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Spectroscopy and Chromatography

1. Spectrometry

- Qualitative and quantitative analyses of polymers and additives
- Physical chemical characterizations
- Analyses of extracts
- Measurements of diffusion coefficients
- Failure analyses
- Quality assurance
- Trace analyses
- Characterization of contact layers

Fourier-Transform-Near-Infrared-Spectrometer (FT-NIR)
Bruker Optics
Type: Matrix-F Duplex (Wavenumber range: 12,800 – 4,000 cm⁻¹)
Sample characterization in reflection und transmission

Fourier-Transform-Infrared-Spectrometer (FT-IR)
Thermo Nicolet Nexus, attenuated total reflection (diamante- or germanium ATR),
micro scale IR spectrometry.

FT-IR-Microscopy
Thermo Nicolet Continuum, imaging system for documentation

Laser Induced Breakdown Spectroscopy (LIBS)
Emission spectroscopy to evaluate compound homogeneity regarding distributive mixing
efficiency of different compound ingredients such as zinc oxide.
Components:
LIBS-6 Modul and sample chamber (Applied Photonics),
5 Spectroscope: Spectral range between 314–977 nm (AVANTES),
Laser: Q-switched Nd: YAG-solid state laser (QUANTEL) [Wavelength: 1,064 nm,
pulse energy: max. 100 mJ, pulse rate: 7 ns, pulse frequency: max. 20 Hz]

UV/VIS-Spectrometer
Thermo Electron, Evolution 300, UV-Spektren, Quantification at component in solutions.

2. Gaschromatography, Mass Spectrometry

- Separation of multi component mixture (extracts, additives, fumes, emissions)
- Identification and quantitative determination of components in extracts, vulcanization fumes etc.
- Determination of compatibility of rubbers and solubility parameters
- Thermodynamic characterization of polymers and fillers by means of „Inverse”
  Gas Chromatography
- Identification of polymers (Pyrolysis-GC)

Instruments with capillary columns
Fisons Instruments (Inverse GC),
Agilent GC 8790B

Injection Systems
Agilent Autosampler 7683, on column, Split/Splitless, Headspace-Technique, Gerstel Multi
Purpose Sampler MPS Robotic XL
Detector Systems
Flame Ionisation Detector (FID), element specific detector for Nitrogen and Phosphorus (NPD), Mass Selective Detector (MSD)

Gas Chromatography-Mass Spectrometry (GC-MS)
Agilent GC 7890B/MSD 5977B,
Agilent GC 6890 N/MSD 5973N,
Agilent GC 6890 N/MSD 5975C with Headspace sampler 7697A,
Mass selective detector: Quadrupole, Chemical Ionization, Electron Impact Ionization

Thermal desorption
Gerstel TDS 3, Peltier-cooling UPC (10 … 400 °C), Heating rate max. 60 °C/min,
Split/Splitless-Injector; Gerstel Cooled Injection System KAS 4 with N₂(liquid) cryo-cooling (-150…+400 °C), Controller 505,
Pyrolysis Modul PM 1

Gerstel TDU 2, UniversalPeltierControl UPC plus (10–350 °C), Heating rate max. 720 °C/min,
Gerstel Cooled Injection System KAS 4 with N₂(liquid) cryo-cooling (-150 … +450 °C), Controller C200, Gerstel TDU Pyrolysis Modul for MPS Robotic XL

3. Nitrosamine analysis
• Nitrosamine determination in air, vulcanisates, uncured rubbers and fillers

Gas Chromatography-Thermal Energy Analyzer
Agilent GC 6890N/Autosampler 7683B with Ellutia Thermal Energy Analyzer TEA 810 detector
Agilent GC 7890A/Autosampler 7693B with Ellutia Thermal Energy Analyzer TEA 810 detector

4. Liquid Chromatography
• Qualitative and quantitative analyses of high boiling or thermally unstable components (e.g. oils, plasticizers, antioxidants, crosslinking chemicals)
• Trace analyses of extracts of polymeric materials (“Leachables/Extractables”)

High Performance Liquid Chromatography (HPLC-UV/RI)
Thermo Scientific UltiMate 3000 with Variable Wavelength Detector VWD 3400RS,
Thermo Scientific UltiMate 3000 with Diode Array Detector DAD 3000 and
Refractive Index detector, 2 × Thermo Separation Products P2000, gradient pump systems with Autosampler AS 1000,
Refractomax 521

