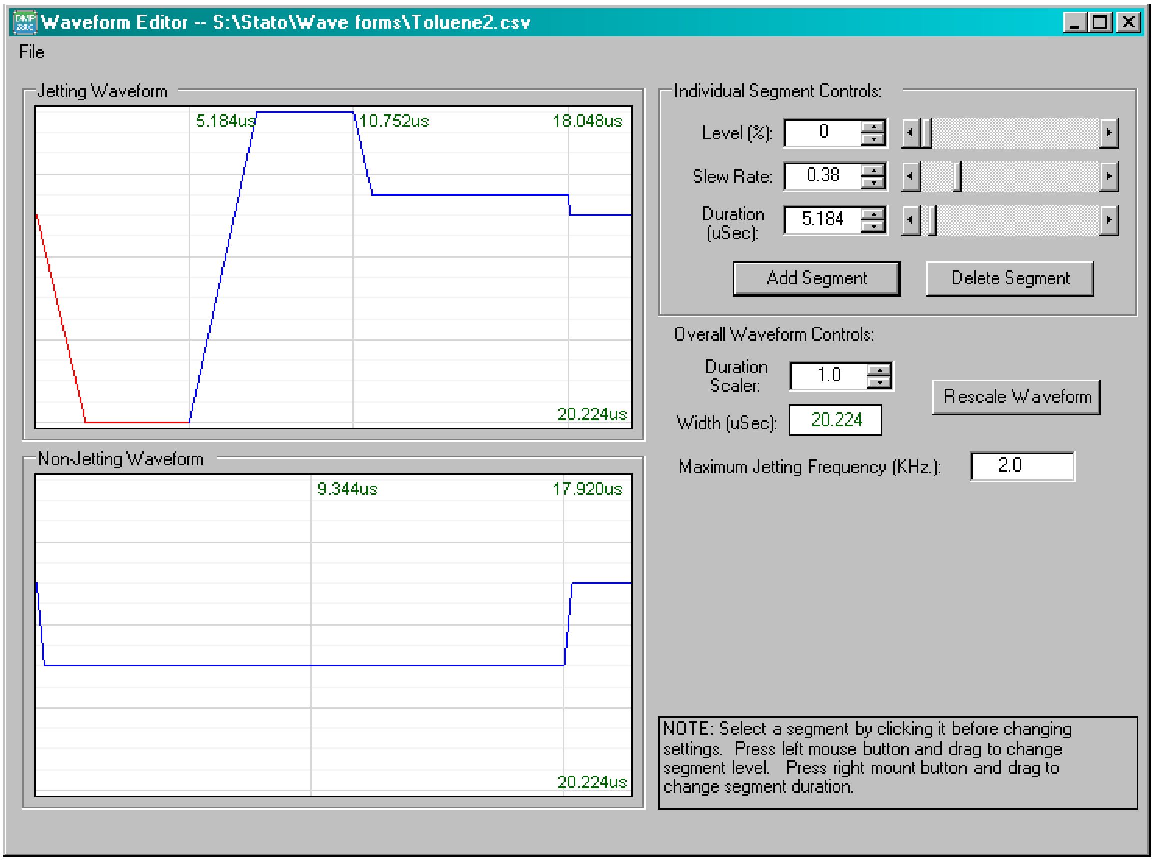
Disposal: Toluene should be stored in a "non-chlorinated waste" container for subsequent disposal.

Protective equipment: Safety glasses. If gloves are required, polyvinyl alcohol is recommended.

