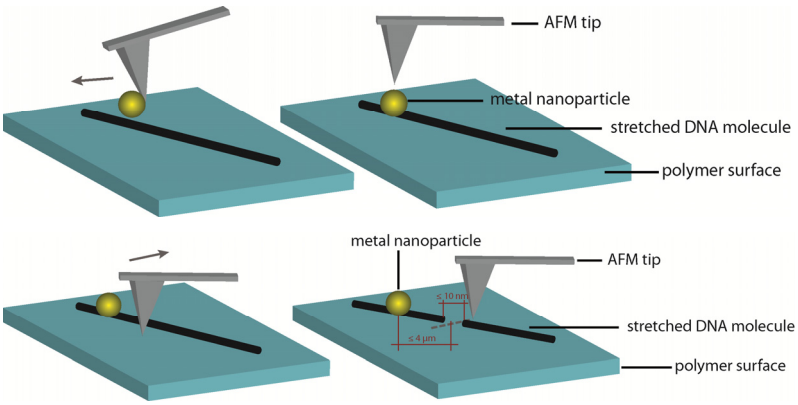
Report: Short Visit Grant (Ref.no: 5144)

1.) Purpose of the Visit

The objective of this two-week research stay abroad at the *Dublin City University* was the preparation, manipulation and characterization of DNA/nanoparticle samples by using the *Nanoman tool*, which allows a highly defined manipulation and positioning of nanoscale objects. In this regard, the research stay was divided into the following tasks:

1. Precise positioning of a metal nanoparticle (gold or silver) on the stretched DNA molecules by the usage of an AFM tip.

2. Mechanical destruction of DNA molecules next to its located nanoparticle by an AFM tip in order to create grooves with a defined diameter and distance to the nanoparticle.



2.) Description of the work carried out during the visit

After a brief introduction into the microscope and its software, grooves in dependency of the *deflection setpoint* of the used AFM tip *(Tap300G)* were scratched on the polymer substrate (Polymethylmethacrylate, abbr. PMMA, 85nm thick) to investigate the smallest possible groove diameter. Afterwards this test was repeated for DNA molecules, immobilized on the polymer as well as for DNA molecules with silver nanoparticles (AgNP), which were immobilized together over night, so that the silver nanoparticles attached unspecifically to the DNA. Hereby, the distance between the scratches and the nanoparticle were varied from 1 to 4µm. At the end of the research stay, these samples were taken back to the *Institute of Photonic Technology Jena*, where they have been irradiated with short laser pulses in order to investigate if the propagation of the plasmonic energy into the DNA molecule could be limited by the interruption.
In the last part of the research stay it could be demonstrated that single silver nanoparticles can be moved specifically by using the same *AFM Nanoman* tool on the polymer surface.

3.) Description of the main results obtained

3.1) Selective destruction of DNA molecules

The *Nanoman tool* enables two possible ways to destroy DNA molecules on a surface: either by reducing the z-distance (Fig.1a) or by a xy-move of the AFM tip (Fig.1b).

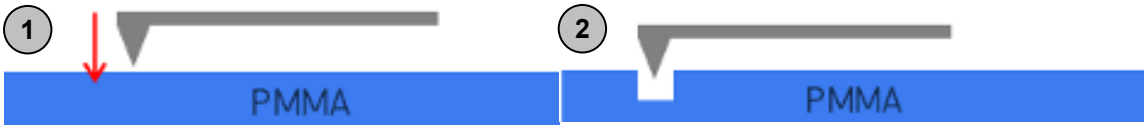


Fig.1a. Schematic illustration of the selective destruction of a polymer by reducing the z-distance of an AFM tip.

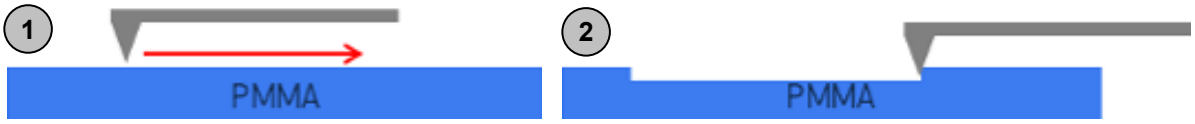


Fig.1b. Schematic illustration of the selective destruction of a polymer by moving the AFM tip in xy-axis.

Both possibilities were tested for a selective destruction of stretched DNA molecules on a PMMA surface in air. It could be shown that the destruction by using the xy-mode is better controllable in comparison to the z-distance-reduction relating to the scratch diameter. The gaps on the DNA molecules, carried out with the xy-mode had the same diameter within the range of the scratch, while the gaps with the z-distance-reduction are much bigger and therefore more difficult to control (Fig.2).

