Electrorheology Visualized at National Institutes of Standards and Technology Center for Neutron Research

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The proper application of Electrorheology can reduce the viscosity of crude oil. As more and more heavy crude oil will be produced in the future, a reliable technology to lower crude oil's viscosity becomes urgent. Observation of an electric field applied to crude oil using a neutron beam shows the microstructure of the crude oil forming short chains therefore reducing viscosity.

On August 2 and 3, 2010, a group from Temple University led by Dr. Rongjia Tao conducted experiments at the National Institute of Science and Technology (NIST) Center for Neutron Research (CNR). NIST, in Gaithersburg, Maryland is the nation's first federal physical science research laboratory. Over the years, the scientists and technical staff at NIST have made solid contributions to image processing, DNA diagnostic "chips," smoke detectors, and automated error-correcting software for machine tools. Just a few of the other areas in which NIST has had major impact include atomic clocks, X-ray standards for mammography, scanning tunneling microscopy, pollution-control technology, and high-speed dental drills.

Fig.1 Center for Neutron Research (CNR) at NIST

The Center for Neutron Research (CNR) at NIST, has many instruments designed to look into matter at a molecular level using neutrons. Neutrons are powerful probes of the structure and dynamics of materials ranging from molecules inserted into membranes mimicking cell walls to protons migrating through fuel cells. The unique properties of neutrons can be exploited by a variety of measurement techniques to provide information not available by other means. They are particularly well suited to investigate all forms of magnetic materials such as those used in computer memory storage and retrieval. For example, atomic motion, especially that of hydrogen, can be measured and monitored, like that of water during the setting of cement. Residual stresses such as those inside stamped steel automobile parts can be mapped. Neutron-based research covers a broad spectrum of disciplines, including engineering, biology, materials science, polymers, chemistry, and physics. CNR has 28 experiment stations: six provide high neutron flux positions for irradiation, and 22 are beam facilities most of which are used for neutron scattering research.

Dr. Tao's team used the NG7 SANS (Small Angle Neutron Scattering) beam. The SANS device uses neutron reflectometry, a relatively new technique for investigating the near-surface structure of many materials.

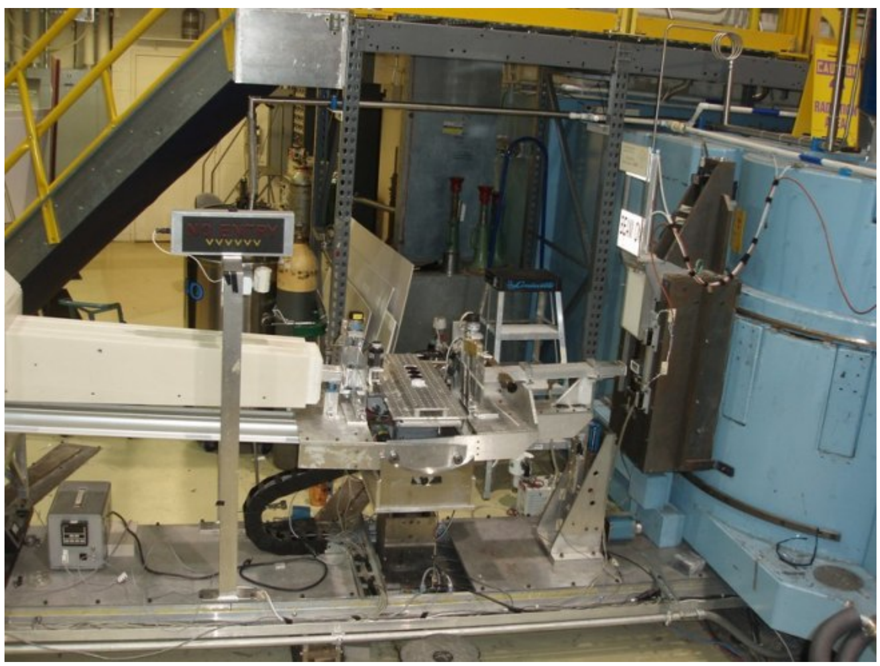

Fig. 2 NG7 SANS (Small Angle Neutron Scattering) beam

NG7 line was built jointly by Exxon and US government, dedicated for fluid research. Dr. Tao and his group collected test data over their 48 hours of access to the NG7 neutron beam. Prior to the testing at CNR, the team made a special capacitor chamber, consisting of two pieces of cadmium as electrodes. The capacitor chamber also has a quartz window in the direction perpendicular to the electric field for the neutron beam to pass. Electrodes made of Cadmium, a neutron absorber were used to reduce unwanted background noises. During the experiment, crude oil was first poured into the capacitor chamber. In the first pass, there was no voltage applied to the electrodes, hence no electric field. Then the neutron beam, passing through the quartz window, shined on the crude oil and was scattered out by the crude oil. Here is a picture of the neutron scattering pattern with no electric field.

