Summary of STREAM program

Rationale of the program

Flanders region as top sector Additive Manufacturing business world-wide

Additive manufacturing (AM) joins materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. AM traces back to about 1990 with the advent of stereolithography, since then a plethora of AM processes appeared. **AM is a fast growing sector** within production industry, see Figure 1 and Figure 2.

The compound annual growth rate (CAGR) of revenues produced by all products and services in the AM sector was 26,2% on average during its 23 year history. Technical improvements of AM have shifted the application of these processes from prototyping to the production of end-use parts either as customised or small series (see figure 2). Flemish industry (e.g. Materialise, Materialise Dental, LayerWise or Melotte) is worldwide leading in AM processes and applications, supported by world-class R&D at universities and research centers. Flemish industry accounts approximately for 8% of the worldwide AM turnover (Flanders accounts only for 2% of industrial turnover in general economics).

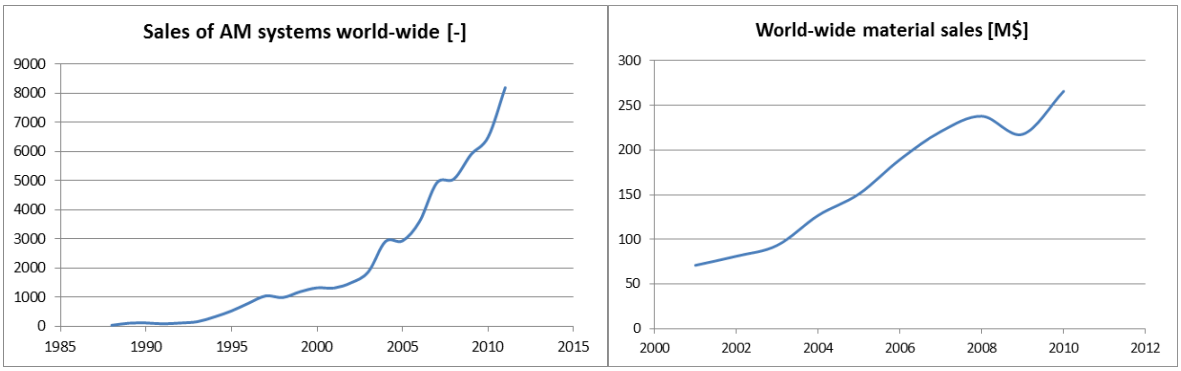

Figure 1: trend in sales of AM systems world-wide and material sales

Flemish companies indicate that a major evolution towards a stable growth market is expected and needed within five to ten years. European and international roadmaps also predict this evolution and growth potential and confirm that AM is still an emerging technology requiring strategic research:

- EU FP7 project DirectSpare (Generic roadmap for spare parts markets, Feb. 2012) estimated that state-of-the-art AM technologies are only meeting all (technical) requirements of approximately 5% of the parts in the aerospace and automotive markets, approximately 7% in the energy industry, and 15-25% in the domestic appliances industry.
- Direct Digital Manufacturing of Metallic Components (Vision and Roadmap 2010, US DoD): DDM has the potential to enhance operational readiness (reduction of throughput by 30%, lead time from design to qualified part by 60%), reduce total - ownership - cost (30%, cost reduction of complex parts fabrication by 50%), reduce energy consumption (total energy content by 60%, weight reduction by 25%, reduce logistic footprint by 20%), and enable parts - on - demand manufacturing (reduce time for out of order repair parts by 90%). DDM favors high value and difficult to machine and process alloys for demanding applications. However this requires still major R&D in different areas, such as: alloys designed for DDM fabrication and with enhanced properties, enhanced in situ and post fabrication techniques, control of surface roughness, predictive process models for microstructure and properties.
- AM Technology Roadmap for Australia (March 2011, CSIRO/Wohlers): Additive manufacturing technology has vast opportunities and the future for additive manufacturing is bright. Additive manufacturing (AM) technology is having an impact on product development and manufacturing

around the world. The overall economic impact of the technology is believed to be in the billions of dollars worldwide. However many problems must be solved before additive manufacturing becomes a mainstream process for part production in Australia or anywhere, e.g.: higher throughput, lower cost of AM materials, new material ranges and composite materials for structural applications, technical standards, methods that minimize or eliminate the need for anchors in metal parts, hybrid approaches, etc.

