

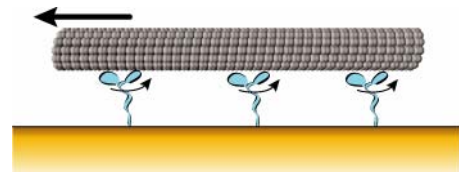
Biological motors sort molecules one by one on a chip

Researchers from Delft University of Technology's Kavli Institute of Nanoscience have discovered how to use the motors of biological cells in extremely small channels on a chip. Based on this, they built a transport system that uses electrical charges to direct the molecules individually. To demonstrate this, the Delft researchers sorted the individual molecules according to their color. Professor Hess of the University of Florida has called the Delft discovery "the first traffic control system in biomolecular motor nanotechnology". The research findings will be published in *Science* on May 12.

The biological cell is a complex of many different small protein factories. The necessary transportation of materials within the cell occurs across a network of microtubules: long, tubular-shaped proteins that extend in a star-shaped formation from the nucleus of the cell to the walls of the cell. Molecular bio-motors, such as the enzyme kinesin, can walk in small steps (of 8 nanometers) with a load of material along these microtubule-networks and thus provide transport within the cell.

Fascinated by these biological motors, the researchers at Delft University of Technology's Kavli Institute of Nanoscience are currently exploring the possibility of inserting these kinesin-motors and microtubules in an electrically directed transport system that is made by the researchers using nano-fabrication techniques.

The researchers turned the system around: the kinesin-motors are fastened in large quantities on a surface with their 'feet' up; the microtubules (measuring approximately 1 to 15 micrometers in length) were then transported over the 'carpet' of motors. The microtubules are, as it were, 'crowd surfing' over the sea of small kinesin motors. A particular challenge of the research was to ensure beforehand that the microtubule tubes could be transported in a determined direction and were not dislodged by collisions of the motor carpet.



Caption: A 'crowd surfing' microtubule is propelled by kinesin-motors (Image TU Delft)

PhD student Martin van den Heuvel, master student Martijn de Graaff and groupleader Professor Cees Dekker have for the first time achieved to control and address individual microtubules. An important step in this was to allow microtubule-transport to occur in small closed liquid channels. This made it possible to apply a strong electrical field locally at the Y-junction in the channels. Because of this, the electrical force could be exerted on the individual microtubules. The researchers discovered that by using this electrical force they could push the front of the microtubule into the determined direction.