Liquid Chromatography-Mass Spectrometry (HPLC-PDA-MS)
Thermo Finnigan Surveyor system with Photo Diode Array Detector PDA Plus and
Mass Selective Detector LCQ Classic, Atmospheric Pressure Chemical Ionisation (APCI), Electrospy Ionisation (ESI), Ion Trap with MS-MS technique
5. Gel Permeation Chromatography (GPC)

- Separation of solved polymers according to the size exclusion principle
- Determination of relative molecular masses
- Determination of molecular mass dispersions

**GPC instrument**
Agilent 1100 Series with Isocratic Pump G1310A, Autosampler G1313A, UV/vis Detector G1314A, Refractive Index detector G1362A, Light Scattering Detector SLD 7000

**Detection systems**
UV/VIS Detector (G1314A), Refractometer (RI, G1362A), Light Scattering Detector (SLD 7000)

6. Thin Layer Chromatography

- Separation of multi component liquids
- Qualitative Analyses of extracts, plasticizers, accelerators and antioxidants

7. Chemiluminescence

- Characterization of the oxidative stability of polymers, oils, biological substances
- Analysis of aging behavior of polymers
- Characterization of the efficiency of antioxidants

**Chemiluminescence-Analyser**
ChemiLume™ CL400 (Atlas),
4 gas tightend test cells with separate control of temperature, of gas flow, of testing time and of photomultiplier -amplification; isothermal and programmed -temperature up to 250 °C; Gas flow: 25 ml/min or 50 ml/min; optical sensitivity: $8.2 \times 10^{10}$ V/Lumen; 2 Counts/s
**Microscopy**

1. **Light Microscopy**

- Failure analyses
- Morphology of blends
- Filler dispersion
- Filler distribution

**Light microscope with phase contrast**
Zeiss Universal
Magnification: max. 2000×, Phase Contrast

**Stereomicroscope**
Zeiss 9901
Magnification max. 100×.

**Light microscope (transmission and reflectance technique)**
Jena Jenaval/Jenavert, Magnification max. 1,250×

**Dispersion Index Analysis System (DIAS)**
Computer-based reflectance-light microscopic determination of filler dispersion and the distribution of the agglomerate size on elastomer surfaces at a magnification of 150×
Software developed by the DIK based on a SIS-picture analyzing program

**Filler Dispersion Analysis using ISO 11345**
Alpha Technologies,
Type: disperGRADER aview SR (for particle sizes between 3–57 μm)
Magnification: 50×

2. **Transmission Electron Microscopy**

- Phase morphology of polymer blends
- Network inhomogeneities
- Carbon black dispersion and -distribution
- Polymer/plasticizer systems
- Particle characterization
- Measurements on elastomer parts under defined strain
- Failure analysis

**Transmission electron microscop**
LIBRA® 120 (Zeiss),
Acceleration voltage 120 kV, Köhler illumination, magnification 8× … 630,000,
point resolution 0,34 nm, Electron Spectroscopic Imaging (ESI); Electron Spectroscopic Diffraction (ESD), element or structure contrast reproduction, electron energy loss spectroscopy (EELS) for chemical analysis, cryogenic table, image processing

**Ultramicrotomy**

Preparation of ultra thin cuts by using glas cutters (80 … 150 nm) or diamant cutters (50 … 100 nm), Semi thin cuts using glas cutters (max. 1 mm),
Operating temperature: −160 … +20 °C,
cryo transfer system for cryo fixed samples
2 Instruments:
Reichert FC-4E Ultramicrotome,
Leica Ultramicrotome UC6 with liquid nitrogen cutting system FC6, equipped with stereo microscope MZ6
3. Atomic Force Microscopy (AFM) and Topography Measurement Systems

- Surface roughness
- Phase morphology of polymer blends
- Filler distribution and dispersion
- Magnetic properties
- Hardness gradient due to oxidative ageing

**Atomic Force Microscope**

Chromatic topography measuring system FRT-CWL 300

Contact-free measurement of the surface topography, lateral resolution < 2 μm, vertical resolution 3 nm, max height difference 4 mm, max image area ca 100 × 100 mm

4. Micro Indenter

LNP nano touch + LNP cross table

Mechanical testing of hardness topography, adhesion, elastic modulus, Shore A micro compact tactile sensor in linear positioning with optical position sensor

Range: 4 mm, Linearity way: < 200 nm to measuring range

Measuring force: 0.6 mN ... 1.4 N; resolution: 0.6 mN; electro-mechanically generation

**Microindentation measurements with high resolution**

- Force or displacement controlled indentation measurements
- Hardness topography
- Hardness (for example IRHD, Shore A/M, Shore A Micro)
- Stiffness, E-Modul
- Adhesion
- Micro-tribology
- Rheology

