

MATERIAL SCIENCE & ENGINEERING

Characterization and processing equipment

POWDER CHARACTERIZATION

- X-ray Powder diffractometer **X'pert Pro** (PANalytical B.V., Almelo, The Netherlands)
- Particle size / Surface area:
 - Laser diffractometer **Malvern Mastersizer 2000**, 0.2 – 2000 μm (Malvern Instruments. Ltd, Malvern, UK)
 - Average particle size by air permeability method. **MDL 95 Sub-Sieve Sizer** (Thermo Fisher Scientific Inc., Waltham, USA)
 - Sieving **Sieve Shaker Retsch AS 200** (Retsch GmbH, Haan, Germany)
- Density and flowability:
 - Apparent density and flowability **Hall Flowmeter, Carney Funnel, Scott Volumeter** (CGT - Cold Gas Technology GmbH, Ampfing, Germany)
 - Tap density **Stampfvolumeter STAV 2003** (JEL Engelsmann AG, Ludwigshafen, Germany)
 - Gas pycnometer **Micromeritics AccuPyc II 1340** (Micromeritics GmbH, Mönchengladbach, Germany)
 - **Multivolume Pycnometer 1305**, (Micromeritics Instrument Corporation, Norcross, USA)
 - Granular material flowmeter **GranuFlow** (Granutools sprl, Awans, Belgium)
 - Granular material flow analyzer **GranuDrum** (Granutools sprl, Awans, Belgium)

POWDER PREPARATION / HANDLING

- Glove box **P[box]** with purification for product protection. Work under positive pressure with controlled atmosphere (Jacomex SAS, Dagneux, France)
- Mini Spray Dryer **Büchi B-191**, water solvent (Büchi Labortechnik AG, Flawil, Switzerland)
- Blending / milling
 - Shaker - mixer **Turbula T2C** (Willy A. Bachofen AG, Muttenz, Switzerland)
 - **Polytron PT 2100** homogenizer (Kinematica AG, Luzern, Switzerland)
 - Drum mills (balls/rods, wet/dry grinding media)
 - Mill, granulator, mixer **Erweka Model AR-400** (Erweka Apparatebau AG, Hersenstamm, Germany)
 - Grinder **IKA A10 Yellow line** (IKA-Werke GmbH & Co. KG, Staufen, Germany)
- Mechanical alloying
 - Vario-planetary mill **Pulverisette 4** (Fritsch GmbH, Idar-Oberstein, Germany)
 - **Batch Attritor** grinding mill (Union Process Inc., Akron, OH, USA)
- Feedstock processing
 - Mixer **Rheomix 600** driven by **HAAKE PolyLab OS-System Rheodrive7**, Tmax 400°C, Torque range 160Nm (Thermo Scientific, Karlsruhe, Germany)
 - Double sigma kneader, **Coperion LUK 1.0**, T<190°C (Coperion GmbH, Stuttgart, Germany)
 - Mill **IKA MF 10.1** cutting-grinding head (IKA-Werke GmbH & Co. KG, Staufen, Germany)

THERMAL ANALYSIS

- Thermogravimetry: TG-DTA **Setaram TAG 24**, RT - 2200°C (Setaram Instrumentation, Caluire, France)
- Dilatometry: Pyro - Vacuum-tight, horizontal pushrod dilatometer **DIL 402E**, RT - 1300°C (Netzsch Gerätebau GmbH, Selb, Germany)
- Differential thermal analysis: **Netzsch DTA 404P**, RT – 600°C (Netzsch Gerätebau GmbH, Selb, Germany)
- Differential scanning calorimetry:
 - **Perkin Elmer DSC-7**, RT - 600 °C (Perkin Elmer, Waltham, USA)
 - **Mettler Toledo DSC 823e**, -100°C to 600°C (Mettler Toledo GmbH, Giessen, Germany)
- Thermo-mechanical analyzer **Perkin Elmer TMA-7**, RT to 600 °C (Perkin Elmer Inc., Waltham, USA)

MATERIALS CHARACTERIZATION

- Mechanical tests
 - Tensile, compression and three point bending tests
 - Universal tensile testing machine **Zwick 1475**, max load 100 kN, climatic chamber -20°C to 1300°C (Zwick GmbH, Ulm, Germany)
 - Universal tensile testing machine **Zwick 1455**, max. load 20 kN (Zwick GmbH, Ulm, Germany)
 - Charpy Pendulum impact tester **Wolpert PW15** (Otto Wolpert-Werke GmbH, Ludwigshafen a. Rh, Germany)
- Surface analysis
 - Surface roughness meter **Diavite DH-7** (Diavite AG, Bachenbülach, Switzerland)
 - **Pin-on-disk** wear test (CSEM, Neuchâtel, Switzerland)
 - **Calotest** (CSEM, Neuchâtel, Switzerland)
 - Coating thickness measurement **Isoscope MP3** and **Deltascope MP3** (Helmuth Fischer GmbH, Sindelfingen, Germany)
- Hardness test
 - **Wilson-Wolpert Testor** (Instron, Norwood, USA)
 - **Hauser 292DR** hardness tester
 - Microhardness tester **Shimadzu** (Shimadzu Corp., Kyoto, Japan)
 - **Leitz** Micro Hardness Tester (Leica Microsystems AG, Glattbrugg, Switzerland)
- Viscosity measurement
 - **DV-II+ PRO Digital Viscometer** (Brookfield Engineering Laboratories Inc., Middleboro, USA)
- Element analysis
 - Oxygen, Nitrogen and Hydrogen elements analyzer **Leco ONH 836** (Leco Instrumente GmbH, Mönchengladbach, Germany)
 - Carbon and Sulfur elements analyzer **Leco CS744** (Leco Instrumente GmbH, Mönchengladbach, Germany)

