NanoRack™ sample stretching stage for Jupiter XR AFM

OXFORD INSTRUMENTS

ASYLUM RESEARCH

The NanoRack Sample Stretching Stage enables direct measurement of nanoscale properties of materials whilst controlling the stress the material is under.

The NanoRack stage (Figure 1) is a high-strain, high-travel manual tension and compression stage that provides two axis stress control of samples under different loads. It integrates force measurements with AFM images and returns both stress and strain data. The stage is compatible with a wide variety of imaging techniques including contact and tapping mode for sample topography characterization and, among others, AM-FM Viscoelastic Mapping mode for investigating nanomechanical material properties. The NanoRack is ideal for a wide range of applications including measurements of adhesive strength in polymers[1], stress-induced deformations and cracking in a variety of biological[2] and inorganic materials.

Features/Benefits

- High-strain, high-travel manual stretching stage provides two axis tensile stress control
- Returns both stress and strain data providing a more complete understanding of the experimental conditions
- Can be used under tension or compression to enable sample stretching or buckling
- The height-adjustable stabilizing pillar under the sample can be adjusted to support the test sample providing better control of the experimental setup
- Compatible with a wide variety of Asylum Research imaging techniques including Contact Mode, Tapping Mode as well as AM-FM Viscoelastic Mapping mode

To demonstrate the functionality of the NanoRack accessory, a microporous membrane was stretched and imaged at increasing stress. Commercially known as Celgard©, this microporous polypropylene membrane is used as a lithium-ion battery separator between the battery electrodes[3]. In addition to being chemically and electrochemically stable, the microporous membrane must be mechanically robust

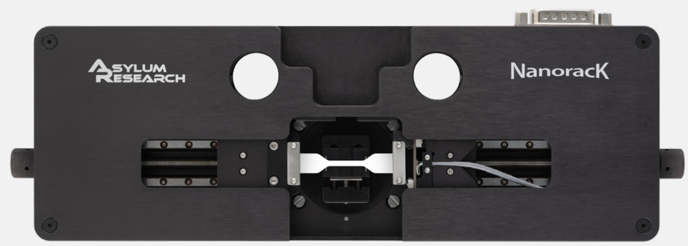

Figure 1: NanoRack is a high-strain, high-travel manual stretching stage that provides control of tensile and compressive loaded samples up to 80 N.

to withstand any stresses during the assembly process and for the lifetime of the battery.

The Celgard membrane was placed in the NanoRack stretch stage and imaged without applying any stress (Figure 2). The distinctive highly oriented, asymmetric pores of the membrane are well resolved in the 3 µm image.

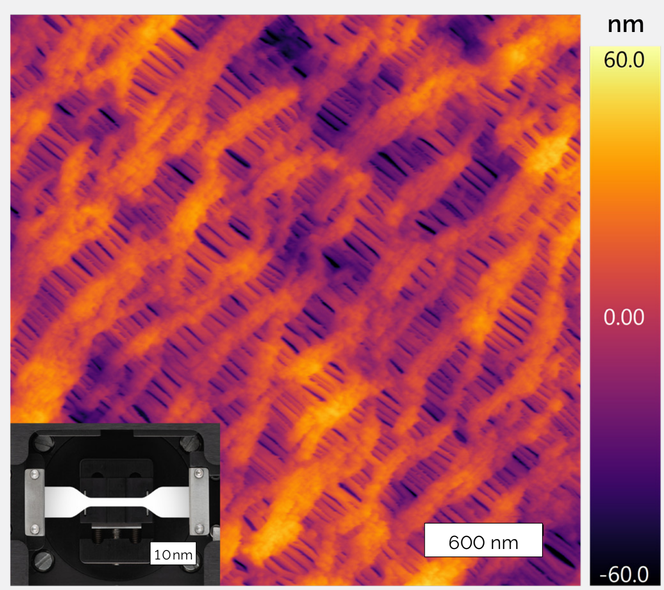

Figure 2: AFM height image of Celgard membrane. Tapping mode imaging at 4 Hz. Inset: Celgard membrane sample (white) clamped in place inside the NanoRack.

