Get a grip on your sample - JPK 3D print option for research and education

Introduction

3D printing is a very fascinating way to create three-dimensional objects out of digital files. In former times, this technique was mostly dedicated to industrial applications to produce expensive proto-types but, due to new cost-reducing innovations, this technique is now affordable for research and education. In particular, the possibilities of 3D printing for educational purposes are nearly unlimited. It is not surprising that more and more universities and schools have access to 3D printers.

In conjunction with AFM, this technique allows not only seeing nanometer sized samples clearer, but also to create 3D models to make a haptic impression of the sample surface. This offers a completely new way of demonstrating results and attracting people to atomic force microscopy (AFM) and to new research topics. Additionally, it enables a new intuitive way of learning about nanoscopic objects like DNA origami (see figure 1).

JPK Instruments AG is the first AFM company that recognized 3D printing as an innovative technique for surface visualization and its potential in education and research.Now, JPK offers a free 3D printing option for all users. This option further links structures on the nanometer scale (which can be investigated by JPK's unique NanoWizard® AFM family) with enlarged structures easily accessible.

This novel technique allows for visualizing very small structures like single molecules, polymers, viruses, bacteria or other nanostructures on a scale which is more intuitive for people starting to work with these kinds of structures or who would like to gain a basic understanding of such structures. It readily shows complex nano-textures or structures in chemistry, physics and biology which can help achieve a better understanding of tissue structures, embedded objects or multicomponent systems. For example, 3D models can be used to investigate interactions between particles and 3D scaffolds. Also, 3D printing can be a very helpful tool in the fields of bionics, biomaterials and molecular assemblies.

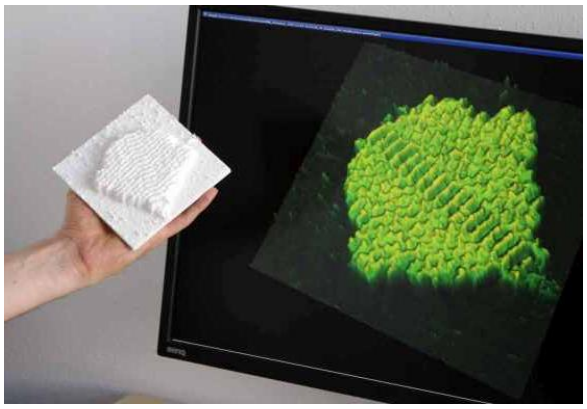

Fig 1: 3D printed model compared to 3D AFM height image. 3D printed model is excellent for educational purposes.

From AFM image to 3D model

AFM is a powerful tool to investigate a huge variety of samples on the nanometer scale under physiological conditions. AFM offers a close look into the nanometer world and can be used as a force sensor to measure interaction forces as well as obtain mechanical properties of samples. A flexible cantilever is used to measure interaction forces and obtain surface topography.

Next to the traditional contact and dynamic AFM modes, JPK's Quantitative Imaging (QI™) mode offers the best option to obtain height images and nanomechanical information on all kinds of sample. In this mode, a force distance curve at each pixel is used to calculate height, stiffness and adhesion with a controlled interaction force and without lateral forces. This is particularly important for soft, loosely attached or sticky samples.

Independently from the measurement mode, the response of the cantilever is used to calculate a height image of the sample surface. This height image contains 3D information which can be visualized and exported in STL file format. STL file format is widely accepted by 3D printing software

and can be used to print a 3D model of the measured surface. This model can easily be used for visualization of the sample under investigation on an enlarged scale. The general principle is explained in the figure 2.

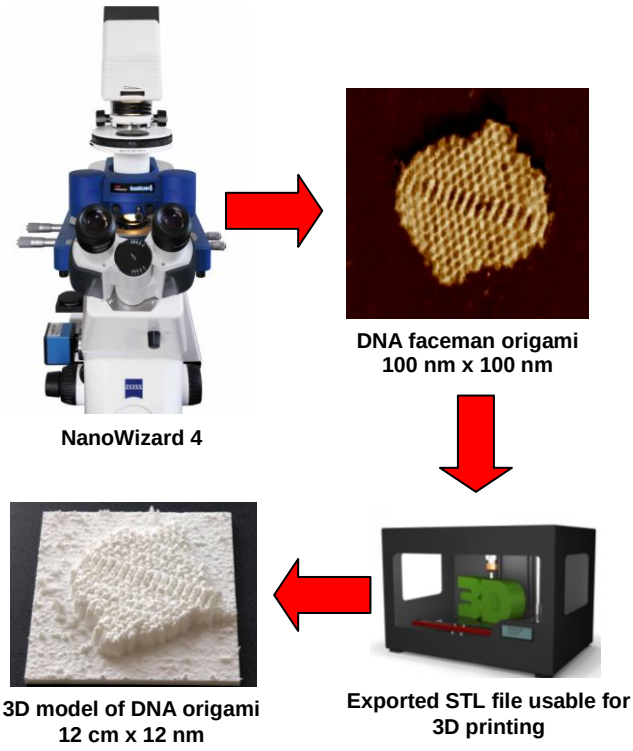

Fig 2: 3D printing allows creating three-dimensional objects out of AFM images. The principle is explained on the example of a faceman DNA Origami.

By combining these two ground-breaking techniques, JPK provides not only the well-established access to the world of tiny structures but also to structures with a size accessible to users in a more relatable way with their senses. This offers new possibilities for universities and scientific institutes as well as museums or schools to present their work and their results to the scientific community and also to a more general audience. Audiences become more enthusiastic about scientific work when they can literally get a grip on it visually.

Outlook

The 3D printing technique is still under development and in the future it may be possible to print 3D models with adjustable stiffness values. This would be even more fascinating when transferring the nanomechanical properties measured by AFM to a 3D model and to get a contrast in stiffness that is accessible by touch too. A transfer of digital files in 3D objects is not limited to AFM measurements. Optical techniques like laser scanning confocal microscopy can offer 3D information that can be correlated with the measured AFM surface scans. Optical tweezers offer a different approach to get 3D information. It is, for example, possible to probe three-dimensional gel samples by photonic force microscopy to get a closer look to whole and gap structures.

Specifications

- Free of charge for all JPK users
- Export of 3D images as STL format (3D printing compatible)
- Available with the newest JPK Data Processing Software version

Applications

- Creating macroscopic 3D structures out of nanoscopic scan templates
- Intuitive learning about nanoscopic objects in education
- Easier understanding of complex 3D nano-textures or structures in chemistry, physics or biology
- Understanding 3D scaffolds, molecular assemblies, DNA origami, cellular structures and tissues, embedded objects, multicomponent systems

Acknowledgement

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- DNA Origami samples, prepared as previously described by Sacca et al., Angew. Chem. Int. Ed. (2010) 9378, were kindly provided by Dr Rebecca Meyer and Professor Christof M Niemeyer, TU Dortmund and Karlsruhe Institute of Technology (KIT), Institute for Biological Interfaces (IBG-1)