NANOVEA
A Better Measure

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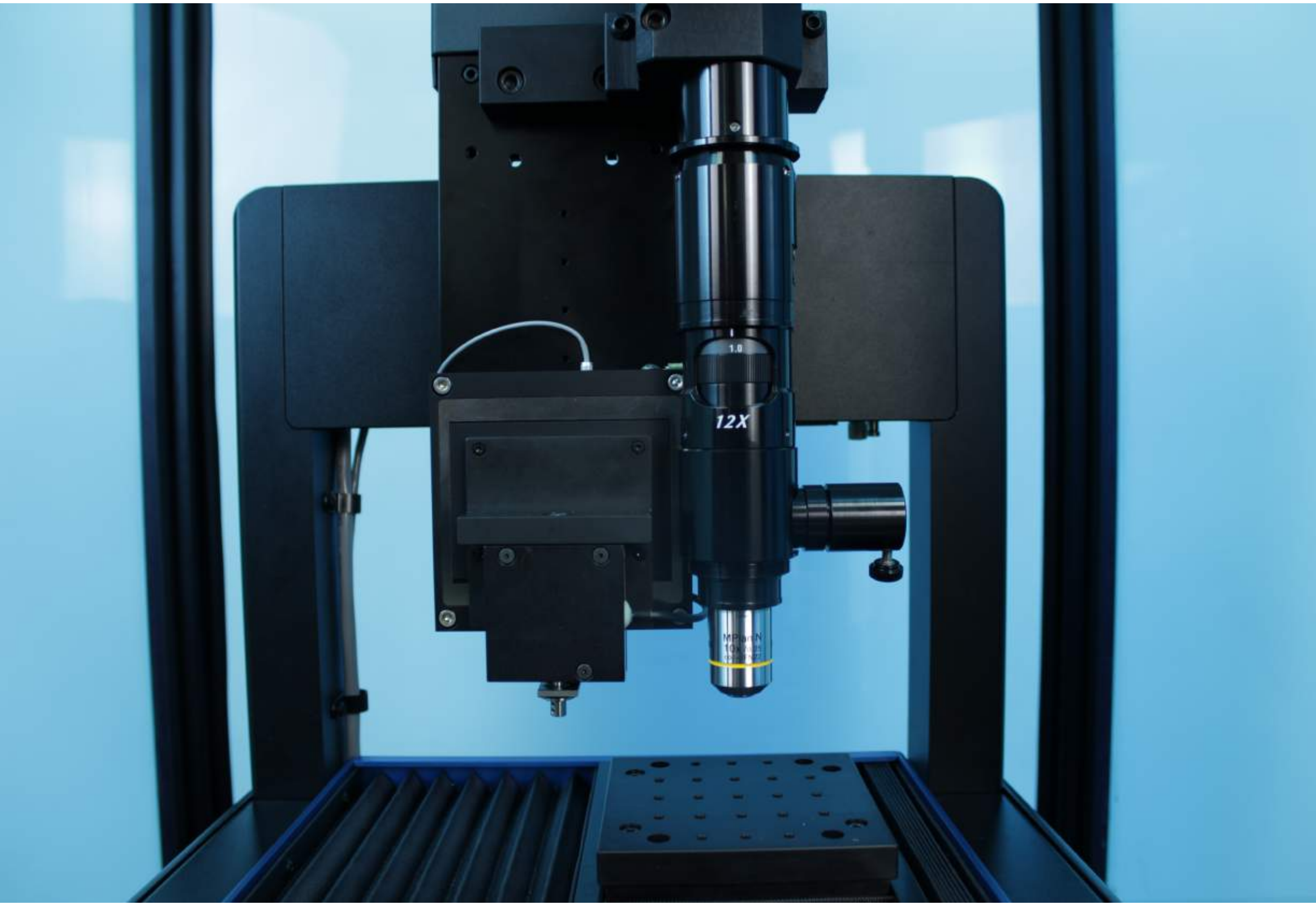


Compression on Soft, Flexible Materials

In the microelectromechanical systems (MEMS) industry, there is a strong need for a mechanical tester capable of applying controlled high-resolution forces and has a wide range of travel for flexible devices sensitive to force. To showcase its high resolution and large travel distance capabilities, the Nanovea Mechanical Tester conducted flat-punch compression tests on very soft and flexible samples at very low loads and displacement ranges exceeding 1mm.

