SHIMADZU
Excellence in Science

Application News

SPM-Nanoa™ Scanning Probe Microscope (Atomic Force Microscope)

Answering the Need for Fast Physical Property Mapping! Fast and High-Resolution Visualization of Mechanical Properties

E. Iida

User Benefits

- Faster measurement of mechanical properties is possible in comparison with the conventional technology.
- Enables high-resolution visualization of distributions of elastic modulus and adhesion, which are mechanical properties.

■ Introduction

Remarkable advances have been achieved in the functional properties of polymeric materials in recent years, and technologies that enable quantitative evaluation of the nanostructure and elastic modulus of those materials are now required. Although the scanning probe microscope (SPM (AFM)) is used in those evaluations, fast physical property mapping by Shimadzu SPM-Nanoa has realized high-speed measurement of mechanical properties.

This article introduces an example of fast and high-resolution visualization of the distributions of the elastic modulus and adhesion of polyethylene (PE) by fast physical property mapping using a SPM-Nanoa and Shimadzu nano physical property evaluation software "Nano 3D Mapping™ Fast."

■ SPM-Nanoa

The scanning probe microscope (SPM) is a type of microscope that enables high-magnification observation and measurement of the 3-dimensional shape and local physical properties of samples by scanning the sample surface with a microscopic probe called a cantilever. The SPM-Nanoa is a new SPM which is equipped with an advanced high-sensitivity detection system and automatic observation system as standard features, answering the user's need for simpler, faster, more detailed visualization. The SPM-Nanoa provides powerful assistance for work ranging from observation of the topography of micro regions to measurement of physical properties. Fig. 1 shows the appearance of the SPM-Nanoa system. SPM-Nanoa has the following three features.

① Automatic Observation : Adjusts Laser Beam, Adjusts Parameter Settings During Observation, and Performs Image Processing Automatically

② Extensive Functionality : 8K Images Enable High-Resolution Observation of Large Areas

③ Saves Time : High-Throughput Observation and Fast Physical Property Mapping

This article introduces feature ③ Saves Time by fast physical property mapping. The nano physical property evaluation software "Nano 3D Mapping Fast" is used in measurements of mechanical properties. "Nano 3D Mapping Fast" measures the force (force curve measurement[1]) that acts on the probe when it is pressed vertically into the sample surface and then retracted. Fast physical property mapping is realized by carrying out this process at high speed for a designated region and number of datapoints, and calculating the elastic modulus and adhesion at each point. Because the load on the sample during measurement is extremely small, this technique is particularly effective for measuring the mechanical properties of thin films, which are difficult to measure with a nano-indenter, and soft materials with elastic moduli in the range of approximately several kPa to 1 GPa.

Fig. 1 Appearance of SPM-Nanoa™ scanning probe microscope

■ High Speed Imaging

Physical property mapping with a conventional instrument requires 70 minutes for 64 × 64 pixels. In contrast, mapping can be completed in only 21 minutes with the SPM-Nanoa, even with resolution of 256 × 256 pixels (Fig. 2). Although high-resolution visualization of the elastic modulus distribution and adhesion distribution is extremely time consuming with conventional instruments, fast visualization is possible with the SPM-Nanoa.