**Microindentor equipment: 031790 LNP nano touch mit Piezo Kreuztisch**

(Ludwig nanoPräzision GmbH)

System for measuring ot distances

Displacement-Meseasurement modus: Optical incrementell, Application range: 4 mm, resolution: 0,00001 mm standard, Linearity of displacement modus: < 200 nm rel. to application range, linearity force: 0...1400 mN, Generation of measuring force: Electromechanical, Measuring force: 0,6 mN...1,4 N

Measuring force resolution: 0,6 mN, Needle geometries: spherical, varying cross section

5. Computertomography

- Analysis of insertions, defects
- Dispersion analyses, fillers and crosslinking chemicals (ZnO etc)
- Analysis of crack initiation and propagation
- Cell structure analysis
- Testing of rubber-metal and rubber-plastic bonding
- Location of reinforcement and fiber orientation
- Non destructive defect analysis
- Dimensional measurements

**Nanotom®; 180 kV/15 W nanofocus-Computertomograph**

GE phoenix x-ray, 180 kV/15 W high power nanofocus tube. 5 megapixel fully digital detector

Maximum sample dimensions 150 × 120 × 120 mm (height × width × thickness)

Best resolution (sample size dependent) 500 nm in 3D

Image processing software for 3D representation and quantitative analysis (particle size distribution)
6. Scanning Electron Microscopy (SEM)

- SEM-pictures, BSE- pictures
- Element identification
- Element quantification and -distribution
- Surface structures
- Material contrasts

**Scanning electron microscope**

EVO MA10, W-Filament, 0.2–30 kV, Magnification: 7 × … 1,000,000 ×,
Variable Pressure 10–400 Pa, SE-Detector, BSE-Detector, EDX-Detector
(Si/Li-cryystal); max. sample height: 100 mm.

**EDX**

Oxford Instruments INCA (EDS8100)

7. Thermo analyses

- Quantitative composition of elatomers (polymer, plasticizer, carbon black, anorganic fillers, soot)
- Determination of glass transition temperatures, of melting point in thermoplastis, rubbers and elastomers
- Morphology of blends
- Heat capacity
- Kinetics of blowing aids and crosslinking chemicals

**Thermogravimetry (TGA)**

TA-Instruments TGA 2950CE-Hi-Res, sample mass: max. 1 g,
Temperature range: 25 … 1,000 °C, heating rate: 0.1 … 200 K/min, Evaluation: PC/Software
Netzsch TG 209 F1, sample mass: max. 2 g, Temperature range: 20…1,000 °C,
Heating rate: 0.001 … 80 K/min, Evaluation: PC/Software

**Differential Scanning Calorimetry (DSC)**

TA-Instruments DSC 2920CE, modulated DDK-MDSC, sample mass: 0.5 … 100 mg, temperature range: –180 … +725 °C, heating rate: 0.01 … 200 K/min linear and 0.01…10 K/min modulated, evaluation: PC/Software-Standard/Kinetic,
Netzsch DSC 204 F1, Temperature range: –180 … +700 °C, heating rate: 0.0001 … 100 K/min, evaluation: PC/Software

8. Emission measurements

**VCI - Fire Simulation Equipment**

Analytik Jena GmbH, Temperature range up to 1,200 °C

**Fogging Test Equipment**

Determination of Fogging-values
Instrument: Heating and cooling device, test chamber acc. to DIN 75 201-B

**Test chamber for emission tests**

Volume 400 l, Temperature range 20–110 °C, controlled air exchange, sampling using ad- or absorption techniques
9. Thermographic Analyses

- Quality control
- Heat loss determination
- Improvement of processes

Rapid Realtime Thermography Camera
VarioTHERM, InfraTec GmbH
Measurement of points and areas with editable emission value, possibility to dub in of Isotherm, Peak-Hold-Function. Spectral range 3.6 … 5 μm; recording method ‘Focal Plane Array’; PtSi-CMOS-Hybrid Detector, 50 Hz Image frequency; Temperature solution (30 °C): < 0.1 (0.01 mA); temperature range: –25 … +1,200 °C; geometrical solution: 1,0 mrad; field of view with standard-optic: 14 × 14°; size of image: 256 × 256 Pixel; signal digitization: 16 Bit; working temperature: –15 … +50 °C; data output: PAL-FBAS, Y/C.

