



# List of Instrumentation





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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  $\text{cm}^{-1}$ )

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 N<sub>2</sub>(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 N<sub>2</sub>(liquid) cryo-cooling (-150 ... +450 °C)

## Pyrolysis

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, accelerators, peroxides)
- 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),  
Electrospray Ionisation (ESI), Ion Trap with MS-MS technique  
Thermo Fisher Scientific Ultimate 3000 system with diode array detector and mass selective  
detector LTQ Orbitrap Velos Pro, chemical ionisation at atmospheric pressure (APCI),  
electrospray ionisation (ESI), ion trap with MS<sup>n</sup> technique, high-resolution Fourier transform  
mass spectrometer



## 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 gase 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:  $8.2 \times 1,010$  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×

### Confocal 3D Laser Scanning Microscope

VK-X1100 from Keyence Deutschland GmbH; measuring method for precise and intuitive surface analysis; measurement of optical and topographic material properties; surface scanning by means of a violet semiconductor laser

Linkam Scientific Instruments LTD, T-96

Temperature control of specimens between –25 °C and 120 °C by means of a Peltier heating table

Optical system: confocal pinhole optics, focus variation according ISO 25178-6

Axial scan range: 7 mm

Axial resolution: 0,5 nm

Edge measurement: up to 87,1°

Max. sample height: 70 mm

Lateral scan range: 100 mm x 100 mm

Lateral resolution: 120 nm



## 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
- Element 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 (AFM)

Dimension Icon (Bruker) measuring method for precise surface analysis on nano scale

AFM modes: Tapping Mode, Phase-Imaging, EFM, MFM, Surface-Potential-AM, Lift Mode, Torsional Resonance Mode, Contact Mode, LFM, Force-Volume, Force Spectroscopy, Piezo-Response, Peak Force QNM

Axial scan range: 10 µm

Lateral scan range: 90 µm x 90 µm

Temperature control possible: -35 °C ... 250 °C





## 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

### Microindenter equipment: 031790 LNP nano touch mit Piezo Kreutztisch

(Ludwig nanoPräzision GmbH)

System for measuring of distances

Displacement-Measurement 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
- Particle Dispersion analysys, fillers and crosslinking chemicals (ZnO etc)
- Analysis of crack initiation and propagation
- Cell structure analysis, porosity analysis
- Testing of rubber-metal and rubber-plastic bonding
- Location of reinforcement and fiber orientation
- Non destructive defect analysis
- Dimensional measurements, coordinate measurement

### 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 VG Studio Max 3.3 for 3D representation and quantitative analysis (particle size distribution)



## 6. Scanning Electron Microscopy (SEM)

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

### Scanning electron microscope

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

### EDX

Oxford Instruments INCA (EDS8100)

## 7. Thermal Analysis

- Quantitative composition of elastomers (polymer, plasticizer, carbon black, inorganic fillers, residues)
- Determination of glass transition temperatures and melting points in thermoplastics, polymers and rubbers
- Morphology of blends
- Heat capacity
- Kinetics of crosslinking
- Phase transitions

### Thermogravimetry (TGA)

Netzsch TG 209 F1 Libra, sample mass: max. 2 g, temperature range: 20 ... 1,100 °C, heating rate: 0.,001 ... 200 K/min

Netzsch TG 209 F1 Iris, sample mass: max. 1 g, temperature range: 20...1,000 °C, heating rate: 0.001 ... 100 K/min

### Differential Scanning Calorimetry (DSC)

Netzsch DSC 204 F1 Phoenix (two instruments), temperature range: –180 ... +700 °C, heating rate: 0.001 ... 100/200 K/min

## 8. Emission and Permeation measurements

### VCI - Fire Simulation Equipment

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

### Fogging Test Equipment

#### Barkey permeation testing device

- Determination of Fogging-values acc. to DIN 75201-B
- Instrument: Heating and cooling device, test chamber acc. to DIN 75 201-B
- Sample numbers: 6
- Temperature range: 20 °C–150 °C