METALLOGRAPHIC PREPARATION

- Cutting
 - **Discotom-2** (Struers ApS, Ballerup, Denmark)
 - **Accutom-50** (Struers ApS, Ballerup, Denmark)
 - **Isomet** low speed saw (Buehler, Lake Bluff, USA)

- Mounting Pronto-Press-20 (Struers Aps, Ballerup, Denmark)
- Polishing
 - 3X **Rotopol-15** (Struers ApS, Ballerup, Denmark)
 - **Tegrapol-15** (Struers ApS, Ballerup, Denmark)
 - **Knuth rotor-2** (Struers ApS, Ballerup, Denmark)

MICROSCOPY

- Scanning electron microscopy
 - **LEO 1525 with Gemini column** (Carl Zeiss Inc., Thornwood, USA)
 - EDX, WDX, BSD analysis
 - Ultra high resolution and image quality - 1.5 nm at 20kV, 3.5nm at 1kV
 - High probe current and stability better than 0.5% per hour, for fast accurate, analysis and mapping
 - In-lens detector for clear, bright surface-specific imaging
 - Short working distance of 8.5 mm for simultaneous high resolution, EDS, WDS, BSD analysis
 - Sputter coater **BAL-TEC SCD050** (Bal-Tec AG, Balzers, Liechtenstein)
- Optical microscopy
 - 2 x Olympus **Provis AX-70** (Olympus Corp., Tokio, Japan)
 - Olympus **BH2** (Olympus Corp. Tokio, Japan)
 - Olympus **PMG-3** inverted microscope (Olympus Corp., Tokio, Japan)
 - Olympus **SZH ILLC-2** Stereo Microscope (Olympus Corp., Tokio, Japan)

PROCESSING

- Injection moulding
 - Injection moulding machine **Arburg Allrounder 221K 350-100** (Arburg GmbH, Lossburg, Germany)
 - **BOY XS** Injection Moulding Machine (Dr. BOY GmbH & Co. Kg, Neustadt-Fenthal, Germany)
 - Electric press **Osterwalder CA-SP 160**, 160 kN (Osterwalder AG, Lyss, Switzerland)
 - Benchtop press **Carver 3891**, Tmax 340°C, 222.5 kN (Carver Inc., Wabash, USA)
- Hot Pressing
 - Hot compaction press **Sintris 10 STV**, Tmax 1300°C, Ar, N (Sintris Macchine, Piacenza, Italy)
 - Hot Isostatic Press **Abra Sinter SHIRP 8/16-200**, Tmax 2000°C and 2000 bar (Abra Fluid AG, Widnau, Switzerland)
- 3D Printing
 - Selective Laser Melting 3D Printer **SLM 125HL**, 400W IPG fiber laser (SLM Solutions GmbH, Lübeck, Germany)
 - 3D Printer **Prometal R1** (ProMetal GmbH, Augsburg, Germany)
 - 3D Printer **uPrint SE Plus** (Stratasys Ltd, Minnesota, USA)
 - 3D Printer SG-3DP (HES-SO Valais-Wallis, Sion, Switzerland)
- Tape casting
 - **Custom made device** (HES-SO Valais-Wallis, Sion, Switzerland)
- Thermal debinding / sintering
 - MIM muffle furnace **Nabertherm VHT 08/16-MO**, Tmax 1600°C (Nabertherm GmbH, Lilienthal, Germany)
 - Graphite furnace **ECM Lilliput** Tmax 1600°C (ECM Infracours Physitherm, Seyssinet Pariset, France)
 - CIM furnace **Nabertherm HT 16/17**, Tmax 1750°C (Nabertherm GmbH, Lilienthal, Germany)

- High temperature tube furnace **Gero HTR 40-250/18**, Tmax 1800°C. MoSi₂ heating elements (GERO Hochtemperaturöfen GmbH & Co., Neuhausen, Germany)
- Compact tube furnace **Nabertherm R40/250/13**, Tmax 1300°C (Nabertherm GmbH, Lilienthal, Germany)
- 2 x horizontal tube furnace **Thermolyne 21100**, Tmax 1200°C (Thermo Fisher Sci. Inc., Waltham, USA)
- Horizontal tube furnace **Heraeus ROK/A 6/30**, Tmax 1100°C (Thermo Fisher Sci. Inc., Waltham, USA)
- Pyromètre **PCE-IR 50**, plage de mesure 0...+500°C, +-1°C de précision (PCE Instruments France EURL, Soultz-sous-Forêts, France)

- Heat treatment
 - Tempering furnace **Solo 221-28/32/30**. Tmax 650°C (Solo Swiss - Patherm SA, Switzerland)
 - Furnace **Solo 111 – 23/13/40**. Tmax 1150°C (Solo Swiss - Patherm SA, Switzerland)
 - Furnace for Jominy tests **Solo 570-28/32/30** (Solo Swiss - Patherm SA, Switzerland)
 - Hardening furnace **Solo 646-3/1**. Tmax 950°C (Solo Swiss - Patherm SA, Switzerland)
 - Dryer oven **WT Binder F115** (WT Binder, Tüttlingen, Germany)
 - Vacuum oven **Fisher Bioblock 45001** (Fisher Bioblock Scientific, Illkirch, France)
- Melting furnace **Nabertherm K1/10**, Tmax 1000°C (Nabertherm GmbH, Lilienthal, Germany)
- Sputter coater **BAL-TEC SCD050** (Bal-Tec AG, Balzers, Liechtenstein)

METROLOGY

- Coordinated Measurement Machine **Tesa 3D Xcel 430** (Hexagon Metrology SA, London, UK)
- High resolution digital camera measurement instrument **Starlite 250** (Quality Vision International RAM, Rochester, USA)