Compact Thermographic Camera
Micro-Epsilon thermoIMAGER TIM 640; dimensions (46 × 56 × 90 mm), 320 g; Measuring range: –20 °C–100 °C, 0 °C–250 °C, 150 °C–900°C (switchable) Spectral range: 7,5–13 μm, thermal resolution: 0,1 °C, emissivity: 0,1–1,0 adjustable Optical resolution: 640 × 480 pixel, refresh rate: 32 Hz; signal output: USB 2.0 Lens focal length: f = 18,4 mm/33°-objektive; f = 7,3 mm/90° × 66°-objektive

10. Low Field Nuclear Magnetic Resonance Spectrometry (NMR)

- Characterization of polymer chain dynamic properties
- T1 and T2-relaxation time determination
- Correlation T2-value-crosslink density
- Aging of polymers (in situ aging)

Instrument: XLDS-15, Innovative Imaging Corp. KG, 0.35 T = 15 MHz, 20–120 °C, solid state spectroscopy
Processing

1. Mixing

Internal Mixers
Werner & Pfleiderer GK5E/GK4N

GK5E: intermeshing rotor system with PES-3-rotor, useful volume 5l, ram 1 ... 7 bar, infinitely variable, rotation of blade 17 ... 100 rpm

GK4N: tangential rotor system in standard or n-geometry, useful volume ~3.6l, ram pressure 1...6 bar, infinitely variable; friction 1 : 1 to 1 : 1.3 rotation of blade 22 ... 135 rpm

GK5E und GK4N: Cooling by water for mixing chamber, ram and rotors, temperature-controlled until 95 °C, process control by mixing time, specific energy, revolutions, temperature; data logging and tabulated/graphical illustration

Gravimetric softener dosage: Injection pressure 30–40 bar, Preheating max. 70 °C (Zeppelin Systems)

Internal Mixer
Werner & Pfleiderer GK 1,5 E
Useful volume ~1l, cooling until 95°C

Two-Roll Mills
Berstorff 250 * 500
Mills diameter 250 mm, mills length 500 mm, drive via 2 × dc motors, batch size ~6 dm³, rotation 1 ... 25 rpm; continuous oil-cooling, apparatus with 10 knives of cutter bar, measurement of flow and return temperature of the heating-cooling circuits, die gap at the end of the mills, 2 × torque, bearing reaction of the fixed mill, 5 × measurements of the melt pressure of the, 2 × rotation
Berstorff 150 * 350 RR
Diameter of mills 150 mm, length of mills 350 mm, cooling until 100 °C

Laboratory Internal Mixer
Mixing of rubber compounds with simultaneous measurement of temperature and torque
Programable mixing intervals for temperature and rotary speed
Chamber Volume: 70 cm³ and 350 cm³
Polylab-System

Planete Mixer
LPV 1A40 Series Nr. 420-16 with integrated vacuum device
Mixing tools: Intermeshing set of blade agitators KES0.57 D90 HVT, mixing speed: 0 ... 620 rpm, wiper Type KES90 AB-Ha Quer V10 with PT 100 and PTFE-blade, mixing speed: appr. 10 rpm, stainless steel vessel with 600 mL volume, Maximal temperature: 150 °C
Maximal pressure using vacuum conditions: 1,100 mbar absolute
2. Extrusion

**Pin-Barrel Extruder**
Krupp KGS 60/14; 60 mm, 14 D
Screw diameter 60 mm, screw length 14 D, drive via dc motor; rotation 7 ... 70 rpm, throughput ~100 ... 200 kg/h, separate heating-cooling circuits for the feed roll, screw and 3 cylinder zones, measurement of input power, speed, mixture temperature radial per 4 × in 3 pin extrusion and 8 × in front of the screw tip, axial pressure curve in 7 levels, extrudate diameter. Remodelling of the extruder and reduction of 10 D allows the application as processability tester for rubber mixtures, continuous process data acquisition.

**Transfermix Extruder**
AZ MCTM 60
Screw diameter 60mm, variable screw length 11 D to 13.7 D with 1 or 2 transfer mixing zones, drive via dc motor rotation up to 205rpm, throughput ~100 ... 200 kg/h, separate heating-cooling circuits for screw and 2 cylinder zones, measurement of input power, rotation as soon as melt temperature and melt pressure in front of the gap tip, pressure in each case after the transfer mixing zones, continuous process data acquisition.

**Laboratory Extruder**
Rubicon EEK 32.12 S-4.0/90
Screw diameter 32 mm, screw length 12 D, input power 4 KW three-phases asynchronous motor, screw rotation 3 ... 90 rpm, throughput ~1 ... 25 kg/h, separate heating-cooling circuits for screw and cylinder, cooling up to 250 °C, access line at gear pump MAAG Enthex SP 21-4, application as extruder-gear pump-combination or anytime for metering of rubber or rubber mixture into the twin screw extruder Berstorff ZE 25, pre-printed form control over control of the gear, measurement of the rotation, melt temperature, melt pressure.

