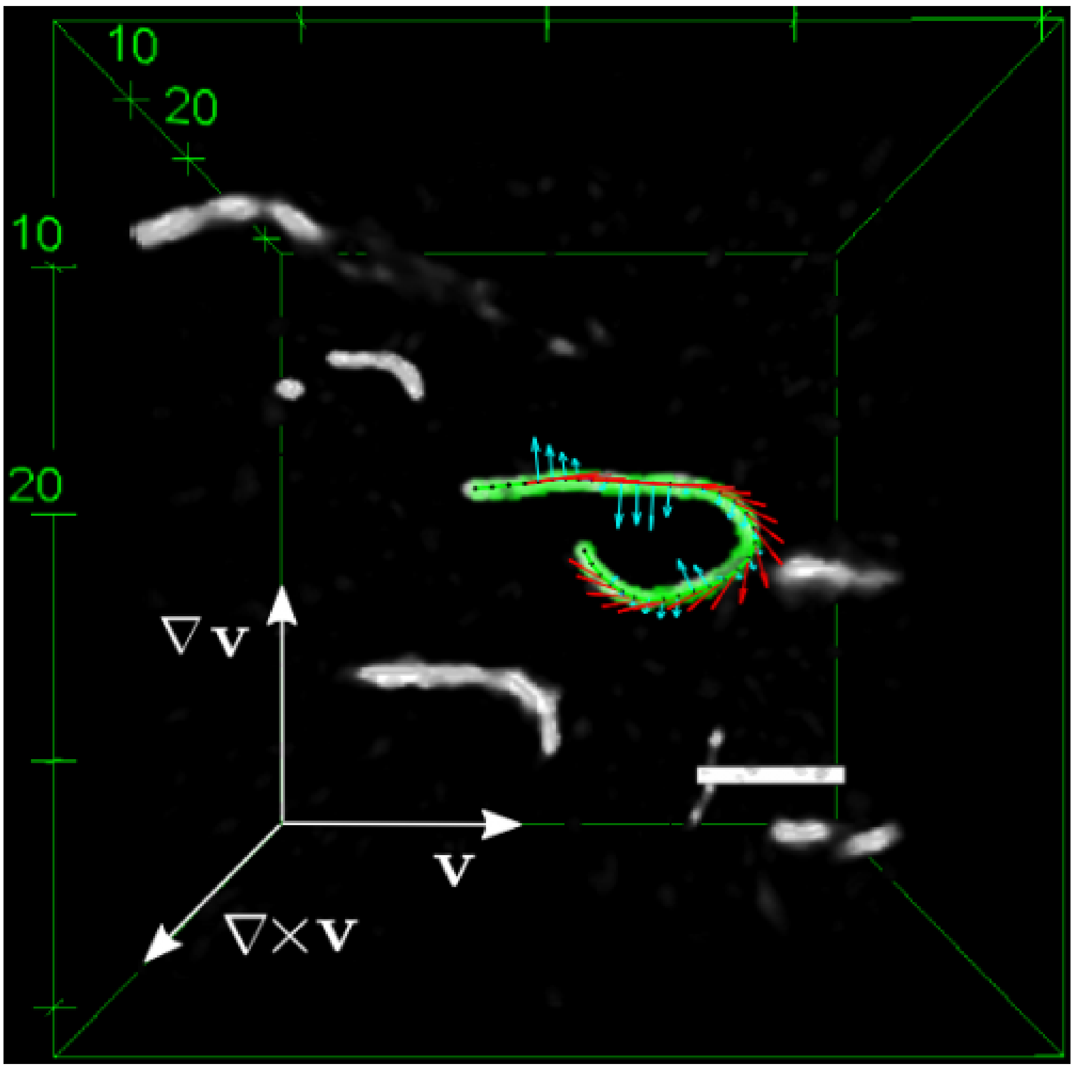
Researchers discover that hairpins can make a polymer spaghetti fluid

October 9 2014, by Ans Hekkenberg



Three-dimensional image of an actin fibre marked with a fluorescent dye in a solution induced to flow. Credit: Inka Kirchenbuechler

Researchers from FOM Institute AMOLF and the German Forschungzentrum Jülich have discovered why polymers in a solution become fluid if the solution is stirred. They discovered that the polymer structure changes from an entanglement of spaghetti into aligned layers of hairpin-shaped filaments that can slide past each other. The discovery can help to provide a better understanding of biological processes such as flows in the cells of embryos. The results of the research are published on 9 October 2014 in *Nature Communications*.

Polymers become fluid in a solution that is stirred or smeared. This property is used in a wide range of everyday materials, including toothpaste and paint. If the material remains unused in the pot, the polymers become entangled with each other and form a solid network that thickens the fluid By smearing the solution or spreading it out the polymers become fluid again. At high flow rates in particular, the viscosity of the solution strongly decreases: the faster you stir the thinner it becomes.

This behaviour also occurs in natural polymers, for example in the actin fibres that provide stiffness to biological cells. Solutions of actin fibres not only become fluid if you stir them from the outside but can also make themselves fluid by the action of molecular motor proteins that slide the fibres past one another.

As polymers are very small and consequently difficult to observe, researchers did not yet fully understand why polymers exhibit this behaviour. The research groups of professor Gijsje Koenderink (Amsterdam) and professor Pavlik Lettinga (Julich) have changed this.

Spaghetti and hairpins

The researchers rendered the three-dimensional form of individual polymer threads within an entangled solution visible at the moment the substance started to flow. They did this using actin fibres purified from biological cells. The physicists marked the fibres with a fluorescent dye. Then they induced the solution to flow while observing the polymer threads through a microscope. They could precisely follow the changes in shape and direction of individual polymer threads.

The scientists saw that in the absence of a flow, the filaments were strongly entangled with each other. If the system became fluid, the filaments assumed a hairpin-like shape and disentangled from each other. At high flow rates the filaments freely glided over each other.

Applications

Now the researchers have a better understanding of how the flow behaviour of a polymer solution arises, they can also influence this. That can be done by varying the properties of the polymers such as fibre length and stiffness. A change in the flow behaviour can, for example, influence the 'mouth feeling' of foods or the application of paint to a wall.

Furthermore the results will help to understand biological processes such as cytoplasmic flow. This flow occurs in the cells of some animal embryos and in large plant cells where protein filaments together with molecular motor proteins ensure a flow that transports cell components and nutrients.

The new microscopy method also opens up possibilities for studying more complex systems. For example, the researchers intend to study the basic mechanism of blood coagulation, by observing the interaction between the network formation of fibrin biopolymers, blood platelets and red blood cells.

More information: Direct visualization of flow-induced conformational transitions of single actin filaments in entangled solutions, Inka Kirchenbuechler, Donald Guu, Nicholas A. Kurniawan, Gijsje H. Koenderink and M. Paul Lettinga, *Nature Communications* (2014)

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