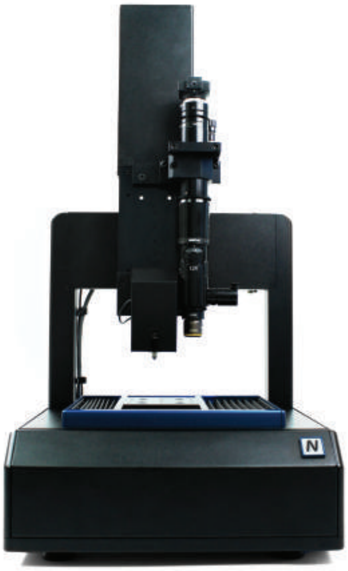
Importance of testing soft, flexible materials

An example of very soft and flexible samples is a microelectromechanical system. MEMS are used in everyday commercial products like printers, mobile phones, and cars [1]. Their uses also include special functions, such as biosensors [2] and energy harvesting [3]. For their applications, MEMS must be able to reversibly transition between their original configuration to a compressed configuration repeatedly [4]. To understand how the structures will react to mechanical forces, compression testing can be conducted. Compression testing can be utilized to test and tune various MEMS configurations as well as testing upper and lower force limits for these samples.

The Nanovea Mechanical Tester Nano Module's ability to accurately collect data at very low loads and travel over 1mm of distance makes it ideal for testing the soft and flexible samples. By having independent load and depth sensors, large indenter displacement does not affect the readings by the load sensor. The ability to carry out low-load testing over a range of more than 1mm of indenter travel makes our system unique compared to other nanoindentation systems. In comparison, a reasonable travel distance for a nanoscale indentation system is typically below 250µm.

Equipment Featured

NANOVEA CB500



Load Control, Multi-Module, & Load Resolution 0.004microN

Broad Application Use

Compact and Modern Design

Full range of testing modes including hardness, scratch and wear

Motorized Stages (X,Y,Z) with Lateral accuracy of 0.1um

Learn more about our Mechanical Tester!

Measurement Objectives

In this case study, Nanovea conducted compression testing on two uniquely different flexible, spring-like samples. We showcase our ability to conduct compression at very low loads and record large displacement while accurately obtaining data at low loads and how this can be applied to the MEMS industry.

Due to privacy policies, the samples and their origin will not be revealed in this study.

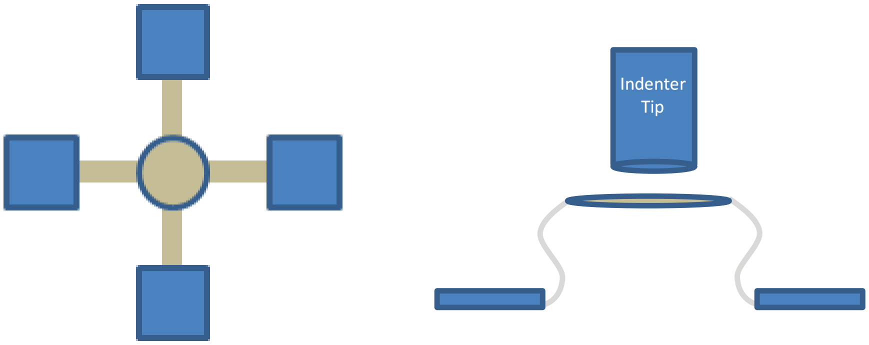


Figure 1: Representative schematic describing sample tested. Top-down view of a flexible sample (left) and side view with indenter (right). Not drawn to scale.

Mechanical Testing Results

Measurement Parameters

Table 1:Test parameters for tribology testing on pistons

Test Parameter	Sample A	Sample B
Maximum Force (mN)	0.075	8.00
Loading Rate (V/min)	1.00	15.00
Unloading Rate (V/min)	1.00	15.00
Indenter Type	Flat	Flat
Indenter Radius (µm)	50	50

Note: The loading rate of 1 V/min is proportional to approximately 100µm of displacement when indenter is in the air.

Compression Test Results

The sample's response to mechanical forces can be seen in the load vs depth curves. Sample A only displays linear elastic deformation with the test parameters listed above. Figure 2 is a great example of the stability that can be achieved for a load vs. depth curve at 75µN. Due to the load and depth sensors stability, it would be easy to perceive any significant mechanical response from the sample.

Sample B displays a different mechanical response from Sample A. Past 750µm of depth, fracture-like behavior in the graph begins to appear. This is seen with the sharp drops in load at 850 and 975µm of depth. Despite traveling at a high loading rate for more than 1mm over a range of 8mN, our highly sensitive load and depth sensors allow the user to obtain the sleek load vs depth curves below.