**Twin Screw Extruders**
Berstorff ZE25, 10.5 kW, Nmax = 550 U/min, screw diameter 25 mm, screw length until 54 L/D, cylinder segment in 6D, Barbender-Flex-Wall main metering, gravimetric Brabender metering with side-way feeding, vacuum cylinder, fluid injection, powered shaft extractor for the screw to process optimisation and sampling (e.g. morphological investigation).

**Twin Screw Extruders**
Berstorff ZE 40 A UTX; 44mm, screw length 55 L/D cylinder segments until 6 D, temperature and pressure measuring stations, gravimetric Brabender-Flex-Wall main metering, gravimetric Brabender metering with side-way feeding, fluid injection. Metering of the extrudat with rubber or rubber mixture in feeding strips over a single-screw extruder-gear pump-combination (transfer mixing extruder AZ MCTM 60, gear pump Troester ZP 56/33). Continuous producing of rubber mixture and thermoplastic vulcanisates.

Fully automatic process data acquisition for the simultaneous, continuous acceptance of the process data of the gravimetric dosing feeder, twin-screw extruder, single-screw extruder and the gear pump Troester ZP 56/35.

**Dosing System**
Mahr; metering of fluids into the twin-screw extruder Berstorff ZE 25 across gear pump and Coriolis sensor; output 2–12 kg/h; metering accuracy +/-2%. temperature-controlled up to 60 °C; viscosity range 200–2,000 mPa·s.

**Twin Screw Micro-Compounder**
(DSM Explore 15 cm³ Micro-Compounder)
Twin-screw extruder with co-rotating conical screws, screw length 150 mm, useful volume 12,5 cm³, rotation 0...245 rpm, temperature range 20...350 °C, max. axial force 8000 N, 6 heating zones, water cooling, by-pass valve (residence time adjustable), computer-aided carrying experimentation und data acquisition.
Granulation Unit
Pell-Tec SPP 50 compact; throughput 180 kg/h, 7 … 50 m/min, max. Strand No. 9, length 4 m.

Gear Pumps
Troester ZP 56/35
Throughput 120 kg/h, back pressure 20 bar, delivery pressure 500 bar, max. differential pressure 450 bar, max speed 48 rpm, continuous process data acquisition, MAAG Entrex SP 21-4
Throughput 2 … 10 kg/h, back pressure 20 bar, delivery pressure 350 bar, differential 250 bar, max. speed 50 rpm.

3. Injection Moulding

Injection Moulding Machines (Loan from LWB Steinl)
LWB Steinl VS EFE 3000/2000 P with EFE-system for cure time reduction
Closing force 3000 kN; Injection volume 2000 cm³; Injection pressure (Injection plunger) 2,200 bar; Injection pressure (E-injection plunger) 1800 bar; Screw diameter 40 mm

Laboratory Injection Moulding Machine
DSM Explore 10 cm³
Nominal volume 10 cm³, injection part \( T_{\text{max}} = 350 \) °C, form \( T_{\text{max}} = 200 \) °C; pneumatic pressure 10 … 16 bar (is equivalent up to 1600 N), two-cylinder heating, form for S2 tensile bar, exchangeable

Two Component Injection Moulding
Both injection units returnable for rubber or thermoplastic, possibility of 2K application: rubber/thermoplastic, rubber/rubber and thermoplastic/thermoplastic. Screw diameter 25 mm, aggregate in l-position, without tie bars construction, closing force 800 kN, 2-station turntable, control CC200. 2K in-mould assemblies as tensile bar and compression member with separate mould temperature control for the two components in the nozzle side and ejection side of the mould. Metal insert into the shear bar possible; pressure test in the mould for both components; data logging via control.
4. Calendering

- production of a flat film or sheet of uniform thickness (coating, double-sided coating, frictioning)
- calender feeding: discontinuous (rough sheet from a mill) and continuous from extruder (strip feed, throughput up to 200 kg/h)
- hot edge trim
- take-off of sheet by center winder

**Four-roll laboratory standard calender**
Troester KQF 200
Four-roll calender, inverted L-type: roll dia. 200 mm, face-width 450 mm, 350 mm of working width, edge trimmer on stripper roll, max. trimmed sheet width 320 mm, calender feeding in 1st or 3rd roll gap alternately, distance pieces in the 1st and 3rd roll gap, operating: four-rolls, three-rolls, or 2 x 2 rolls, circumferential speed for each roll separately 2.0...20 m/min, friction ratio from 1:1.25 up to 1.25:1, temperature for each roll separately up to 200 °C, electric roll adjustment, min. roll gap clearance 0.3 mm, pneumatic pre-load for 1st, 2nd and 3rd roll, roll crossing for 3rd roll.
Calender train: roller train, cooler (two cooling drums, dia. 300 mm each), winder.
Data Acquisition System: measurement of roll gap size, roll speed, axis load (1st and 2nd roll), gap pressure in the 1st and 2nd roll gap (three pressure sensors build in second calender roll), electric power.

