Spinsolve

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Compact NMR for Tire and Rubber Testing

Rubber consists of long and flexible macromolecules, which are physically entangled. During processing, raw rubber is mixed with fillers and processing agents, and usually sulfur following the formulation oft the manufacturer. The raw product is vulcanized at elevated temperature and pressure where the sulfur forms cross-links between the macromolecules. The resulting rubber network derives its physical properties from the type of polymer, the polymer-filler interactions and the cross-link density. Rubber tubes, conveyor belts and tires consist of several layers of rubber with different properties and often fiber and steel belts to provide extra strength. The cross-link density correlates with the transverse NMR relaxation time T_2, which can be estimated with the NMR-MOUSE at different positions and depths in the intermediate and final rubber products. Depth profiles through tires can also be measured with the NMR-MOUSE and reveal the succession and properties of the different rubber layers. The type and quality of raw rubber can be controlled with a Spinsolve spectrometer by ^{1}H NMR spectroscopy of the raw product dissolved in a solvent like chloroform.

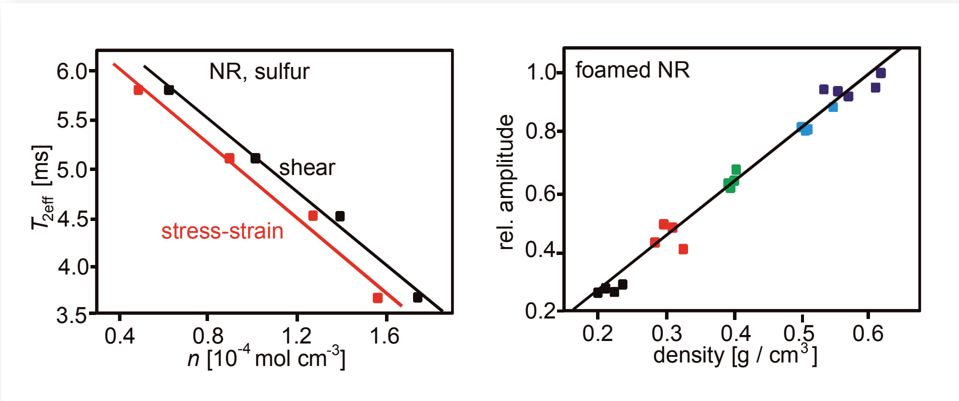
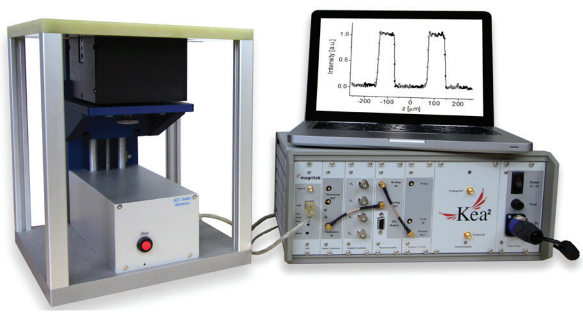


Figure 1: Correlation of NMR parameters measured with the NMR-MOUSE with physical properties of elastomers [Adapted from J. Kolz *et al.*, Investigation of the elastomer foam production with Single-Sided NMR, Kautschuk Gummi Kunststoffe **60** (2007) 179 - 183]. Left: Correlation of the NMR relaxation time T_{2eff} with cross-link density n for sulfur cross-linked NR. T_{2eff} is the NMR relaxation time measured with the multi-echo CPMG technique in the magnetic stray fields of the senor. Right: Correlation of the signal amplitude with the gravimetric density of NR foam.