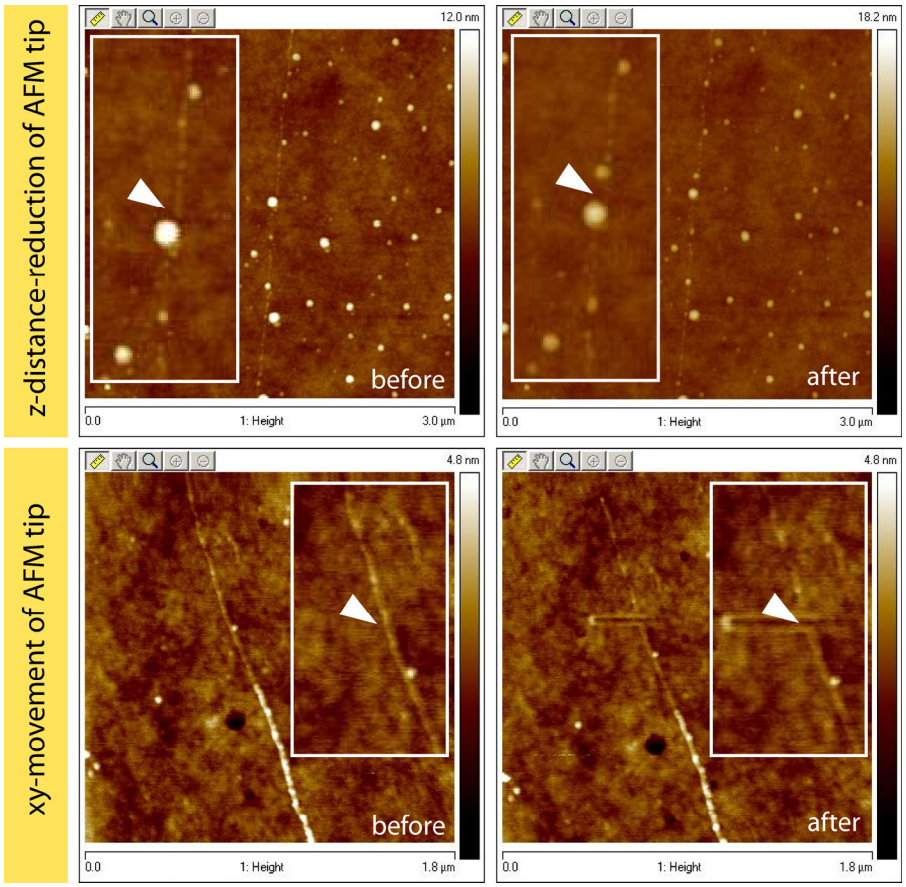


Fig.2. Selective destruction of stretched DNA on PMMA by reducing the z-distance (top) and xy-moving of the AFM tip (bottom). For the destruction of the DNA only by changing the z-position the z-distance was reduced to -10nm. The diameter of this gap in the DNA is about 70nm, while the gap, produced by the xy-move of the tip is only about 50nm.

Afterwards the gaps with the xy-move on the DNA were optimized to get the smallest possible diameter by reducing the deflection setpoint of the AFM tip from 0.5V to 0.1V. Thus, gaps with a diameter of up to 40nm could be established (Fig.3).