**Calender feeding by conveyor belt**
Scholz
Infinitely variable speed and oscillation of the conveyor

**Calender train**
DIK
Cooling section with two cooling drums – diameter 300 mm, manual speed control

5. Vulcanization

**Vulcanization press**

- **Rucks Maschinenbau KV 207.00**
  Electrical heating: 250 x 250 mm, evaluable

- **Wickert & Söhne WLP63/3,5/3**
  Electrical heating: 350 x 350 mm

- **Berstorff**
  Electrical heating: 300 x 350 mm, evaluable
6. Surface Treatment

- Plasma treatment

Plasma Treat, PFW20
8 parallel plasma torches, plasma activation and plasma polymerization (PE-CVD) at atmospheric pressure, treatment of areas with a range of 40 … 120 mm, process speed 1 … 60 m/min.

Plasma Treat PFW 10
One plasma torch, plasma activation and plasma polymerization (PE-CVD) at atmospheric pressure, treatment of areas with a range of 5 … 220 mm, process speed 1 … 60 m/min.

7. Electrospinning

- Preparation of nano fibres
- Non wovens
- Orientated fibres

Electrospinning equipment (manufacturer: Mecc, type Nano-01 A)
High voltage device (0.5–30 kV), Injection pump for up to 3 syringes, flexible spinning jets for 3 needles, Volumeflow (0.1–99.9 cm³/h)
3 different collectors:
Disk (perimeter 600 mm; max. 3000 rpm),
Drum (perimeter 600 mm; 210 mm broad; max. 2500 rpm),
flat stainless steel plate (145 × 250 mm)
Physical and Dynamic Mechanical Properties

1. Physical Testing

- Determination of physically properties of vulcanized rubber (ISO, DIN and ASTM norms)
- Stress relaxation
- Ageing behavior of vulcanized rubber
- Heat resistance
- Resistance to ozone cracking
- Resistance to light
- Contact discoloration
- Contact angle and surface energy

**Uniaxial Stress-Strain**
Zwick 1445, max. force 5 kN, heating chamber (–60 ... + 150 °C).
Zwick Z010, max. force 2.5 kN.

**Biaxial Stress-Strain**
Elastocon EB 02, Stress Relaxation in a temperature range of 10 ... 200 °C,
max. force 800–1600 N (stress), 70N (strain), measurements in Air, Nitrogen
and Oil (ISO 3384)

**Goodrich-Flexometer**
Doli FlexoB 1170, frequency 30 Hz, tension ½ MPa, heating up to 100 °C.

**Fatigue to Failure Test (de Mattia)**
Frank 13515, Determination of cracking speed and cracking growth resistance,
Frequency: 5 Hz

**DIN Abrasion Tests**
Frank 11565, Testing of abrasion resistance

**Hardness**
Zwick digitest, Shore A, Micro Hardness

**Rebound Resilience**
Frank 23267, Zwick 5109.01, with temperature control

**Electrical Resistivity**
Dr. Kamphausen, Determination of surface resistance and conductance

**Ozone Ageing**
Argentox 3MR-3R, Temperature 0–70 °C, Specimen Room: 200 l, concentration O₃
50–250 pphm (0.5 – 2.5 ppm), humidity 10 – 90 %

**Contact Angle Measurement**
Dataphysics OCA20, temperature control system –20 ... +150 °C, multiple dosage system,
calculation of the free surface energy of solid materials and the surface tension of liquids

**Tensiometer and Dynamic Contact Angle Measurement**
Dataphysics DCAT11, temperature control system (–10 ... +130 °C),
contact angle measurement on powder or fibres
Gas adsorption for filler characterization
Gas adsorption equipment: BELSorp max.
Principle: volumetric gas adsorption
3 Ports (2 high resolution types, parallel measurements possible)
Adsorption using different gases: nitrogen, ethane, ethene, propene, 1-butene and iso-butene
Different temperatures: −200 °C (liquid N₂) and −60 °C bis +20 °C
pressure range: 10⁻²–10⁵ Pa
Evaluation methods: BET-Adsorption, energy distribution, porosimetry