The stiffness was calculated from the unloading portion of the load vs depth curves. Stiffness reflects how much force is necessary to deform the sample. For this stiffness calculation, a pseudo Poisson's ratio of 0.3 was used since the actual ratio of the material is not known. In this case, Sample B proved to be stiffer than Sample A.

Table 2: Results from compression testing on soft, flexible samples.

	Max Depth (µm)	Unloading Stiffness (mN/nm x 10^6)
Sample A	29.20 ± 0.71	2.552 ± 0.319
Sample B	1084.33 ± 18.49	7.470 ± 0.204

Mechanical Testing Results

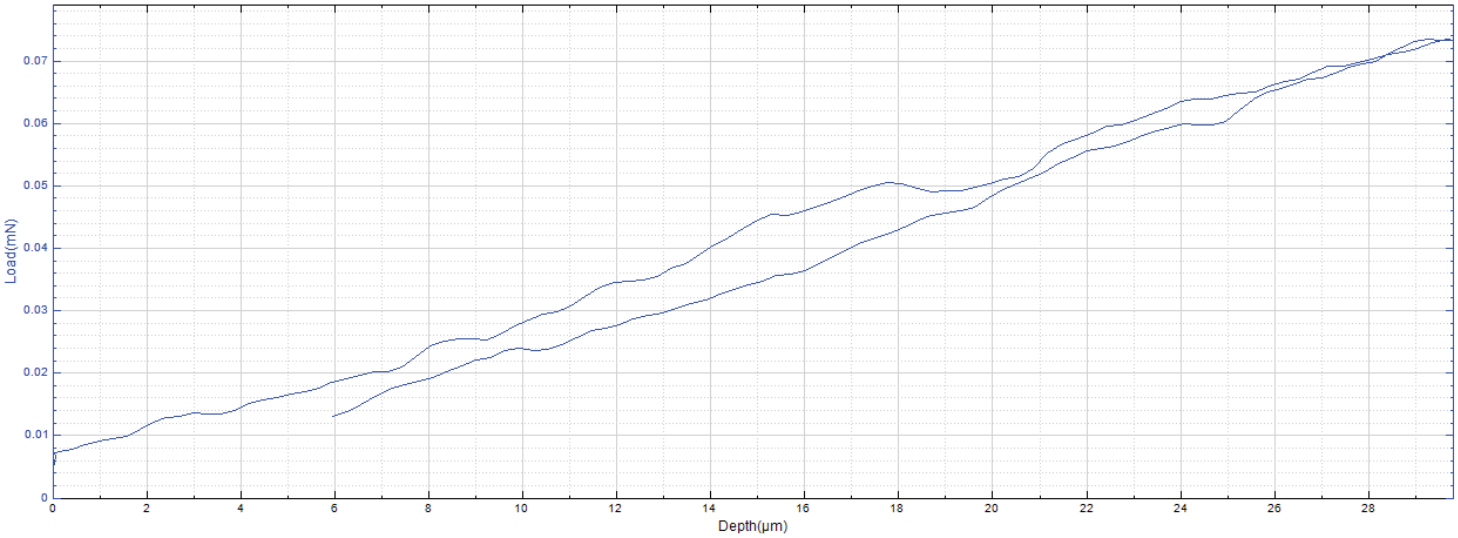


Figure 2: Load vs Depth curve for Sample A at 75µN