All roadmaps agree that capturing the full benefit of AM and overcoming current barriers, which prevent AM from breaking through on a larger scale, **requires a more in-depth understanding**. These barriers are identified in the areas of material, process, machine, design & ICT.

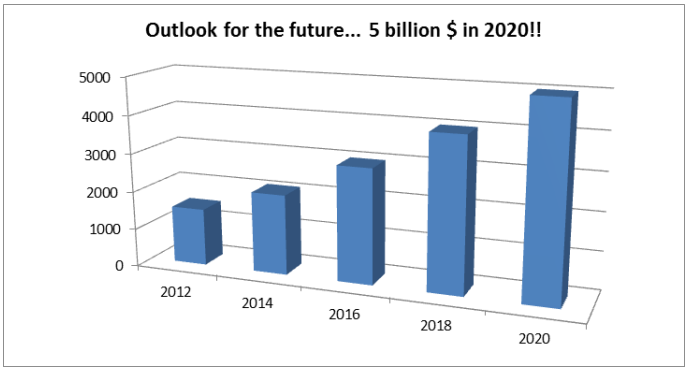

Figure 2: extrapolated growth in AM business until 2020

Industrial roadmap of the STREAM program

The industrial roadmap shown in Figure 3 provides an overview on the current industrial take-up in Flemish industry and the fields in which it could be leading in a time frame from 5-10 years based on the STREAM program results. The following paragraphs underpin the industrial roadmap for Flanders and describe the state-of-the-art and the vision within a time frame of 5-10 years.

Current industrial take-up in Flanders (blue frames in the roadmap figure)**:**

- Flanders has **world-class AM companies** (service offices and manufacturers) in polymers (Materialise) and metals (Layerwise and Melotte). They co-shaped AM process and post-process technology and supporting AM ICT & Design tools (e.g. Magics and Mimics software packages from Materialise) in strong collaboration with Flemish research groups. To illustrate the level of innovation, both Materialise (SLA) and LayerWise (SLM) developed their own specific machines to gain market lead. They play an active role in EU funded research projects. Besides these top players, several **small service offices** provide standard polymer additive manufacturing mainly for dental applications and 3D presentation models (e.g. architectural prototypes).
- Flemish companies use standard materials and/or develop their own material combinations for polymers and metals. Although Flemish **material developers** have been active in the field, they do not yet provide for a commercial offer (e.g. Agfa-Gevaert holds several patents in the domain of AM, suppliers tested the applicability of some of their high-end materials for AM).
- **Leading edge applications** have been developed, triggered by end-users for medical implants, surgery tools, hearing aids and functional metal components, etc. as illustrated by the examples below.

STREAM industrial roadmap for Flanders (green frames in the roadmap figure)**:**

The industrial roadmap for Flanders (5-10 years horizon) supports the long term needs of current players along the AM value chain (AM companies and leading end-users) and intends to extend the Flemish chain with additional players (material developers and suppliers towards AM-industry).

- The current Flanders' **world-class AM companies** play an important role and have already a clear vision on their future needs. In accordance with international roadmaps, STREAM must support them to extend their range of polymer and metal materials (and their composites) and to conquer

new leading-edge application domains in functional, load-bearing applications. First industrial applications are within this target group.

> For Materialise a rule of thumb is: *"For every 10°C increase in temperature resistance we can gain, 5 to 10% of extra applications and business become in reach. For SLA we are at this moment at 45-50°C, for SLS at 90°C and for FDM we reach 150°C."*

- Internationally, demand is coming from several industrial sectors. In Flanders **leading end users** are within **aerospace, machine building, mechatronics, automotive and medical industry**. Besides the current AM companies, leading manufacturers in the domain of aerospace, mechatronics and medical are looking at AM as mainstream manufacturing technology for their complex functional components and/or products based on shapes that would be "impossible to produce" with traditional manufacturing. There is an increasing demand for AM of ceramics for medical (biocompatibility), electronic and optic applications (high temperature and non-conductive), but the companies involved cannot find commercial solutions yet. The table below provides an overview on the functional demands requested.