2. Dynamic Mechanical and Durability Properties

- Dynamic properties
- Fatigue properties
- High frequency properties (ultrasound)
- Elastic modulus, shear modulus, damping
- Temperature, frequency and amplitude dependence
- Standard and customer specific measurements
- Dynamic crack propagation behaviour

Automatic Tear and Fatigue Analyzer
Elastomer Testing System for Fatigue Testing with tracking of dynamic crack propagation according to the Tear Analyzer System Bayer/Coesfeld. Crack propagation resistance under dynamic load. Investigations on laboratory test specimens under tensile, compression or shear loading. Optical online acquisition of the crack surface, energy recording. Calculation of fracture mechanics factors for lifetime predictions (tearing energies) up to 10 ms pulses.
Electrical direct drive 5 kN; amplitude range up to ±50 mm. Traverse for fivefold parallel inspections; each measuring station with separate load cell up to ±1 kN and compensation of permanent set by electromotive retensioning. Temperature controlled test chamber, air or N₂.

Tear Analyzer, dynamic crack propagation
Tear analyzer system Bayer-Coesfeld, crack propagation resistance under dynamic load. Optical online acquisition of the crack surface, energy recording. Calculation of fracture mechanics factors for lifetime predictions (tearing energies) up to 10 ms pulses, temperature controlled testing chamber in air or nitrogen environment.

Ultrasonic spectrometer (Prototype)
Measurement of the ultrasonic attenuation and sound velocity (enabling the calculation of the storage and loss moduli) using the transmission principle. Frequency range 0.5 MHz, 1 MHz, 2 MHz. Temperature range: coupling fluid dependent between −100 °C and +100 °C.

Dynamic-mechanical thermal analyzer (DMTA)
Mettler Toledo DMA B61, tests in double shear sandwich geometry between −150 °C 500 °C and 0.001 Hz–1,000 Hz, 0.01–5 % amplitude

GABO Qualimeter
Eplexor 500N/1500N static, Investigations under shear-, compression and tension
−150 °C ... 500 °C; 0,01 ... 100 Hz
Static and dynamic strain sweeps; +/- 3 mm dynamic

Dynamic mechanical analyzer
Rheometrics RDA II, shear measurements on unvulcanized mixes (double plate geometry) and vulcanizates (strip samples) −150 °C + 350 °C, 0.002 Hz ... 16 Hz; 0.05 ... 5 % amplitude

ARES Rheometer system
Rheometrics Scientific, shear measurements on unvulcanized mixes (double plate geometry) and vulcanizates (strip samples) −150 °C +350 °C, 0.002 Hz ... 80 Hz; 0.05 10 % amplitude
Dynamic mechanical Spectrometer
Rheometrics RSA II, Compression and tension tests –150 °C … +500 °C, 0.002 Hz … 16 Hz, 0.01 % … 1 % amplitude

Servohydraulic Elastomer Testing System
MTS 831.50, Shear, compression and tension tests on specific dumbbells. –120 °C …+200 °C, 0.01 Hz … 1000 Hz, 0.1 … 100 % amplitude. Tests according to client specific requirements; dynamic and fatigue properties under rapid pulse load. Force range ±5 kN; displacement ±25 mm

Biaxial Servohydraulic Elastomer Testing System
MTS 322.21, linear biaxial tests on specific dumbbells. Dynamic mechanical properties and fatigue properties.
1. Axis: 0.1 … 100 Hz, ±25 kN, ±100 mm.
2. Axis: 0.1 … 150 Hz, ±10 kN, ±50 mm.
Dynamic and fatigue properties under pulsed oscillations, force and displacement controlled

3. Dielectric Properties

Dielectric Broadband Analyzer
Novocontrol GmbH, Measurements on vulcanizates, mixtures and liquids

BDS 40
Frequency range: $3 \times 10^{-5}$… $2 \cdot 10^{7}$ Hz
Impedance range: $10^{-4}$… $10^{14}$ Ω
Capacity range: $10^{-15}$… 1 F
Resolution (tan δ): $3 \times 10^{-5}$

BDS 60
Frequency range: $10^{6}$… $3 \times 10^{9}$ Hz
Impedance range: $10^{-1}$… $10^{5}$ Ω
Resolution (tan δ): $3 \times 10^{-3}$

Quatro Cryosystem Temperature Unit
Temperature range: –160 …+400 °C
Temperature resolution: 0,1 °C