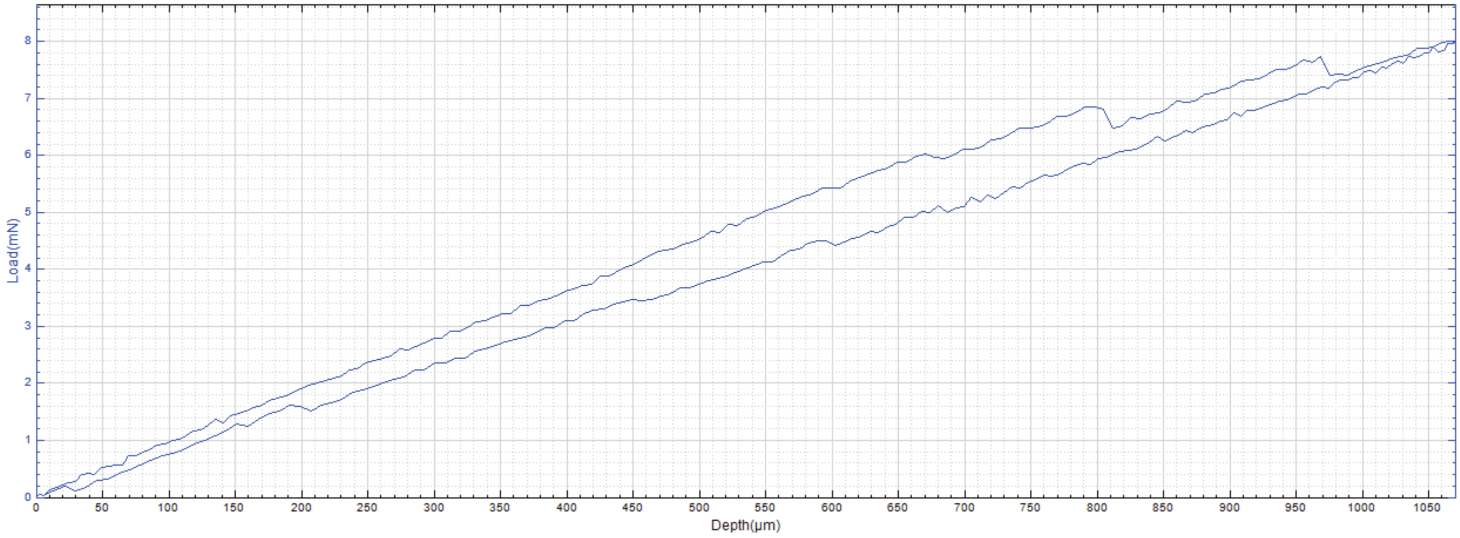
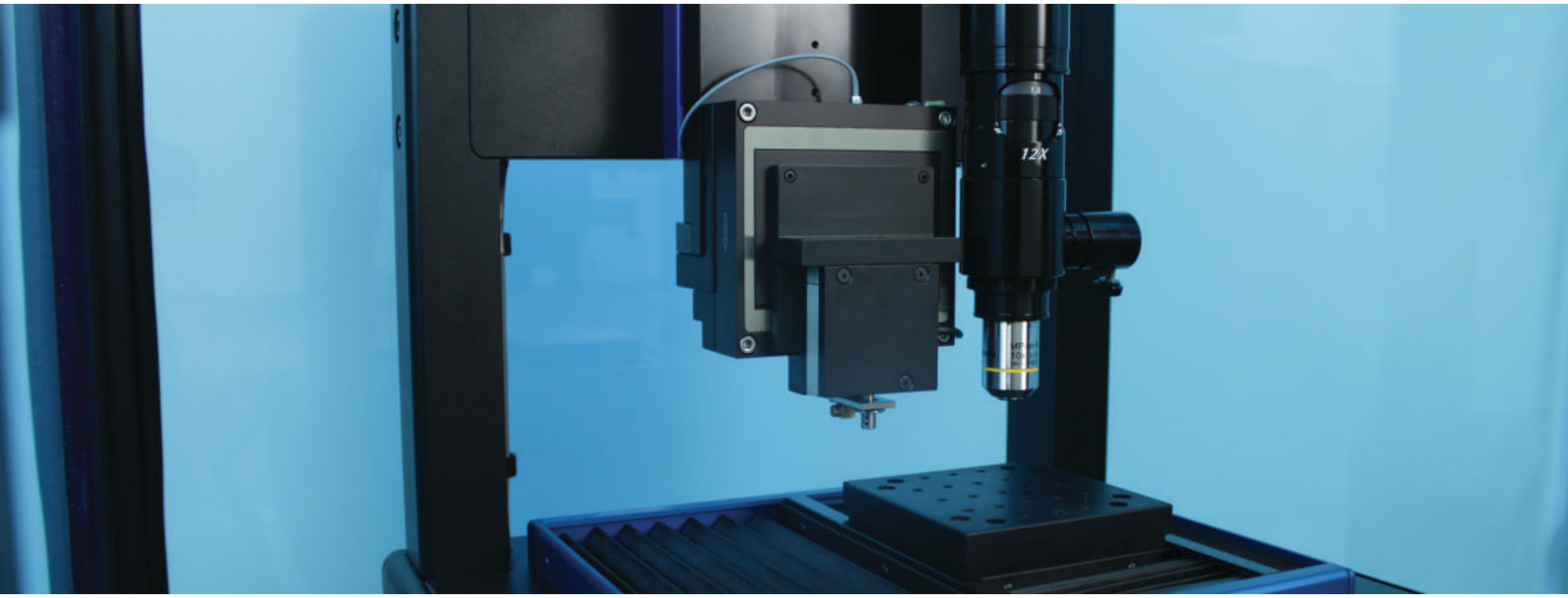


Figure 3: Load vs Depth curve for Sample B at 8mN



Conclusion

Two different flexible samples were tested under compression using the Nanovea Mechanical Tester's Nano Module. The tests were conducted at very low loads (<80µN) and over a large depth range (>1mm). Nano-scaled compression testing with the Nano Module has shown the module's ability to test very soft and flexible samples. Additional testing for this study could address how repeated cyclical loading affects the elastic recovery aspect of the spring-like samples via the Nanovea Mechanical Tester's multi-loading option.