Waveform

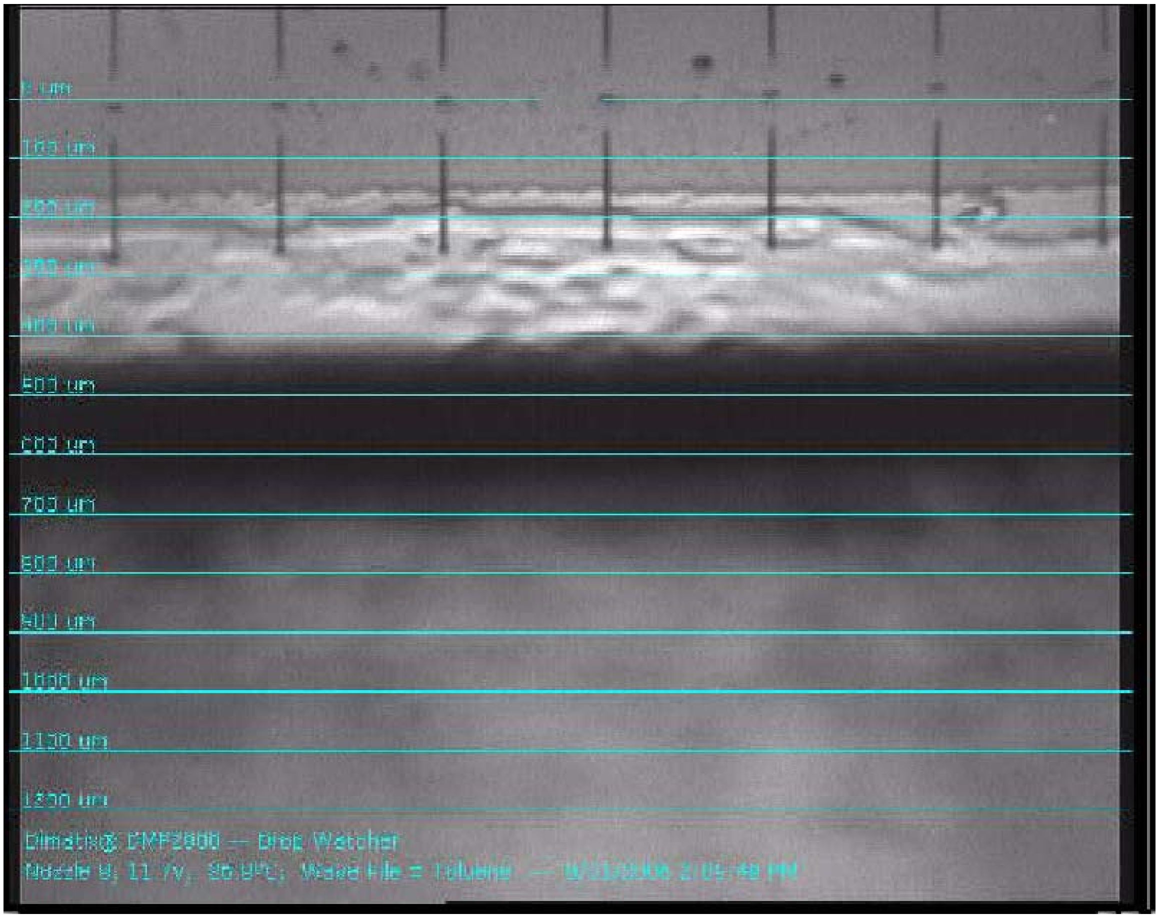
Description:

This waveform pulse has a maximum jetting frequency of 2.0 KHz. The pulse length is 2.24 microseconds (μs) with the maximum peak (100% total frequency) occurring at 5.184 μs. This maximum peak plateaus for 5.558 seconds and then with a slew rate slope of 0.38, another minor peak (70% total frequency) initiates at 11.224 μs and lasts for 6.816 μs. The waveform then slopes to 0% and recovers the next pulse. In general, the printhead nozzles are run between 11 and 12 volts using this waveform setting.



Conclusions

Toluene is jettable using the right parameters albeit at lower frequency. We have been able to reproduce these parameters independently with different cartridges and DMPs. The toluene evaporates quickly, so it is up to the researcher to allow for a smaller stand-off printing distance to the substrate if required for their application. As you can see from the figure below, the toluene comes out of the nozzles with nice ligaments that all form into single drops before hitting the substrate.



References

1. Principles of Chemical Vapor Deposition by Michael K. Zuraw, Daniel Mark Dobkin.
2. Dirk W. Schubert, Thomas Dunkel; Spin coating from a molecular point of view: its concentration regimes, influence of molar mass and distribution; Materials Research Innovations Vol. 7, p. 314 (2003).
3. http://ptcl.chem.ox.ac.uk/~hmc/hsci/chemicals/toluene.html

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