#### Test chamber for emission tests

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

### Gaspermeation measurements

- Determination of diffusion and permeation coefficients
- Gas transmission Tester GTT, Brugger München
- Gases: non-corrosive, not burning
- Temperatur range: 15 °C–45 °C



## 9. Thermographic Analysis

- 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 Iso-therm, Peak-Hold-Function. Spectral range 3.6 ... 5  $\mu\text{m}$ ; recording method 'Focal Plane Array'; PtSi-CMOS-Hybrid Detector, 50 Hz Image frequency; Temperature resolution (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  $\times$  14°; size of image: 256  $\times$  256 Pixel; signal digitization: 16 Bit; working temperature: -15 ... +50 °C; data output: PAL-FBAS, Y/C.

### Compact Thermographic Camera

Micro-Epsilon thermIMAGER TIM 640; dimensions (46  $\times$  56  $\times$  90 mm), 320 g; Measuring range: -20 °C-100 °C, 0 °C-250 °C, 150 °C-900 °C (switchable) Spectral range: 7,5-13  $\mu\text{m}$ , thermal resolution: 0,1 °C, emissivity: 0,1-1,0 adjustable Optical resolution: 640  $\times$  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°  $\times$  66°-objektive

## 10. Low Field Nuclear Magnetic Resonance Spectrometry (NMR)

- Characterization of polymer chain dynamic properties
- T1 and T2-relaxation time determination
- Different pulse programs
- DQ-Experiments
- Statistical distribution of chain segments mobility
- Correlation T2-value-crosslink density
- Aging of polymers (in situ aging)

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

**II. Instrument:** Bruker minispec mq 20, Bruker BioSpin GmbH, 47 T = 20 MHz, 20-100 °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 dm<sup>3</sup>, 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 cm<sup>3</sup> and 350 cm<sup>3</sup>

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, coolind up to 250 °C, access line at gear pump MAAG Enhex 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 cm<sup>3</sup> Micro-Compounder)

Twin-screw extruder with co-rotating conical screws, screw length 150 mm, useful volume 12,5 cm<sup>3</sup>, 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 Steini)

LWB Steini VS EFE 3000/2000 P with EFE-system for cure time reduction  
Closing force 3000 kN; Injection volume 2000 cm<sup>3</sup>; 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 cm<sup>3</sup>

Nominal volume 10 cm<sup>3</sup>, injection part  $T_{\max} = 350\text{ }^{\circ}\text{C}$ , form  $T_{\max} = 200\text{ }^{\circ}\text{C}$ , 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, thermoplastic or thermoset, possibility of 2K application: rubber/thermoplastic, respectively thermoset, rubber/rubber and thermoplastic/thermoplastic. Screw diameter 25 mm, aggregate in I-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 × 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 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> roll, roll crossing for 3<sup>rd</sup> 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 (1<sup>st</sup> and 2<sup>nd</sup> roll), gap pressure in the 1<sup>st</sup> and 2<sup>nd</sup> 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 × 250 mm, evaluable

#### Wickert & Söhne WLP63/3,5/3

Electrical heating: 350 × 350 mm

#### Berstorff

Electrical heating: 300 × 350 mm, evaluable

#### High-pressure autoclave

Zirbus Technology, Type: HDA-H 65-10-180

For thermal vulcanization processes of rubber based molded parts under pressure. Geometry of the chamber: diameter 400 mm x 500 mm length; volume of the chamber: 62 liter; max. overload pressure: 10 bar; max. temperature: 182 °C; max. operating pressure: 9.5 bar.

