KLA INSTRUMENTS

# Dynamic Mechanical Analysis of Small Volumes of Styrene Butadiene Rubber at Low Temperatures with Nanoindentation

## Introduction

Styrene Butadiene Rubber (SBR) is a synthetic rubber polymer designed to replace natural rubber. SBR is a versatile rubber, and both emulsion- and solution-polymerized SBR are used in tires, binders, batteries, speakers, and construction applications. SBR is commonly used for its elastic properties and abrasion resistance. In this work, the storage modulus of SBR rubber is measured at low temperatures using local dynamic mechanical analysis with a nanoindenter.

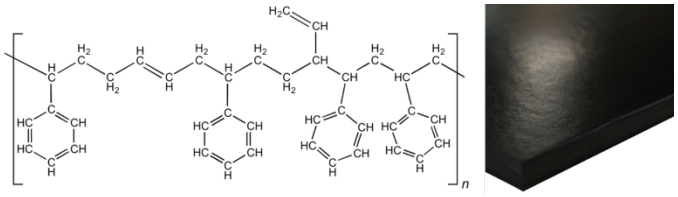

Figure 1. The chemical formula for Styrene Butadiene Rubber (SBR).

## Experimental Method

A KLA nanoindenter equipped with an InForce 50 actuator and a 50µm diameter flat punch was used to perform local dynamic mechanical analysis (DMA) testing on SBR mounted inside a cold chamber. The cold chamber is capable of cooling a sample down to -60°C while leaving access for nanoindentation. The sample temperature is PID controlled with both heating and cooling elements while the external surfaces of the chamber are maintained at room temperature. Inert gas floods the chamber to mitigate chemical reactions with the atmosphere and to limit the amount of ice formed on the surface of the sample during testing.

## Probe DMA Testing Technique

ProbeDMA™ is a nanoindentation technique for measuring frequency-specific viscoelastic material properties. ProbeDMA has the advantage of quantifying local mechanical properties by targeting specific surface locations with the nanoindenter. In addition, ProbeDMA can test polymer coatings and films on samples that do not fit into a traditional DMA tester. The Probe DMA test flow is illustrated in Figure 3.

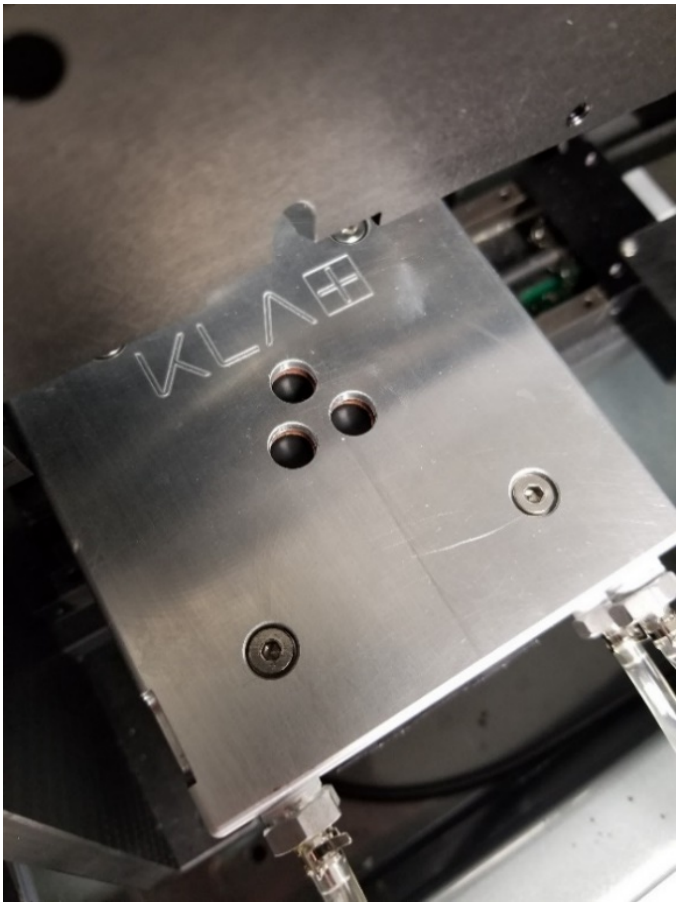


Figure 2. KLA nanoindentation cold chamber.

ProbeDMA is available on all KLA nanoindenters and works with a wide range of flat punch indenter tips. KLA offers a sample temperature range from -60°C to 800°C on various platforms. This temperature range allows for time-temperature superposition experiments and creep compliance function measurements on a wide range of materials.