For more information on this testing method, feel free to contact us at info@nanovea.com and for additional application notes please browse our extensive Application Note digital library.

References

[1] "Introduction and Application Areas for MEMS." EEHerald, 1 Mar. 2017, www.eeherald.com/section/design-guide/mems_application_introduction.html.

[2] Louizos, Louizos-Alexandros; Athanasopoulos, Panagiotis G.; Varty, Kevin (2012). "Microelectromechanical Systems and Nanotechnology. A Platform for the Next Stent Technological Era". Vasc Endovascular Surg. 46 (8): 605–609. doi:10.1177/1538574412462637. PMID 23047818.

[3] Hajati, Arman; Sang-Gook Kim (2011). "Ultra-wide bandwidth piezoelectric energy harvesting". Applied Physics Letters. 99 (8): 083105. doi:10.1063/1.3629551.

[4] Fu, Haoran, et al. "Morphable 3D mesostructures and microelectronic devices by multistable buckling mechanics." Nature materials 17.3 (2018): 268.

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Recommended Reading

Check out our other application note where we conduct a Viscoelastic Analysis on Rubber with Nanoindentation

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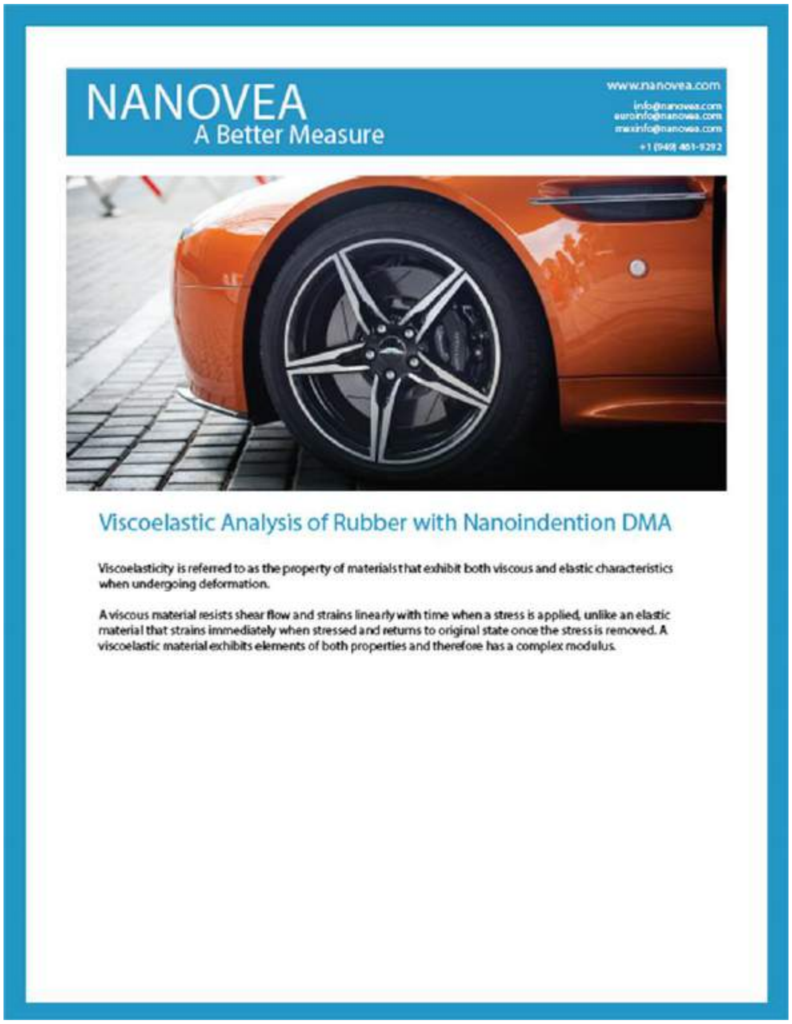

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Viscoelastic Analysis of Rubber with Nanoindention DMA

Viscoelasticity is referred to as the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation.

A viscous material resists shear flow and strains linearly with time when a stress is applied, unlike an elastic material that strains immediately when stressed and returns to original state once the stress is removed. A viscoelastic material exhibits elements of both properties and therefore has a complex modulus.