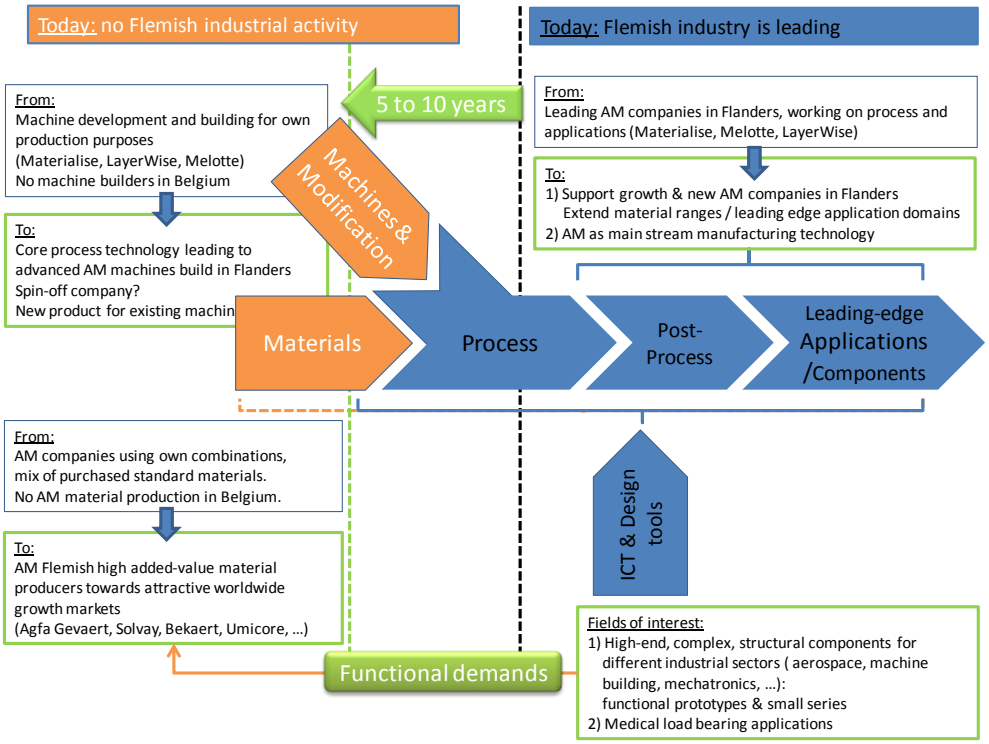

Figure 3: industrial roadmap of STREAM

Scientific program and research projects

Barriers for implementation of the roadmap

To achieve these main goals within Flanders, current state-of-the-art at industrial as well as R&D side in Flanders faces however some barriers, which are shown in Figure 4.

Barriers for material production in Flanders.

- There is a need to reduce the lead time of material development for AM. Screening methodologies are needed for advanced manufacturable materials to answer the question why some materials are processable by AM and some are not.
- Currently there is no knowhow about design and production of dedicated AM materials in order to achieve superior material properties.

Barriers for launching AM as a mainstream manufacturing technology for part production in Flanders.

- Available material palette is limited. Currently, roughly 8 different polymers are available, about 10 metallic materials and no ceramic materials having good final material properties (for usage in structural applications). Criteria to illustrate the aim and ambition level of STREAM are:
- Material properties of AM produced materials do not comply with industrial standards for many properties: e.g. fatigue behavior of Ti6Al4V not sufficient for usage in aerospace, too high surface roughness, density of polymers too low...
- Material properties of AM produced parts are not consistent and vary between different machines, in between different build jobs on the same machine, between different operators,...
- Cost of production process is too high, which is mainly caused by the low production speed.
- Product properties of AM parts are not sufficient.
- Recyclability: Although AM is regarded as a sustainable and energy- and material-efficient production process, the recyclability of used powder material in AM is low.

Barriers for production of advanced machine tools in AM.

- The most important material related barrier for this goal is that there is no fundamental understanding of the effect of typical AM processing parameters on the final material properties (e.g. development of new powder bed illumination strategies requires an in-depth understanding of the effect of process-material interaction).