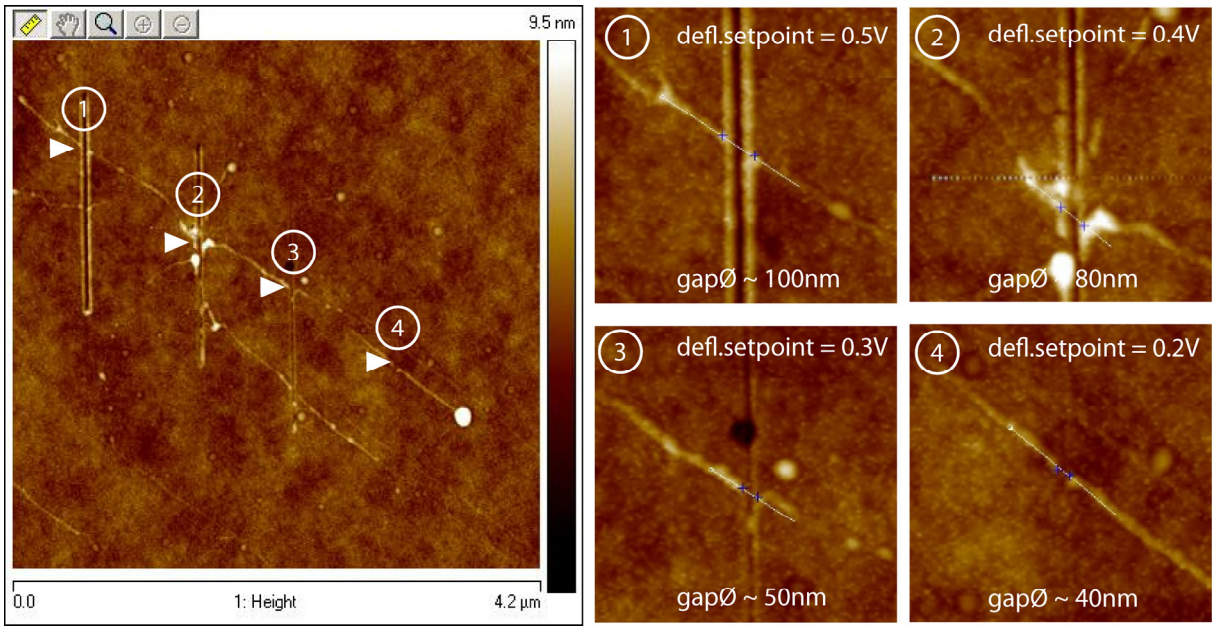


Fig.3. AFM images of several gaps on one stretched DNA bundle, produced by xy-movement of the AFM tip. By reducing the deflection setpoint of the AFM tip thinner gaps could be created. For this AFM tip a thinnest gap of 40nm at a deflection setpoint of 0.2V was achieved. Deflection setpoints below 0.2V did not influence the DNA.

Then, the setpoint with the smallest possible scratch was used to produce selective gaps on AgNP-labeled DNA molecules in different distances ranging from 1 to 4µm to the nanoparticle (Fig.4).

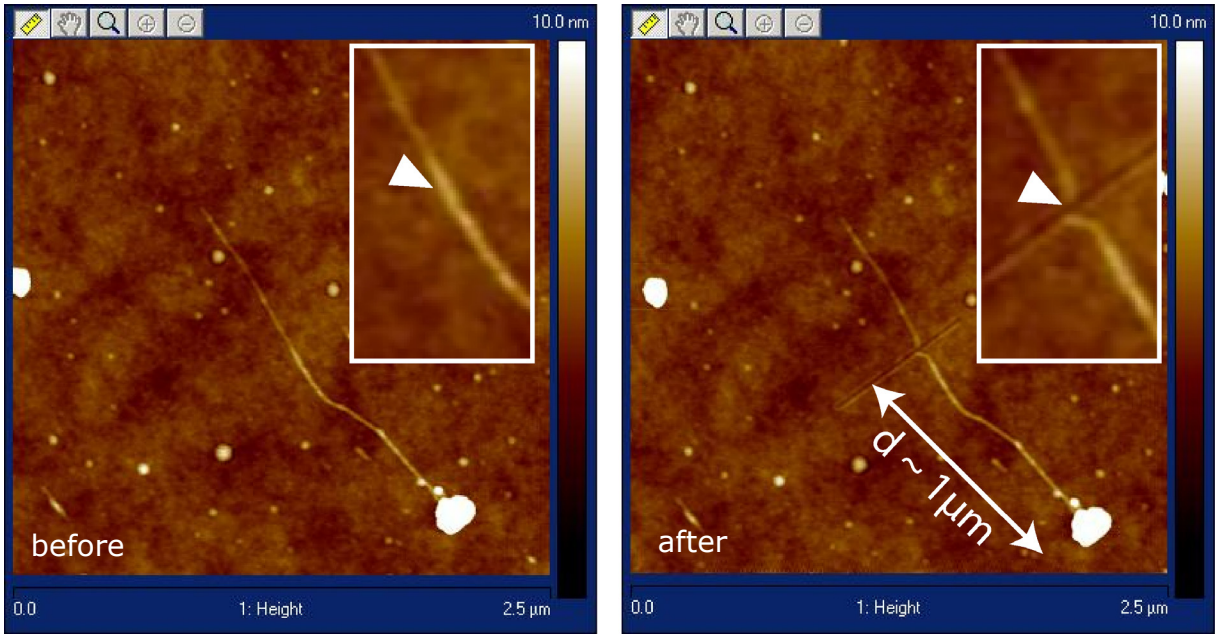


Fig.4. Example of a DNA bundle with a gap in a distance of ~1µm away from the AgNP. The gap itself had a diameter of only 20nm.