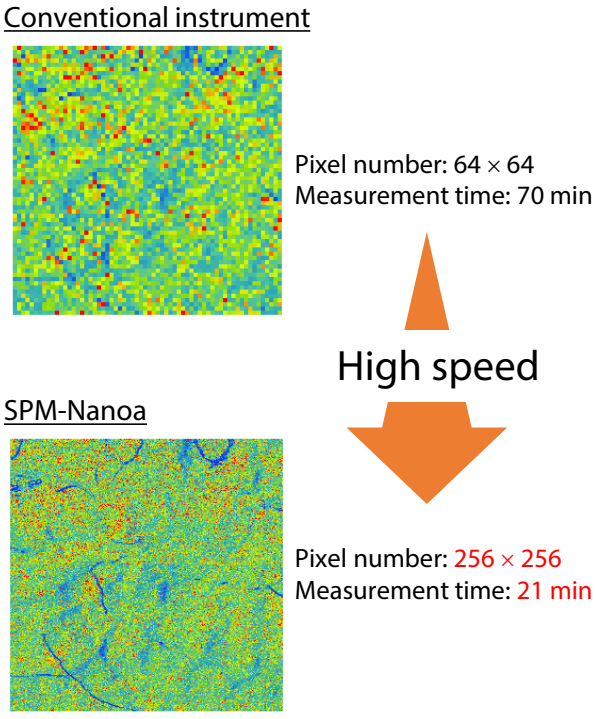


Fig. 2 Output images of elastic modulus distribution by conventional instrument and SPM-Nanoa

■ Fast Physical Property Mapping of LDPE and HDPE

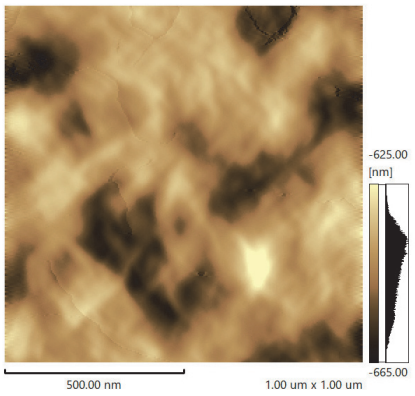
Fast physical property mapping was carried out with low density polyethylene (LDPE) and high density polyethylene (HDPE). Table 1 shows the measurement conditions. The two-point JKR method[2] was used in calculations of the elastic modulus.

Table 1 Measurement Conditions

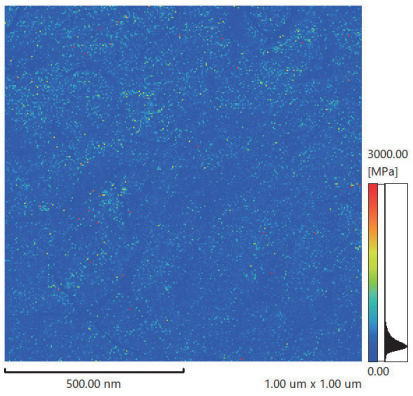
Instrument	: SPM-Nanoa scanning probe microscope
Scanner	: HT scanner (10 μm)
Measurement mode	: Nano 3D Mapping Fast
Observation field	: 1 μm × 1 μm
Pixel number	: 256 × 256
Sweep rate	: 50 Hz (measurement time: 21 min)
Elastic modulus calculation method	: Two-point JKR method