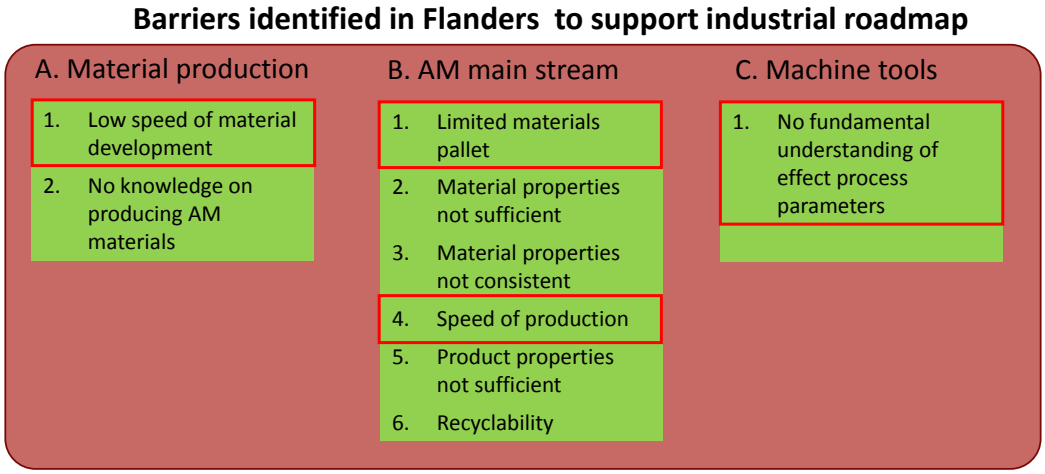

Figure 4: barriers for implementation of the roadmap of STREAM in Flanders. The most important barriers which will be tackled at the start of the program are highlighted in red.

Scientific program

The vision behind the scientific program within STREAM is to build up more fundamental understanding of the material-process interaction within SBO-projects. ICON projects will bring the knowledge to the market by industrial research, by solving the roadmap barriers identified above.

STREAM will start up with one SBO-project 'POLYFORCE', and two ICON projects 'PRODENSIA' and 'EXPAMET'.

STREAM Program Roadmap

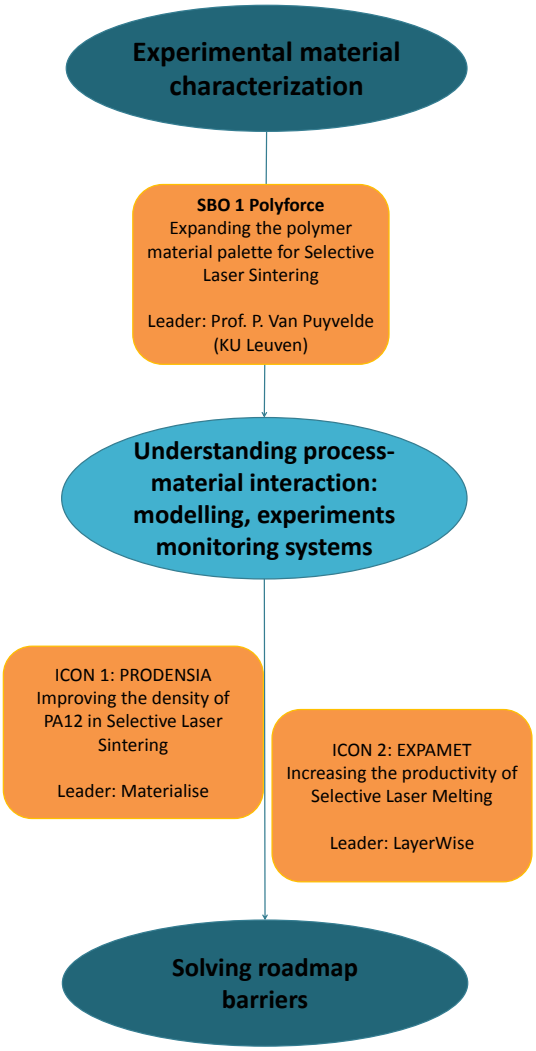

Figure 5: scientific roadmap in STREAM and projects at the start-up in 2013.

Partners

The STREAM consortium covers the whole process chain in Additive Manufacturing both from industrial as well as academic side.

Figure 6: partners within STREAM