To access its mechanical stability, the membrane was successively stretched by applying force either from the left or the right side of the sample. The exact force applied to the sample can be read from the NanoRack software panel and is displayed on the force *vs* time graph shown in Figure 3. Prior to imaging the membrane, it was left to relax which corresponds to the exponential decay of the force following the peaks in the graph of Figure 3. In addition to the force, the extent of membrane displacement is also plotted in the graph.

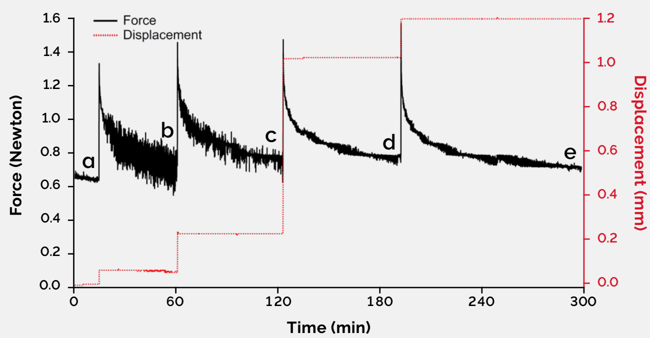

Figure 3: Force (Newtons) vs. time (minutes) curve of Celgard membrane as it is being stretched on the NanoRack. Letters in the graph correspond to the time at which AFM images were acquired (see figure 4).

AFM images were collected after each stretching event and are shown in figure 4. The images reveal changes in the alignment of the pores, but, most importantly, the membrane did not exhibit any rupture even after 1.2 mm of displacement due to applied stress.

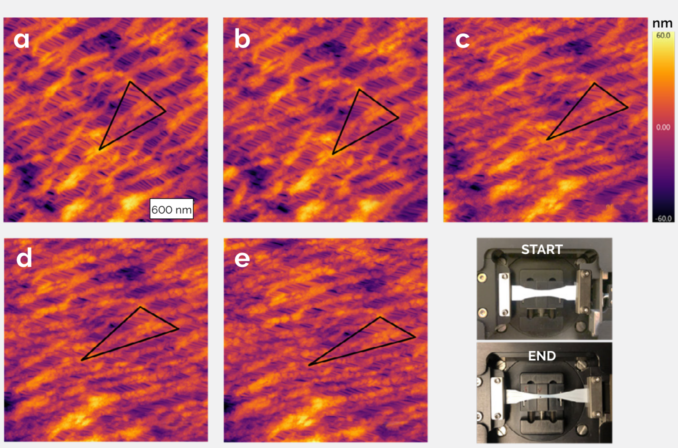

Figure 4: Consecutive AFM height images of Celgard membrane as it is stretched on the NanoRack. Triangles are drawn to help guide the reader through the sample changes as it is stretched. Letters in the images correspond to the events in the stress *vs* time graph of Figure 3. Bottom right image shows the sample mounted in the NanoRack at the beginning (START) and at the end (END) of the experiment.

The NanoRack accessory mounts on the accessory chuck of the Jupiter XR AFM.

Figure 5: NanoRack accessory installed on the Jupiter XR AFM.

Specifications of the NanoRack

- Sample Size: 12 mm wide maximum, 41 mm long minimum, 6 mm thick maximum
- Sample is supported by a height-adjustable stabilizing pillar that can be removed to provide bottom access to the test sample
- Maximum range of motion: 120 mm (30 mm relaxed to 150 mm fully stretched)
- Maximum 80 N load (strain gauge limit)
- Strain (force) gauge can be swapped from a 80 N (±0.8 N) version to 20 N (±0.2 N) version for higher resolution at lower forces
- Knobs adjust sample 500 µm per revolution
- Can discretely adjust to 5 µm encoder resolution
- Mounts on the accessory chuck of the Jupiter XR AFM

References

1. "Applications of the NanoRack Sample Stretching Stage to a Commercial Impact Copolymer" by D. Yablon, et al., ExxonMobil.
2. "Crack Propagation in Bone Captured with In Situ Mechanical Testing During AFM" O. Katsamenis, et. al, University of Southampton.
3. www.celgard.com