4. Tribological properties

Tribometer
IMKT Construction;
Measurements of the static and dynamic friction coefficient; Velocity range: 0.005–10 mm/s and 0.1–30 mm/s; Pressure range: 0.01–10 MPa; Temperature range: –40 to +100 °C
Rheology und Rheometry

1. Rheology

• Viscous and elastic properties of rubber mixtures
• Mooney-Relaxation
• Mooney-Scorch
• Wall-slip behaviour

Mooney-Viscometer

• Measurement of mooney viscosity of rubber and rubber mixtures. Flexible data collection options.
Alpha Technologies MV 2000 E

Laboratory Extruder

• Measurement of the shear rate dependent viscosity by using different extrusion dies (e.g. flat slit, tube) with sensors for pressure and temperature
Polylab-System

Rotational-Rheometer

Physica MCR 501 S, Anton Paar
Maximum Torque 300 mNm, Normal forces –70 to 70 N. Various measurement geometries: plate-plate, cone-plate for measurements of the normal stress coefficient, rotational – and oscillating measurements. Possibility of combining rheological and dielectric or magnetic measurements.
Dielectric sample cell: Temperature range: –25° to 180° C. Dielectric Broadband Analyzer by Novocontrol
Frequency range: 3 · 10⁻⁵ to 10⁷ Hz
Magnetic sample cell: Temperature range: –10° to 180° C. Maximum magnetic field strength of 1 T

High Pressure Capillary Viscometer

• Measurement of shear and viscosity in dependency of shear rate, determination of flow anomalies (e.g. wall-slip); determination of swell profile, data collection of the pressure profiles; collection of the pressure profile along the capillary.
Göttfert Rheograph 6000
two methods of measurement: constant shear rate, constant shear, maximum shear: 2 × 10⁶ Pa, shear rate 2 × 10⁻² - 2 × 10⁶ s⁻¹, capillary diameter 0.5–4 mm, capillary length 5–120 mm; special capillaries with sensors for pressure and temperature (also as slit capillary), Rosand RH 7-2, two capillary system
• Simultaneous Measurements using long and short capillary systems to correct the inlet pressure lost
Capillaries with different length/diameter ratios for measuring the shear rate dependency of the viscosity
Dynamic data range 50,000 : 1 in a temperature range of 50–400 °C. The automatic rheometer with Servoelectric motor is equipped with a double capillary system.
Ubboelohde-Viscosimeter
- Determination of Staudinger index and mol mass; max. 5 dilution steps
- Determination of kinematic viscosity. Measurement range: 0.35 ... 5000 mm²/s
- Data acquisition, evaluation of data: PC, Software
Visco System® AVS 370 (SCHOTT Instruments)

Rubber Process Analyzer
Alpha Technologies RPA 2000
The RPA measures the viscoelastic properties of polymers and elastomeric compounds providing comprehensive data on key parameters such as
- Processability
- Cure characteristic
- Final cured properties
Temperature range: 40–250 °C, oscillation strain 0.5–150 %, oscillation frequency 0.1–33 Hz.

Rubber Process Analyzer
TA Instruments RPA elite
The RPA measures the viscoelastic properties of polymers and elastomeric compounds providing comprehensive data on key parameters.
Torque range 0.0001 ... 25 Nm; Shear amplitude ±0.005 ... ±360°;
Strain ±0.07 ... ±5000 %; Frequency range 0.001 ... 50 Hz;
Temperature range from ambient to 230 °C
The following variants can be selected as test methods:
Cure (isothermal, ramp, step); Strain (sweep, offset, LAOS); Frequency sweep;
Stress relaxation; Advanced (multi-frequency, arbitrary waveforms).

2. Rheometry
- Curing kinetics
- Activation energy
- Incubation behaviour
- Blowing behaviour

Rheometer
- Torque- and loss angle measurement
Alpha Technologies MDR 2000 E
rotorless, variable operating points
Simulation Software

1. FEA-Software

SIMULIA Abaqus 2017
Abaqus/CAE/Standard/Explicit

MSC.Marc 2017
Marc® Mentat® 2017.1.0

COMSOL Multiphysics

SIGMASOFT Virtual Molding
SIGMASOFT v5.2.1.0, SIGMA Basic Elastomer, SIGMA Stress, SIGMAlink, SIGMAstep
Reader/Writer

2. Mathematical Computation

MATLAB R2017a
Curve Fitting Toolbox, Global Optimization Toolbox, Optimization Toolbox, Parallel Computing Toolbox

MAPLE 17
Computer Algebra System for Symbolic and Numeric Calculations