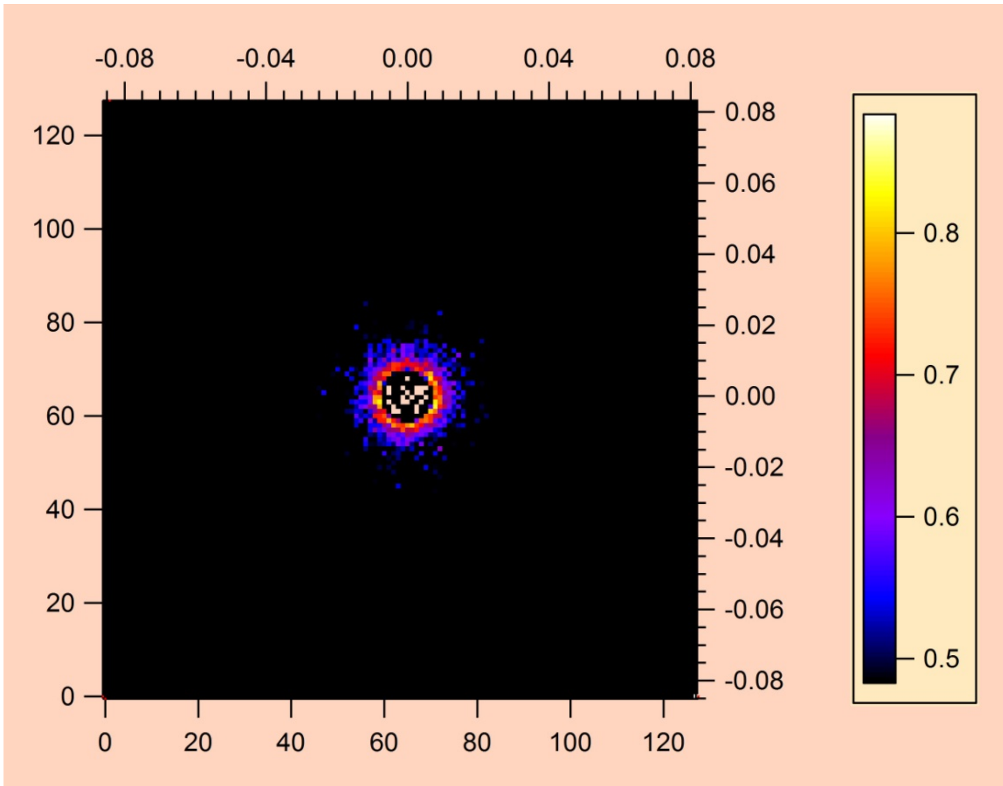

Fig.3 When there is no electric field applied, the neutron scattering from the crude oil is isotropic.

With no electric field applied, as shown in Fig.3, the scattering pattern was isotropic, indicating that the nanoscale particles in the crude oil were randomly distributed, making viscosity high.

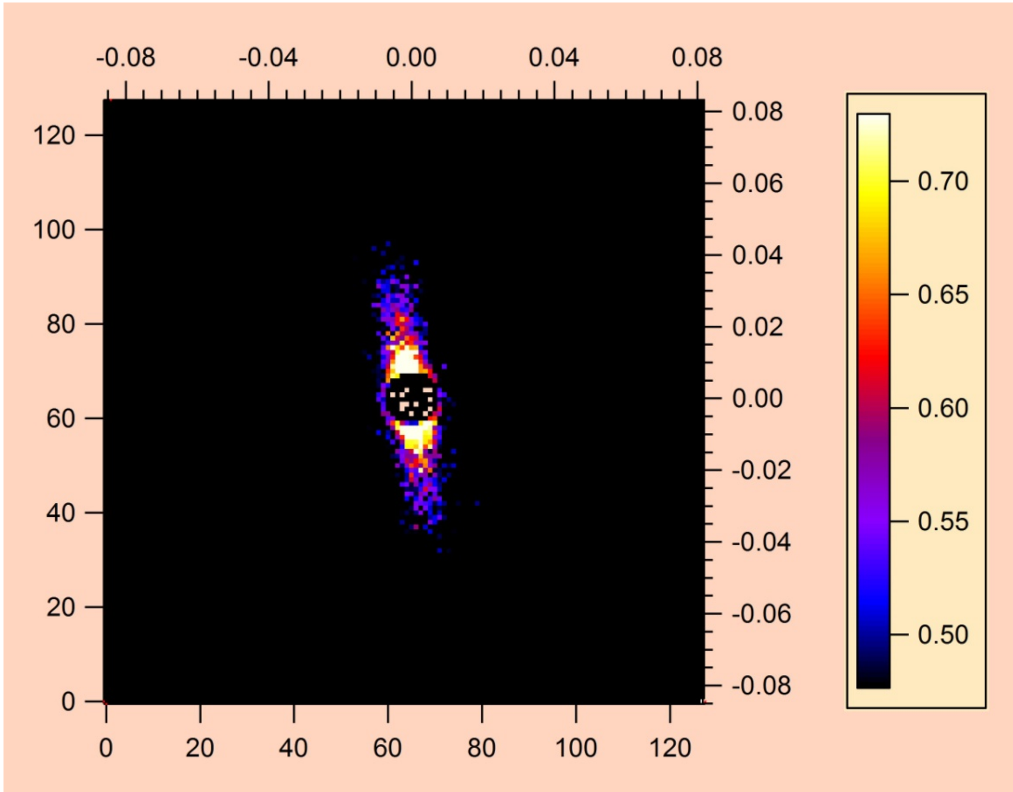

Fig.4 Under an electric field of 750V/mm, the neutron scattering indicates that nanoscale particles form short chains along the field direction.

We then applied an electric field and gradually increased the field strength to 2000V/mm. After the electric field exceeds a critical value, around 750V/mm, the nanoscale particles form short chains along the field direction. From the scattering pattern in Fig.4, we can estimate the size of the chains. The aggregated short chains are similar to the short polymers used in DRA (Drag Reducing Agent), which lead to the viscosity reduction. DRA is an expensive, widely used, chemical added to crude oil to increase flow rates by reducing viscosity.

The result clearly shows the microstructure change of crude oil under an electric field leads to the viscosity reduction, confirming the basic science for the electrorheology technology.