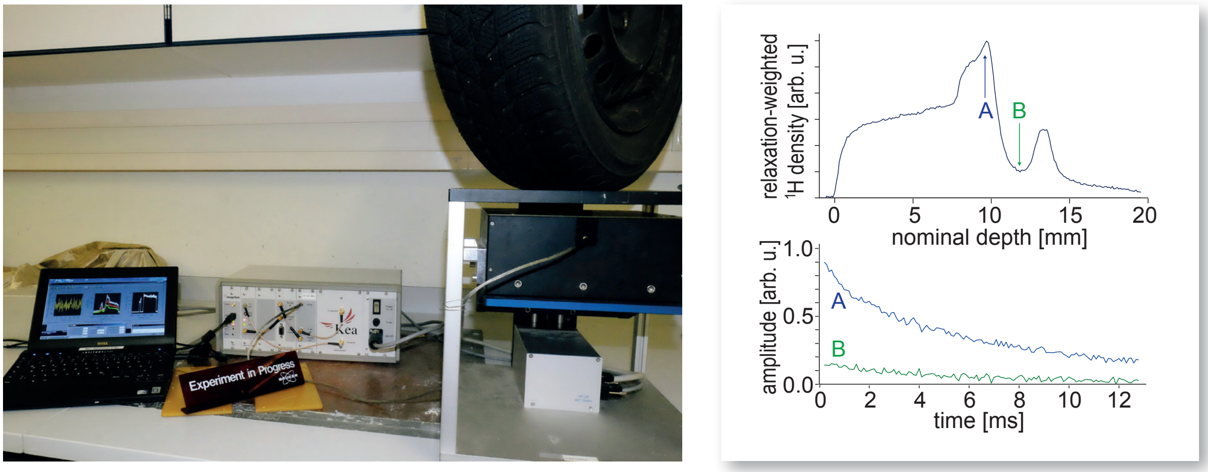


Figure 2: Depth profiling with the NMR-MOUSE. Left: Photograph of the NMR-MOUSE PM25 measuring a depth profile through a winter tire mounted on a steel rim. Right, top: Depth profile through the tire tread. The amplitude is a relaxation weighted proton density corresponding to the grey scale in a magnetic resonance image. The depth scale is distorted by the presence of the steel belt. The signal decays at positions A and B differ in their amplitudes as well as in their decays corresponding to different T_{2eff}.

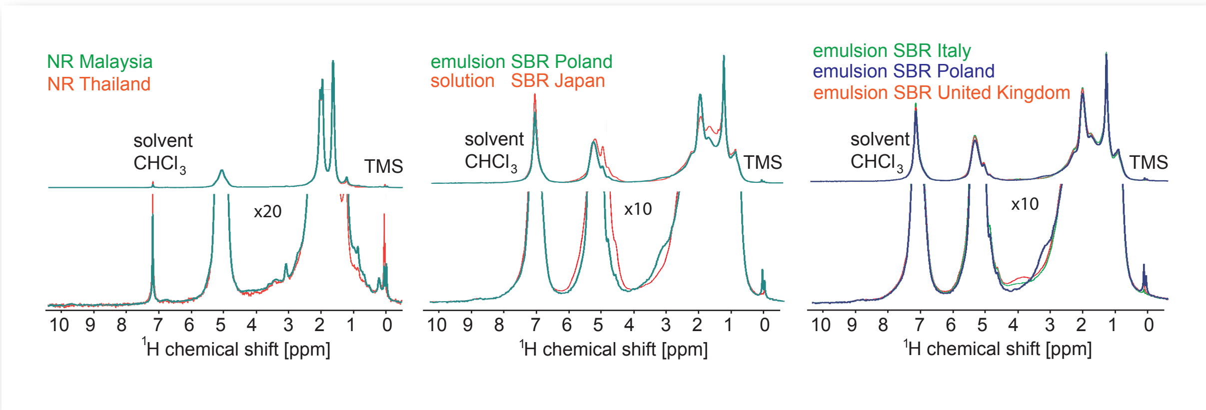


Figure 3: Spinsolve ^{1}H NMR spectra of rubber dissolved in deuterated chloroform without (top) and with (bottom) magnification. Left: NR from different plantations. Middle: Comparison of emulsion and solution SBR. Right: Comparison of emulsion SBR from three different manufacturers.

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