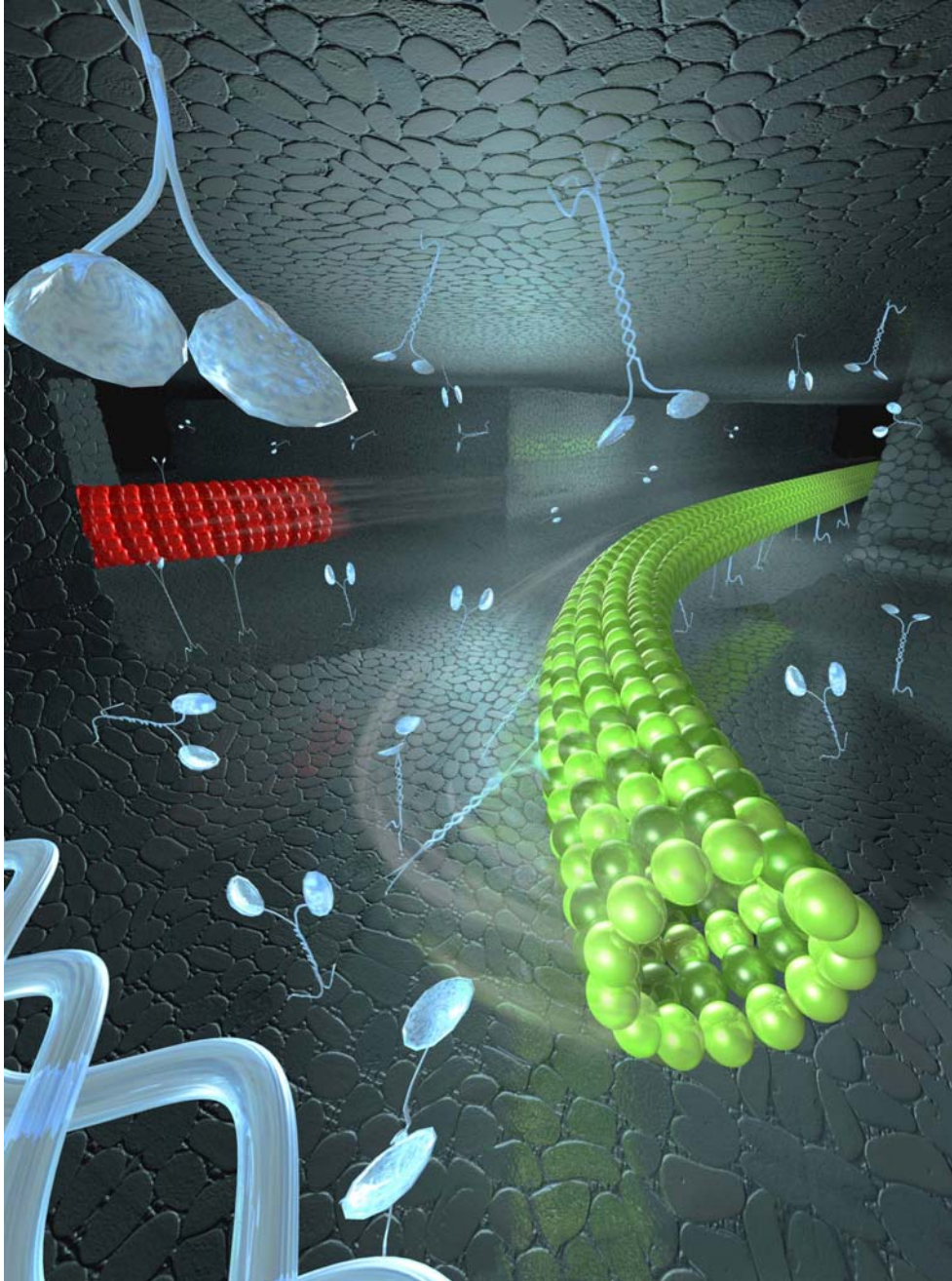
To demonstrate this, the researchers allowed a mixture of green and red fluorescent microtubules to arrive at a Y-junction. By changing the direction of the electrical force, depending on the color of the microtubule, the Delft researchers were able to collect the green and red microtubules in different reservoirs.

With their approach to the nano-channels, the researchers killed two birds with one stone. In addition to the possibility of steering individual microtubules, they were able to prevent the microtubules from derailing from their tracks. Incidentally, the Delft researchers discovered that their work contained a third interesting aspect. The closed channels offered the possibility to observe the electrical transport of freely suspended microtubules, thus proving that the speed of the microtubules under an external electrical field is largely dependent on the orientation of the cylinder-shaped molecules. This was the first time that this orientation-dependency of the electrophoretic mobility was observed.

In an accompanying Perspective article in *Science*, Professor Hess of the University of Florida wrote that the Delft researchers had developed the first traffic control system in biomolecular motor nanotechnology.

