Development of High Performance, Fuel-Efficient Tires

Analysis of three-dimensional structure in tire material at the nano to micrometer scale

Achievements

- Development of **a time resolved two-dimensional ultra-small angle X-ray scattering technique (2D-USAXS)** that can measure the three-dimensional structural information of silica nanoparticles in the rubber of tires
- By combining 2D-USAXS with **time resolved two-dimensional small angle X-ray scattering (2D-SAXS)***, development of a new material using molecular design based on the results of the two analyses
- Commercialization of high performance tires, with **rolling resistance**** reduced by 39% and fuel-efficiency improved by about 6% compared with their predecessors

Research and development institution : Sumitomo Rubber Industries, Ltd.

*Time resolved two-dimensional small angle X-ray scattering (2D-SAXS): A method for measuring the size and shape of structures smaller than several hundred nanometers (nm: 10^{-9}m) within substances. The BL03XU completed in 2011 by the Advanced Softmaterial Beamline Consortium and the BL40B2 Structural Biology Beamline II public beamline were used for measurement.

**Rolling resistance: A force that acts in the opposite direction to the direction of travel of the tire. This involves three factors, air resistance, ground friction, and tire deformation, but tire deformation accounts for about 90%.

Role of SPring-8

Background

The **fuel-efficiency of tires** has a significant effect on improving the fuel-efficiency of vehicles. Incidentally, deformation of the tire against the road surface results in gripping performance through energy loss, thereby making driving safer.

Generally the main material of tires is rubber, but adding nanoparticles of carbon or silica increases their strength and enables the development of tires that resist deformation and have high grip. However, raising gripping performance increases energy loss, which reduces mileage performance. This was thought to be because the nanoparticles in the rubber cohere in a network configuration, but there was no method of investigating structures in this submicrometer range.

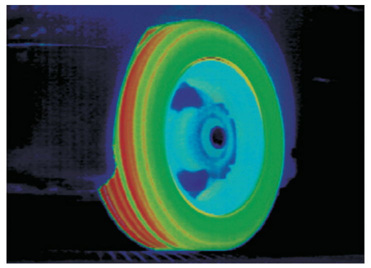
Results

First, we developed a time resolved two-dimensional ultra-small-angle X-ray scattering method (2D-USAXS) that can measure the submicrometer range using the high-brightness, highly parallel X-ray at SPring-8, and observed the network structures formed by silica particles in the rubber at the SPring-8 site. Then we conducted molecular level measurement in the nanometer range, and from the two sets of data, we identified the part of the **silica network structure** that increases frictional force and reduces mileage performance.

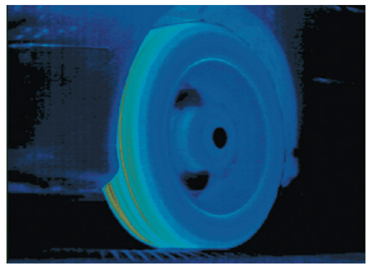
In addition to this experiment, we carried out molecular design reflecting the result of simulation in which temporal change is applied to the network structure to develop a new material, with a structure in which the silica particles are dispersed. This gave rise to a high performance tire with outstanding grip and fuel-efficiency.

Thermographic capture comparing the temperatures of the tire surfaces when driving

Much of the former tire is orange and yellow, indicating high temperatures. The low temperature of the new product reflects its excellent mileage performance.



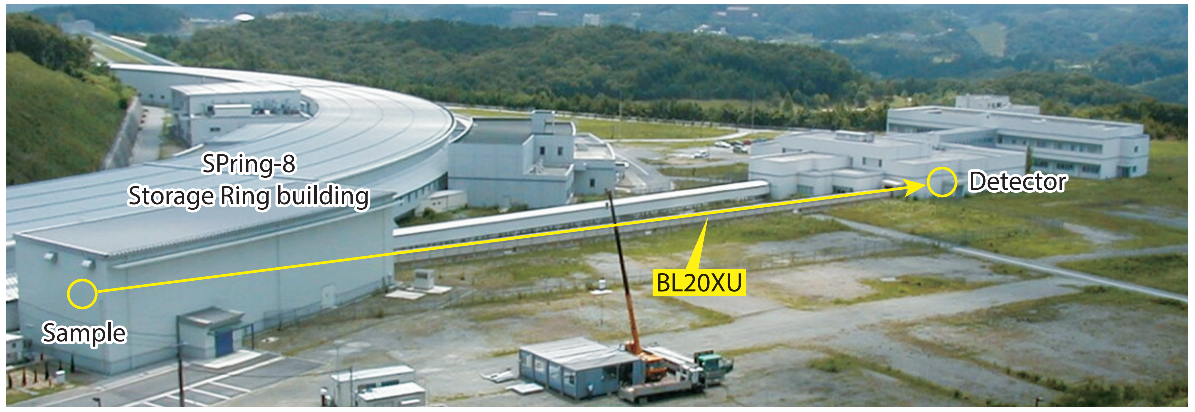
Former tire

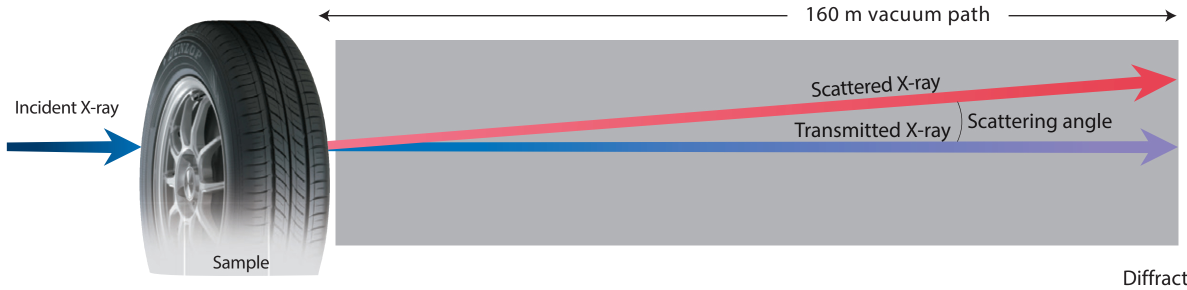


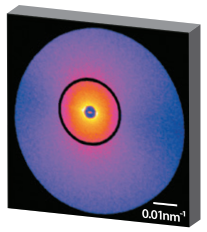
Newly developed fuel-efficient tire

Time resolved two-dimensional ultra-small-angle X-ray scattering (2D-USAXS)

A method for measuring the size and shape of structures in the submicrometer range (10^{-7}m) within substances. By making the 160 m long vacuum path of the BL20XU the camera length, it was possible to observe X-rays scattered at an extremely low angle of less than 1/100,000 to analyze the structures in this range. As a result, we could identify the network structure formed by the silica particles in the rubber.







Diffraction image obtained with 2D-USAXS

Comparison of the molecular bonds in rubber

The rubber of tires is composed of synthetic rubber, natural rubber and a stiffener. In the former tires (top), there are few links, which is a factor in heat generation. In addition, the silica coheres to form a network structure. In the new product (bottom), a "both-ends-modified polymer" is used as the synthetic rubber. The denatured bases at the ends of the polymer and the new bonding material work to improve the bonding power of the silica and polymer, and to increase the dispersibility of the silica.