LDPE

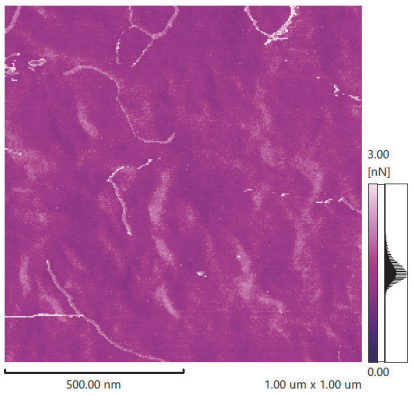
(a) Shape Image



(b) Elastic Modulus Image



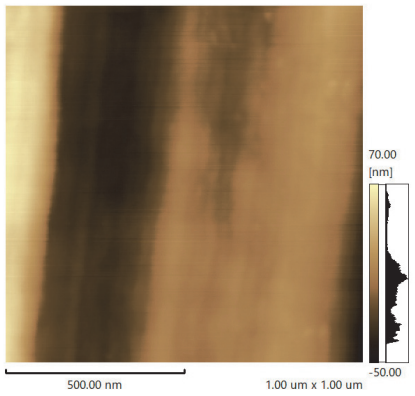
(c) Adhesion Image



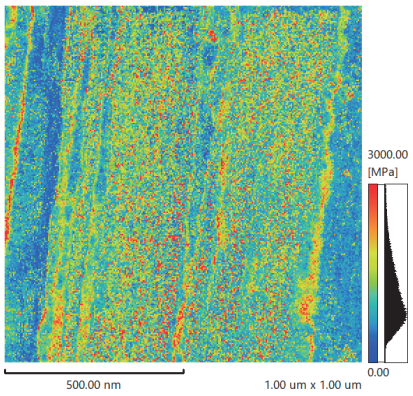
Median value of elastic modulus: 286 MPa

HDPE

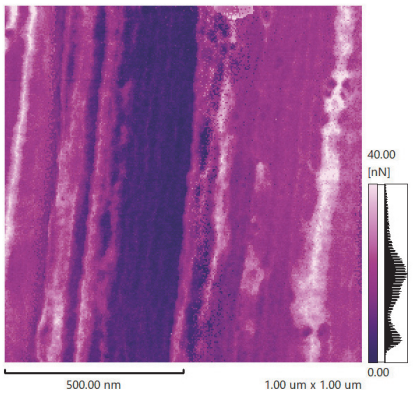
(d) Shape Image



(e) Elastic Modulus Image



(f) Adhesion Image



Median value of elastic modulus: 1087 MPa

Fig. 3 Fast physical property mapping of LDPE and HDPE
LDPE: (a) Shape Image, (b) Elastic Modulus Image, (c) Adhesion Image
HDPE: (d) Shape Image, (e) Elastic Modulus Image, (f) Adhesion Image

Fig. 3 shows the shape images, elastic modulus images, and adhesion images of the LDPE and HDPE. In the shape images in (a) and (d), fine roughness can be seen in the LDPE, while the HDPE displays an undulating surface structure. In the elastic modulus images in (b) and (e), the difference in the elastic moduli of LDPE and HDPE appears clearly, and the black histogram in the scale bar of the elastic modulus at the right also shows that the median value of the elastic modulus is different. The median values of the elastic moduli are LDPE: 286 MPa and HDPE: 1087 MPa, showing a good correspondence with the tensile elastic modulus values of LDPE: 180 to 280 MPa[3] and HDPE: 1070 to 1090 MPa[3], which are the values for general bulk materials. In the adhesion images in (c) and (f), the LDPE shows uniform adhesion of 1 to 2 nN over the entire field of view, but in the HDPE, there are differences in the adhesion depending on the position.

As illustrated by this example, short-time and high-resolution visualization of the elastic modulus distribution and adhesion distribution of samples is possible by using the fast physical property mapping function of SPM-Nanoa.

■ Conclusion

Measurement of the mechanical properties of polymeric materials with different mechanical properties could be completed in a short time of 21 minutes by using the fast physical property mapping function of the SPM-Nanoa. Fast physical property mapping answers the user's need for fast, simple and high-resolution visualization.

<References>

(1) Hiroyuki Akinaga, General Editor, Introduction to Scanning Probe Microscopy, Ohmsha, Ltd., 76, 2013.
(2) K. L. Johnson, K. Kendall and A. D. Roberts, Proc. R. Soc. Lond. A324, 301-313 (1971).
(3) Website of Japan Plastics Industry Federation (Retrieved June 1, 2021) http://www.jpif.gr.jp/00plastics/conts/pe_c.htm

01-00149-EN First Edition: Jul. 2021

SHIMADZU
Shimadzu Corporation
Analytical & Measuring Instruments Division
Global Application Development Center

www.shimadzu.com/an/

› Please fill out the survey

Related Products Some products may be updated to newer models.

› SPM-Nanoa

Scanning Probe Microscope/Atomic Force Microscope

Related Solutions

› Plastics

› Chemicals

› Price Inquiry

› Product Inquiry

› Technical Service / Support Inquiry

› Other Inquiry