

## Application Note: Viscosity measurement of Various Inkjet Inks

In 2006, the growth of the global ink industry exceeded \$14 billion. Today, the inkjet ink industry of that market continues its rapid growth, becoming a premier digital printing technology. The advancement of the inkjet technology opened new applications such as precise liquid dispensing, patterning for RFID, and so on. This application note provides information about using the VROC™ in the inkjet industry.

### Application—Measure Viscosity

Two physical components of ink determine the print quality—surface tension and viscosity. These two factors affect the droplet formation of the ink, which in turn affects the quality of the resulting printout. For quality printing, ink viscosity must be controlled.

The viscosity of ink depends on the components of ink, including pigments, resins, or binding agents. As these formulas are complex, ink can exhibit a very complex viscosity behavior, which is related to the extent of shearing or the inkjetting rate.

As liquid ink flows through the inkjet nozzle, the ink is subject to a complex time dependent shearing. In particular, the ink experiences a high shearing near the nozzle. The magnitude calculation implies that the shear rate can range from  $10^5 \sim 10^7 \text{ (s}^{-1}\text{)}$ <sup>1</sup>.

The calculation indicates that determining the low shear rate viscosity values is not enough. That information alone does not provide a full analysis of how inks behave during inkjetting—the viscosity at high shear rates is another important property to consider. In addition, Non-Newtonian inks show a dramatically different viscosity, which is also related to the inkjetting rate (shear rate).

Due to the physical complexity of inks, viscosity measurement over a wide range of shear rates (low and high shear regimes) must to be performed for better understanding, which leads to better control.

For this application note, three inks were tested to obtain full viscosity curves, which indicate that inks can show dramatically different viscosities. It was also noted that viscosity measurements were dependent on the formulation of the inks, as well as the low and high shear rates.

### VROC™ Chip technology

VROC™ (viscometer/rheometer-on-a-chip) is the smallest viscometer built in a chip, which provides a complete viscosity characterization over the wide range of shear rates of any liquid. This chip has been proven for its precision and accuracy, and adopted for the viscosity characterization method for high throughput systems.

For ink rheology characterization, VROC's micron scale of the flow path in the chip is very similar to actual inkjet conditions. This feature provides viscosity measurement beyond  $10^5 \text{ s}^{-1}$ , thus simulating actual inkjet conditions. Because of its range and accuracy, VROC™ is a very important instrument for characterizing inks over the complete shear rate range and for quality control.



### Measurement Study

Viscosity curves were measured for three different inks. The results strongly suggest that the viscosity curve is complex—viscosity between inks behave quite differently, even when the viscosity was very low. Following is a summary of how the test was run.

- 1) Test sample is loaded into a syringe and then mounted onto a syringe pump.
- 2) Using VROC\_RateSweep program, the viscosity was measured as a function of shear rate (flow rate). For non-Newtonians, 2D-Weissenberg-Rabinowitsch correction was applied to extract the “true viscosity”.
- 3) The measurements were recorded and graphed.
- 4) After each test, the flow paths were cleaned with the appropriate solvent.

<sup>1</sup>  
<http://www.cheng.cam.ac.uk/research/groups/polymer/RMP/InkJet/inkjet.html>.

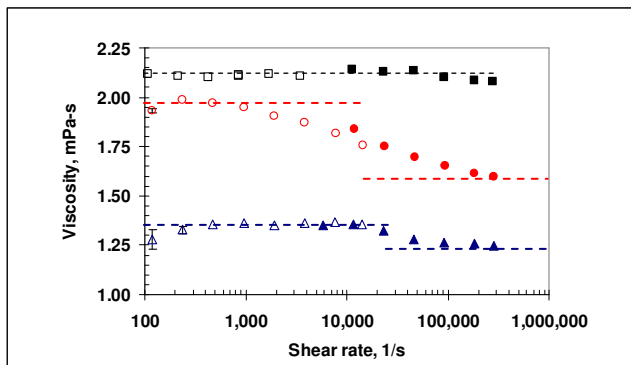
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### Test Setup

- **Test samples:** Nukote replacement black inks were purchased from WalMart and two other inks from another source.
- **VROC™ chip:** C-05 and A-05 types
- **Syringe:** 25 ml and 1 ml.
- **Flow channel depth:** 50 μm.
- **Temperature:** ambient condition, 23 ~ 23.7 °C.

### Measurement

#### Viscosity vs. shear rates



Symbol	Sample description
■, □	Nukote Black Ink
●, ○	Y Ink
▲, △	C Ink

- The filled symbols (■●▲) indicate measurement with C-05 chip; the open symbols (□○△) indicate measurement with A-05 chip.
- Nukote Black ink is replacement ink, which is available at retail stores. The ink viscosity was measured to be constant at  $2.11 \pm 0.02$  mPa-s over the entire shear rate range from  $100 \sim 2.5 \times 10^5$  s<sup>-1</sup>.
- In contrast, Y and C inks showed different trends. The shear thinning: viscosity of Y ink decreased significantly from 2.0 mPa-s at  $100$  s<sup>-1</sup> to 1.6 mPa-s at  $2.8 \times 10^5$  s<sup>-1</sup>. The viscosity of C ink showed a smaller decrease with the shear rate.

The viscosity measurements indicate that the viscosities of inks and their shear rates dependencies vary. Similar viscosities at low shear rates did not provide sufficient information to determine if the two inks performed the same. The differences in inkjetting performance may be attributed by dissimilar viscosity at high shear rates. These measurements show that

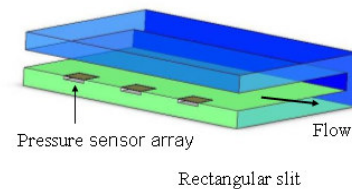
complete viscosity characterization is essential—measuring the entire viscosity curve provides more information, which leads to more control of the quality of ink.

### Principle

The viscometer-on-a-chip measures viscosity from the pressure drop, while a test liquid flows through a rectangular slit. This scientific application is well known (K. Walters, Rheometry<sup>2</sup>).

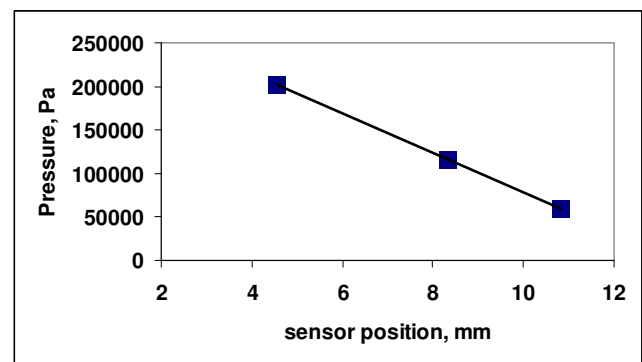
### Physical Structure

The VROC chip consists of a rectangular slit that is formed with glass and a monolithic Si pressure sensor array. The width of the rectangular slit is far greater than the depth of the slit — the edges of the slit are a negligible contribution to the pressure drop.



### Usage

When the test sample is pumped to flow through the slit channel, the monolithic pressure sensor array measure pressure at separate locations. As previously described, the flow disturbance is negligible.



Data was obtained for Newtonian Glycerol at  $1,220$  s<sup>-1</sup> using a type C sensor.

If you have questions or need more information, please contact us.

<sup>2</sup> K. Walters, Rheometry, Chapman and Hall, London, 1975