Advanced materials – proposed clusters, and possible relevance criteria with focus on chemical safety issues

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Background, Motivation and Objective

The field of materials sciences is broad and highly dynamic. New and improved materials have been developed to overcome property limits with regard to static performance as well as functional tasks. Due to the high innovative potential and importance for technological progress, advanced materials can have a significant contribution to solutions for environmental and societal challenges. In the realm of materials sciences "advanced materials" has become a frequently used term for new or improved materials which cover also the field of nanomaterials. Since the term advanced materials is not clearly defined, our project conducted a survey on advanced materials to be able to identify potential implications for chemical safety.

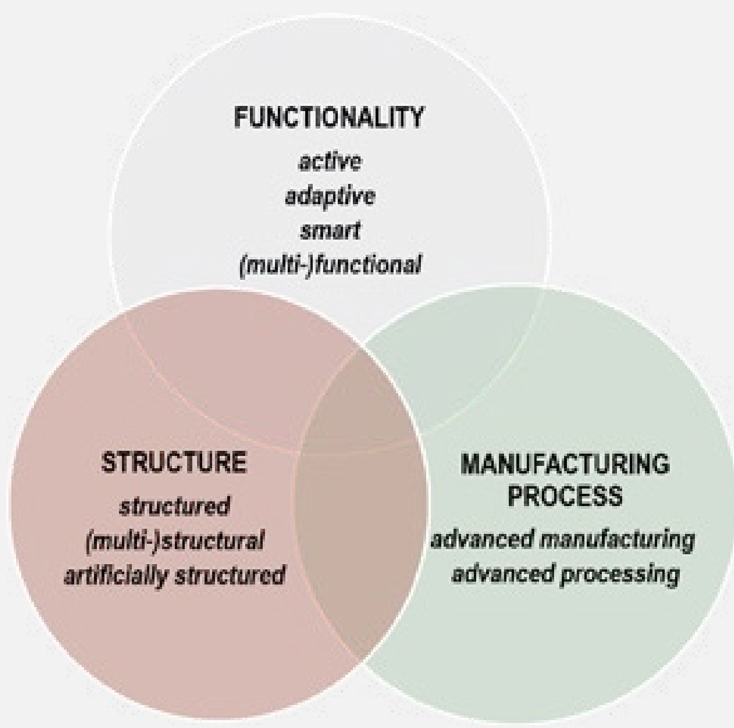

Figure 1: Three dimensions related to advanced materials identified during the assessment of existing clustering approaches by a quantitative literature review considering substance independent keywords.

Methods

Four methodological approaches were used to characterise and screen the field of advanced materials for relevant material types:

a) a literature research divided in a statistical analysis of 21,100 scientific publications (Web of Science Core Collection, July 2019), a network analysis of the scientific field (13,471 publications), and a qualitative analysis of 62 review articles,
b) expert interviews,
c) a two-day international conference to obtain opinions on the field of advanced materials and the relevance of different material types in the research field as well as
d) an online survey to obtain expert feedback on the identified advanced material types.

Results/Discussion

Relevant clusters of advanced materials were identified and described according to their chemical composition and structure, their behaviour and potential hazardous effects on human health and the environment. Additionally, exemplary current and potential future applications were listed. The resulting factsheets give an overview of the field based on current knowledge.

A set of criteria that could be applied to screen for the relevance of advanced materials regarding chemical safety was developed and is provided for further discussion and refinement.

Proposal to structure the field of advanced materials into 8 clusters with sub-clusters

Cluster of advanced materials	Sub-cluster, e.g.
Advanced Alloys	intermetallic, shape memory, high entropy
Advanced Polymers	electro-active, self-repairing, co-polymers
Biopolymers	DNA-based, RNA-based, protein-based, sugar-based, lipid-based
Porous Materials	microporous, mesoporous, macroporous
Particulate Systems	quantum dots, supra-particles, nanoflowers, graphene
Advanced Fibres	organic, carbon-based (incl. CNTs), inorganic (e.g. silica)
Composites	macroscopic, fibre-reinforced, particle-reinforced, hybrid materials (combination of organic and inorganic materials)
Metamaterials	electromagnetic, acoustic

Figure 2: Overview of identified clusters. For each cluster sub-cluster were deduced which were further de-scripted in so-called fact sheets.

Advanced materials are:

- Mainly combinations of either materials and/or structures with particular focus on the micro- and nanoscale
- Above all, extended functionalities based on the structure and composition of the materials are aimed
- Besides new material groups that often represent combinations of „classical" materials (+ bio-based materials), these classical materials undergo new applications and production processes

Limitations of a clustering approach for advanced materials:

- Lack of accessible information
- High number of possible characterising properties vs need to define a manageable number of features
- Need to established (working) definitions and nomenclature for clusters and sub-clusters of advanced materials