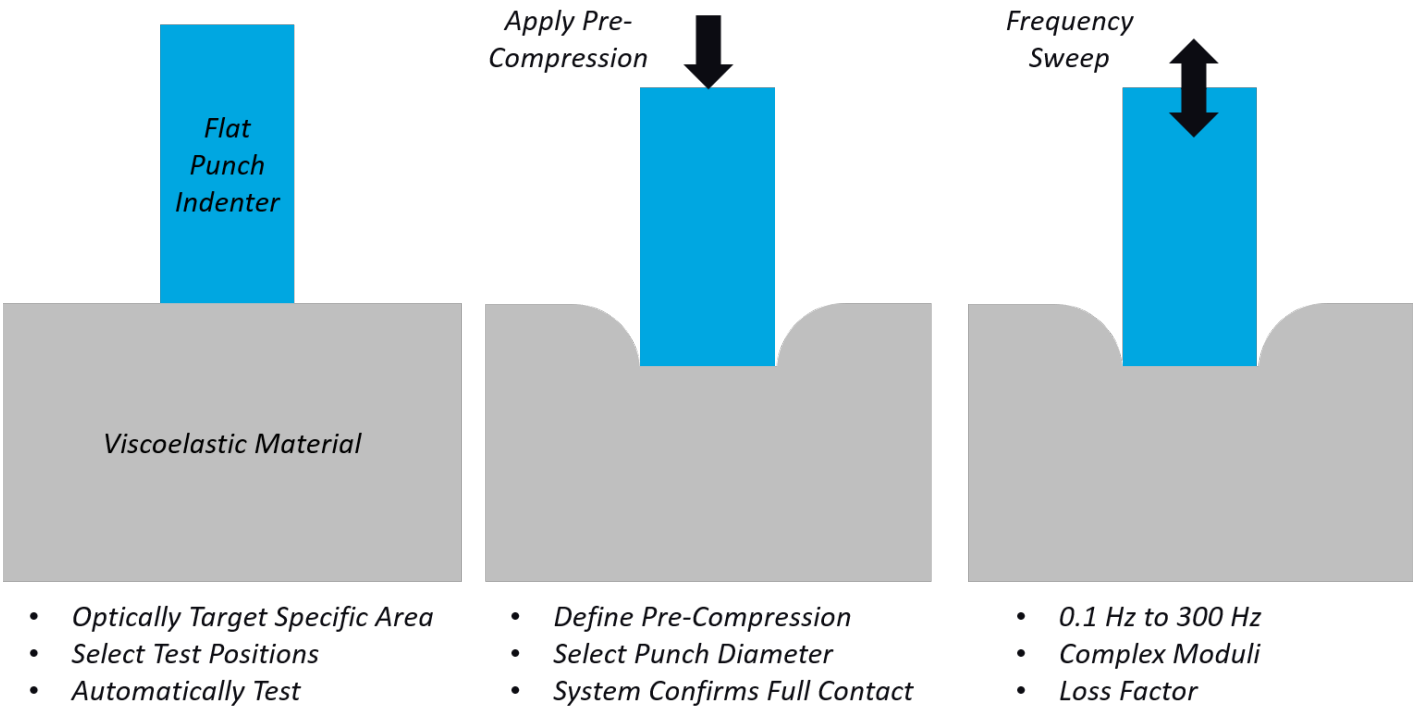


**Figure 3. ProbeDMA test flow: a flat punch with a known contact area is pushed into the surface of a viscoelastic material and the dynamic mechanical response is measured as the indenter oscillates through a frequency sweep.**

## Results and Summary

Storage modulus of Styrene Butadiene Rubber (SBR) as a function of temperature and frequency is shown on the log-log plot in Figure 4. The three temperature bands represent data from 1Hz to 200Hz at room temperature, -28.5°C, and -66.0°C. There is a marked increase in stiffness with decreasing temperature 80MPa at 1Hz and 21.0°C to 1600MPa at 1Hz and -66°C. The severe change in stiffness as a function of temperature highlights the need for testing polymers at operational temperatures.

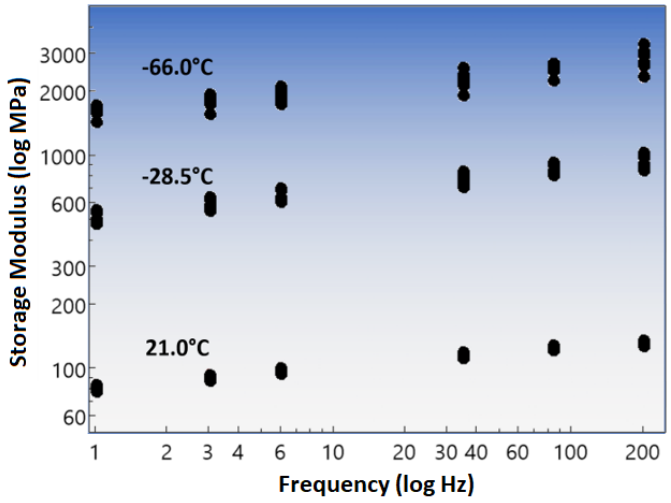


**Figure 4. Storage modulus of Styrene Butadiene Rubber as a function of temperature and frequency as measured by ProbeDMA nanoindentation.**

**KLA SUPPORT**

Maintaining system productivity is an integral part of KLA's yield optimization solution. Efforts in this area include system maintenance, global supply chain management, cost reduction and obsolescence mitigation, system relocation, performance and productivity enhancements, and certified tool resale.



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One Technology Drive
Milpitas, CA 95035
Printed in the USA
Rev 4 2020-08-07