## 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 keV), Injection pump for up to 3 syringes, flexible spinning jets for 3 needles, Volumeflow (0.1–99,9 cm<sup>3</sup>/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 physical 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 O<sub>3</sub> 50–250 ppm (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

#### Refractometer

Refractometer "Refracto 30GS, Mettler Toledo GmbH

- Determination of fraction index number
- Method: Total reflection at  $\lambda = 589.3$  nm
- Measuring range: 1.32–1.65
- Temperature range: 10 °C–40 °C





### **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:  $-200\text{ }^{\circ}\text{C}$  (liquid  $\text{N}_2$ ) and  $-60\text{ }^{\circ}\text{C}$  bis  $+20\text{ }^{\circ}\text{C}$

pressure range:  $10^{-2}$ – $10^5$  Pa

Evaluation methods: BET-Adsorption, energy distribution, porosimetry

### **UV-Xenon weathering instrument**

Amatek Xenotest 440. xenon weathering instrument designed for fast testing. The Xenotest 440 utilizes a new twin-lamp operating technology which enables high irradiance levels of  $120\text{ W/m}^2$  of total UV radiation.  $2310\text{ cm}^2$  testing area, sensors for radiation intensity and temperature. The weathering (water spraying) is established by means of an ultrasonic device. An intensity of  $120\text{ W/m}^2$  is possible.

Standard tests (examples): ISO 105-B02, -B04, B06, -B10, 4892-2, 11341, 16474-2

GB/T 8427; ASTM G151, G155, D2565; AATCC TM 16.3; VDA 75202; VW PV 1303, PV 3929,

PV 3930 etc.

## **2. Dynamic Mechanical and Durability Properties**

- Dynamic properties of laboratory specimens and technical parts
- 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  $\pm 50\text{ mm}$ . Traverse for fivefold parallel inspections; each measuring station with separate load cell up to  $\pm 1\text{ kN}$  and compensation of permanent set by electromotive retensioning. Temperature controlled test chamber, air or  $\text{N}_2$ .

### **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, 1MHz, 2 MHz. Temperature range: coupling fluid dependent between  $-100\text{ }^{\circ}\text{C}$  and  $+100\text{ }^{\circ}\text{C}$ .



### **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, two similar machines, 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

### **Servo-hydraulic 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 Servo-hydraulic 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

### **Torsional Testing System**

Inova servo-hydraulic torsional system, testing on laboratory specimen and technical parts;  
Dynamic and Fatigue properties in torque or angular control;  
Torque up to 600 Nm, sensitivity 2 Nm; torsion angle maximum ± 50°;  
Signal: sinus at frequency up to 175 Hz/triangle/ramp/service load tracking test; temperature chamber 40–180 °C

## **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:  $10^{-2}$ ...  $10^{14}$  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

### IMKT Linear Tribometer

Measurement of static and kinetic friction properties

Velocities: 0,005 ... 15 mm/s and 0,1 ... 300 mm/s

Load range: 20 ... 500 N

Temperature range: -40 ... +100 °C

### Coesfeld Linear Tribometer

Measurement of static and kinetic friction properties; long runs possible

Velocities: 0,01 ... 2000 mm/s

Load range: 50 ... 500 N

Temperature range: -20 ... +100 °C

### Coesfeld Friction- und Wear Tester

Measurement of friction properties in dependence of longitudinal and side slip; measurement of  $\mu$ -slip curves; measurement of wear for braking, accelerating and cornering

Speed: up to 4 m/s

Load: up to 250 N

Temperature: room temperature

## 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:  $3 \cdot 10^{-5}$  to  $10^7$  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:  $2 \times 10^6$  Pa, shear rate  $2 \times 10^{-2} - 2 \times 10^6$  s<sup>-1</sup>, 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.

### Ubbelohde-Viscosimeter

- Determination of Staudinger index and mol mass; max. 5 dilution steps
- Determination of kinematic viscosity. Measurement range: 0.35 ... 5000 mm<sup>2</sup>/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  $\pm 0.005$  ...  $\pm 360^\circ$ ;

Strain  $\pm 0.07$  ...  $\pm 5000$  %; 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**

COMSOL Multiphysics 5.3, Acoustics Module, Nonlinear Structural Materials Module, Structural Mechanics Module, CFD Module, Chemical Reaction Engineering Module, Heat Transfer Module

#### **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

### 3. Sustainability

#### **I. Carbon-Footprinting-Software Ecoinvent 3.5**

#### **II. Carbon Footprint GaBi ts version 10.0.0.71**

Life cycle inventory database, life cycle assessments, environmental impact assessments, carbon footprint calculation