Proposal of criteria to assess the relevance of specific advanced materials

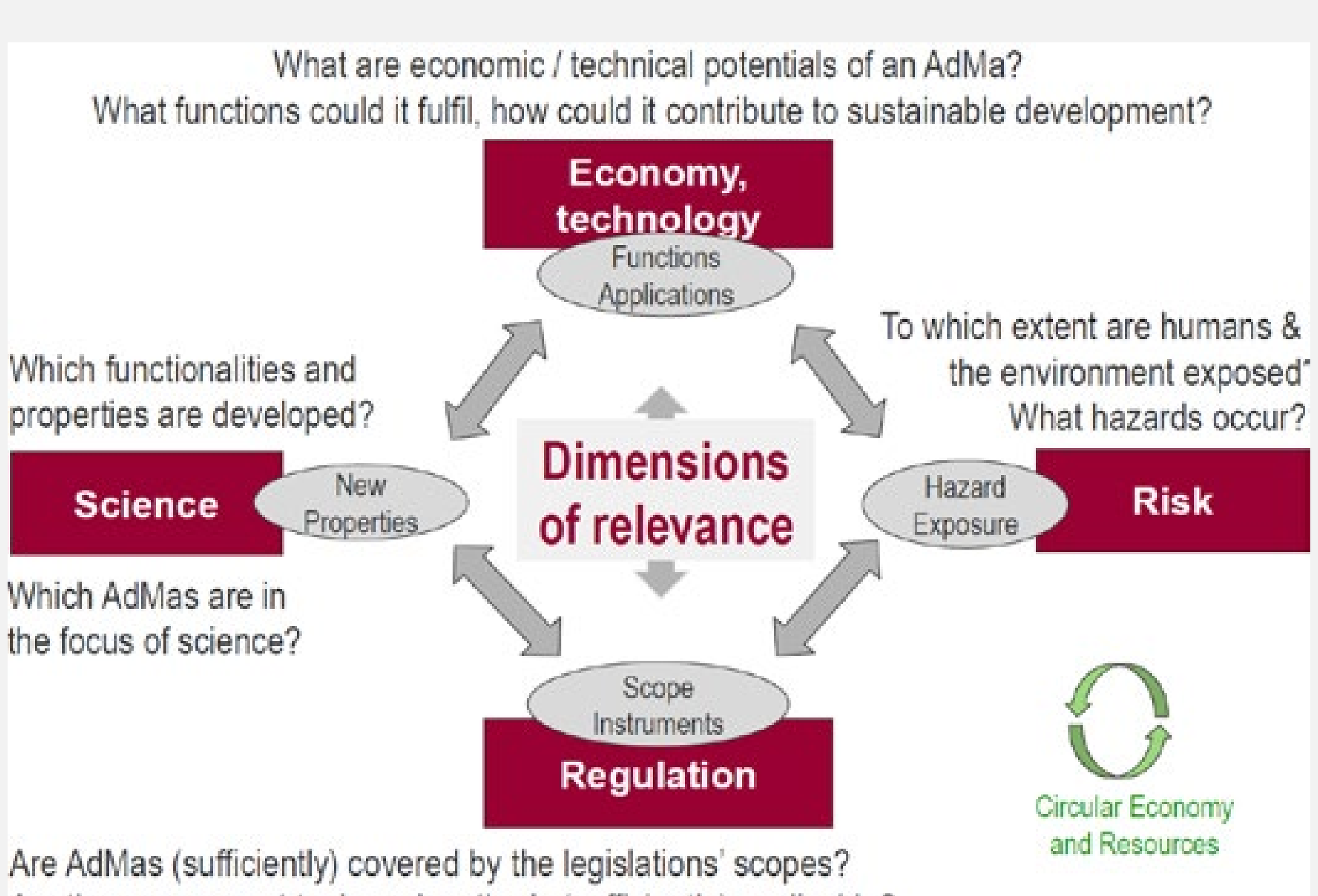

Figure 3: Relevance includes various dimensions related to the perspective of e.g. science, economy & technology, chemical safety and regulation.

From the perspective of chemical safety the following aspects need to be considered:

- Identification of hazards, exposure and risk
- Lack of data on hazard and risk
- Lack of/unclear legal coverage (in (intended) applications)
- Assessment approaches and tools not (fully) applicable
- Challenges for circular economy, resource consumption

The aim of relevance screening regarding chemical safety is to identify advanced materials that may be of concern and prioritise them for further action.

Criterion of relevance	Types of indicators
Dimension hazard, exposure and risk	
(Indication of) adverse effects	Data on toxicity and ecotoxicity
	"Critical properties" (of building blocks) e.g. high reactivity
Critical morphology and/or structure(s)	e.g. (Structures that could break into) WHO fibres, granular, biopersistent dusts (GBD)
Content of critical building blocks	e.g. biological structures or biologically active structures.
Persistence during use and in the environment	e.g. stability during use; persistence, (bio) degradation; composition
	Conditions of and functionality for intended use
Emission potential	Type of use and use conditions via "classical" emission parameters
Dimension: Circular economy and resources	
Separability from the waste stream	Possibility to separate products (and/or their components) that contain advanced materials from the waste streams
Recyclability	Ability to recover the advanced material with an intact (meta) structure
	Contamination of material cycles; (Eco-)toxicity and/or content of (eco-)toxic building blocks
	Disturbance of the recycling process and / or decrease in the quality of recyclates

Figure 4: Possible criteria and corresponding indictors to screen advanced materials from perspective of "hazard, exposure and risk" and "circular economy and resources" for potential further action need.

Detailed information of clusters and sub-clusters of advanced materials as well as relevance criteria are available at:

https://www.umweltbundesamt.de/publikationen/advanced-materials-overview-of-the-field-screening

https://oekopol.de/archiv/material/756_AdMa_Factsheets_final.pdf

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