Finally, these samples were taken back to the *Institute of Photonic Technology Jena* and irradiated with fs- laser pulses in order to find out if the propagation of the plasmonic energy, generated by the irradiation of the nanoparticle, could be interrupted at the gap in the DNA molecules. Fig.5 shows an AgNP-labeled DNA molecule with a gap in a distance of ~1.7 µm away from the nanoparticle and a diameter of about 50nm before and after its laser treatment. After the laser exposure the DNA is interrupted at several positions next to the excited particle (blue arrows) resulting in holes in the polymer surface. But it seems that these holes are not a result of any propagation along the DNA molecule, because these holes are mostly located on small nanoparticles (see before image). Thus, in this experiment it could not clearly shown if a propagation of an excitation could be limited by a gap along the DNA.

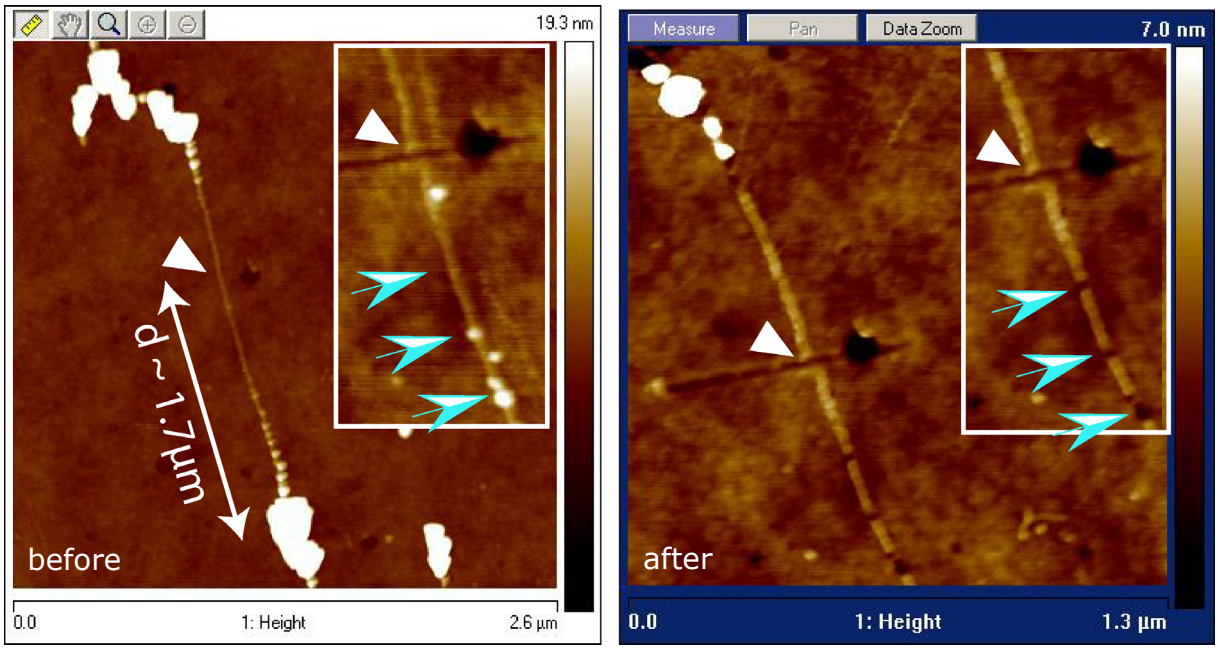


Fig.5. AFM images of AgNP-labeled DNA bundle with a gap (white arrow) before and after its fs-laser treatment. The holes after the exposure are due to the high excitation of small nanoparticles (blue arrows).

3.2) Selective movement of silver nanoparticles

The xy-moving of the AFM tip can also used to manipulate nanoscale structures. In the second half of the research stay, the movement of two single AgNPs by this method could be demonstrated. For this, a AgNP solution with a concentration of ~ particles/ml were immobilized on PMMA by drying over night. Then a suitable region with 2 nanoparticles was chosen for manipulation. Fig.6 shows the selective movement of one particle next to the other. Further experiments could be the selective movement and placement of single nanoparticles next as well as onto the DNA molecule.

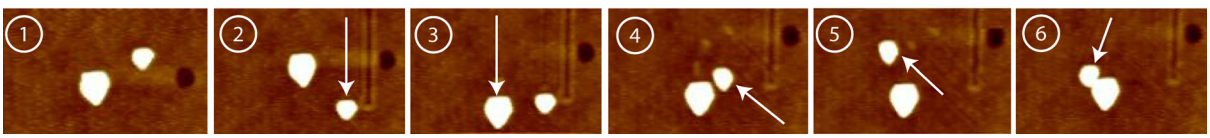


Fig.6. Selective movement of single AgNPs with the xy-move of a *Nanoman tool*.

4.) Future collaboration with host institution

Future collaborations are planned relating to further exchange programme for master and PhD students between the *Dublin City University* and the *Institute of Photonic Technology Jena*.