Application Note:

Viscosity Measurement of a Solvent Mixture

Application

This application note addresses the accuracy and resolution of VROC™ technology. VROC™ is a viscometer-rheometer-on-a-chip, which is a micron scale viscosity sensor chip for small samples. Micron scale geometry enables measuring viscosity at shear rates beyond the limits of conventional technology.

Viscosity measurement is a direct method that can monitor a concentration of simple mixtures such as ethanol and water. The concentration of such a mixture greatly exceeds the density change. By monitoring the viscosity, the concentration of a mixture is well monitored. Closed-loop control can be initiated when the viscosity deviates from the specified value.

Sample Preparation

HPLC grade 200 proof ethanol was acquired from Sigma-Aldrich. The ethanol was mixed with distilled water at various concentrations. The ethanol concentrations of these mixtures were 100, 80, 60.06, 40.3, 20, 10, 8.01, 6.02, 2.04, and 0.0. Viscosity measurements were performed at 25°C ±0.2°C.

Measurement Procedure

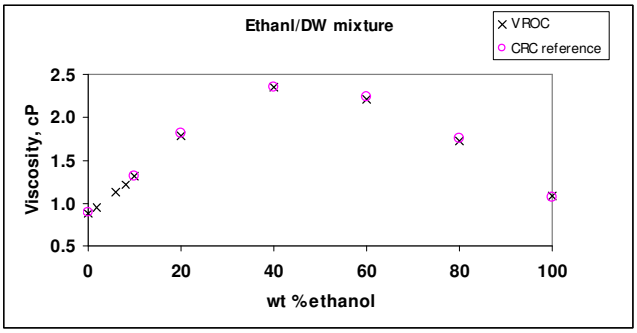
1) Load the sample into a syringe.
2) Mount the syringe to the pump.

   The syringe and A-05 VROC chip were connected through a switching valve. A-05 is a chip with a 50 um flow channel depth, designed for a sensitive and accurate measurement of the low viscosity range (0.2 ~ 100 cP).
3) Turn on the water bath to control the temperature jackets for the syringe and the chip at 25 °C.
4) Measure viscosity.
5) Repeat the procedure for the next sample.

Results

Viscosity vs. Concentration

The following graph compares the viscosity values measured with VROC™ to the values from the CRC handbook[1].



Symbol	Representation
X	VROC data
○	CRC handbook value

The following table lists the measured viscosity values.

Ethanol wt%	Value measure with VROC, cP
0.00	0.885
2.04	0.956
6.02	1.122
8.01	1.209
10.00	1.316
20.00	1.789
40.30	2.361
60.06	2.214
80.00	1.726
100.00	1.080

The standard deviation was calculated from three or more measurements. The results — deviation was less than or equal to 0.01 cP, an indication of repeatable measurements. The following table shows the reference values of the mixture at various concentrations.

[1] CRC Handbook of Chemistry and Physics, 74th ed., CRC Press, Boca Raton

Ethanol wt%	CRC Reference value, cP
0	0.89
10	1.32
20	1.81
40	2.35
60	2.24
80	1.75
100	1.07

As shown in the results, the VROC data measurements are in close agreement with the reference values of the CRC handbook. The differences are within 0.7% of the reference values.

Summary

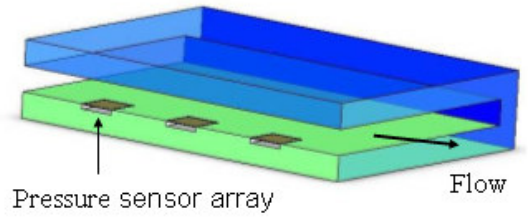
- VROC™ is demonstrated as an effective viscosity measurement tool for low viscosity mixtures
- No solvent evaporation
- High accuracy and high resolution

Principle of Viscosity Measurement with VROC™

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

Physical Structure

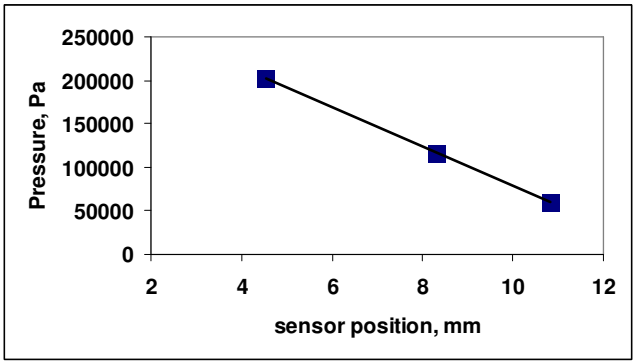
The VROC chip consists of a rectangular slit that is formed with glass and a monolithic Si pressure sensor array. The width of the rectangular slit is far greater than the depth of the slit — the edges of the slit are a negligible contribution to the pressure drop.



Rectangular slit

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^{-1} using a type C sensor.

Packaged VROC™ Chip

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

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[2] K. Walters, Rheometry, Chapman and Hall, London, 1975