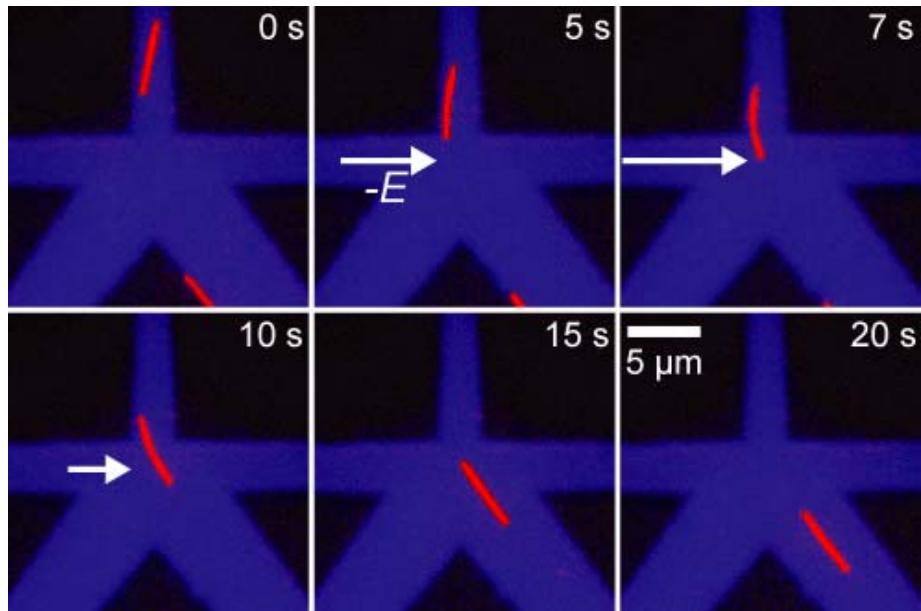
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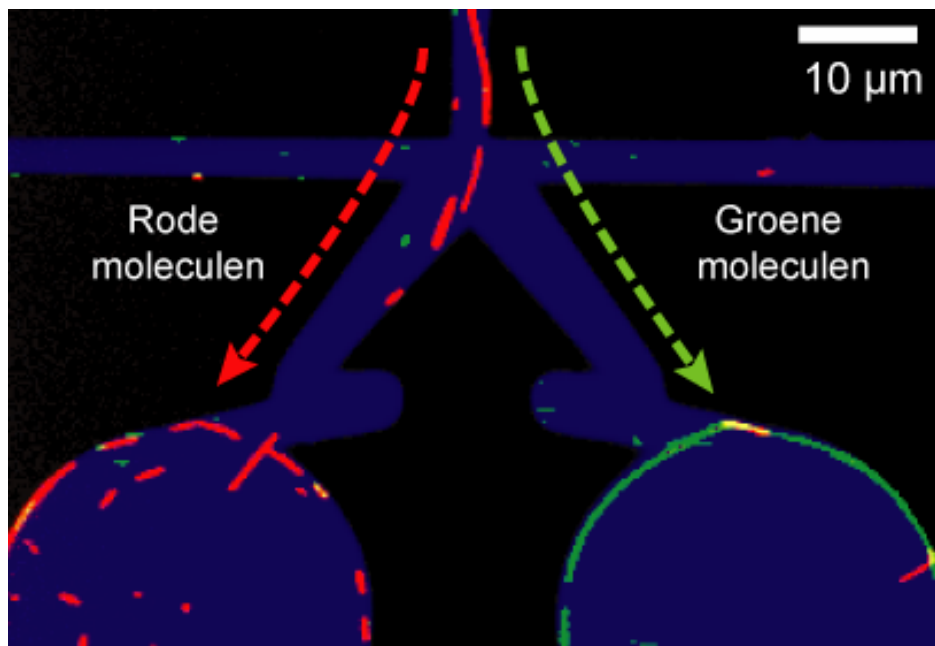


Caption: Artist impression of the sorting of green and red microtubules in nanochannels. Kinesin motors on the walls push the microtubule forward while an external experimentalist can steer the direction by exerting an electrical force on the tube (Image TU Delft/Tremani)

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Caption: Images from an experiment where a single microtubule is steered between 5 and 10 seconds. The electrical force pushes the microtubule to the right (Image TU Delft)



Caption: Snapshot of an experiment where red and green molecules are sorted in two different reservoirs (Image TU Delft)