

BASF Research Press Conference
on May 27, 2014

Encapsulation enables controlled release of active substances



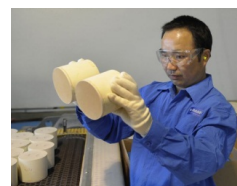
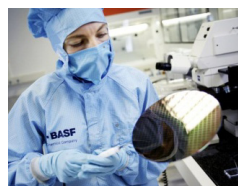
Dr. Mónica Fernández González
Head of Formulation Research, BASF SE, Ludwigshafen

Formulation

Continuously improving performance



- Formulation: mixture of chemicals or materials to improve performance and/or handling properties
- Advancement in many disciplines contribute to progress in formulation science



Engineering Physics Informatics
Chemistry Mathematics ...



**Thousands
of years ago**

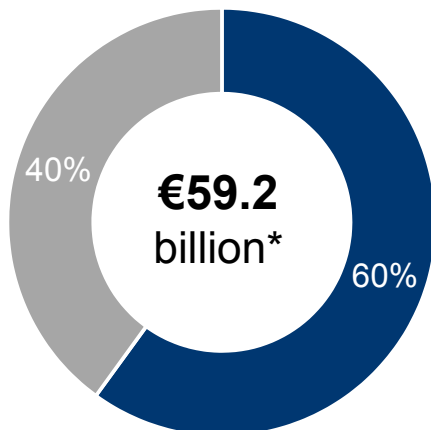
Today

Relevance of formulation for BASF

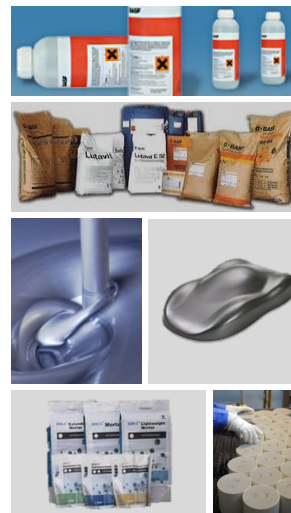
60% of 2013 sales with formulation relevant products



Chemicals of no direct formulation relevance



Formulated products/
Raw materials for formulations



* BASF Group sales excluding Oil & Gas

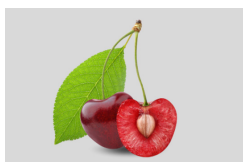
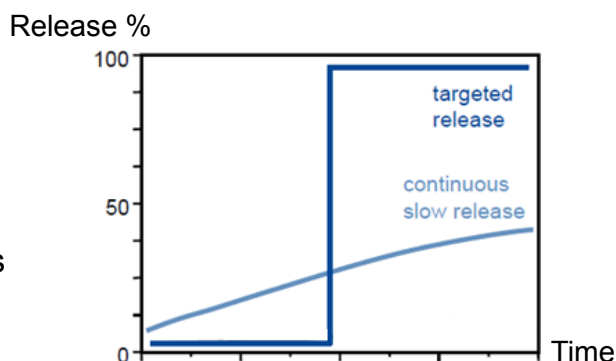
3

Pharmaceuticals, agrochemicals, nutrition and cosmetic ingredients

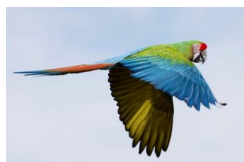
The challenge of stability and targeted delivery to increase efficacy



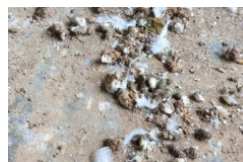
- Chemical actives are formulated to improve applicability and efficacy
- Controlled release is key
- Nature protects “actives” during “transportation” and “application” to be released only under certain stimulus



↑
“Formulation”



“Transport”



“Application”



“Release”

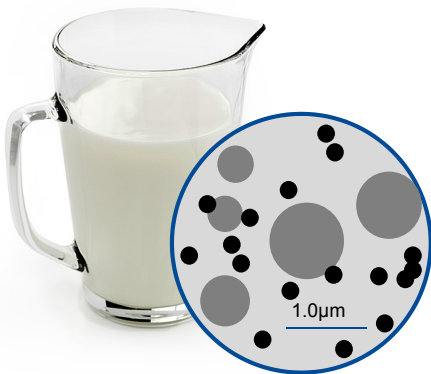
4

Emulsions

From milk to delivery of active ingredients

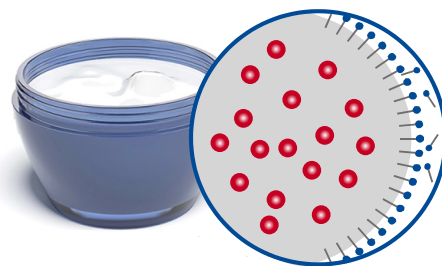
Emulsion:

- Fluid system in which liquid droplets are dispersed in a liquid
- Interfaces stabilized by emulsifiers



Emulsions for delivery of active ingredients:

- Water in oil (W/O) or oil in water (O/W) for cosmetic ingredients (e.g. creams, milks, etc.)
- Emulsifiable concentrates for crop protection, etc.

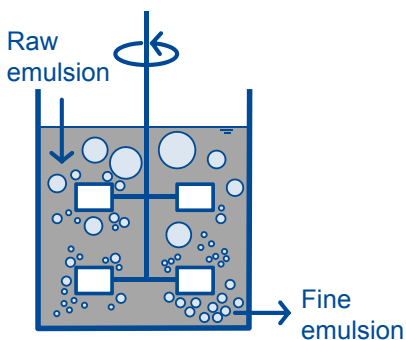


Emulsion technologies

From shear stress to dripping

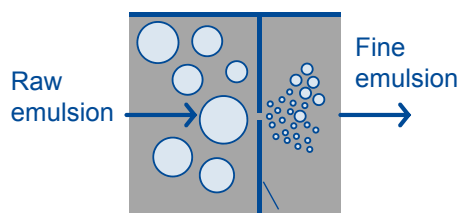
Dispersing small drops in a continuous phase

Rotor-stator principle

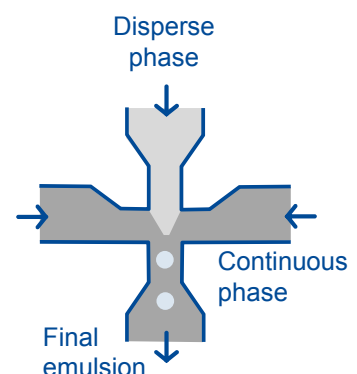


Droplet formation by shear forces

High-pressure homogenization



Microfluidic emulsification

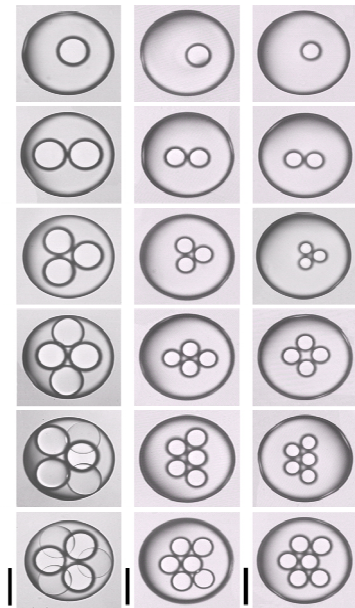
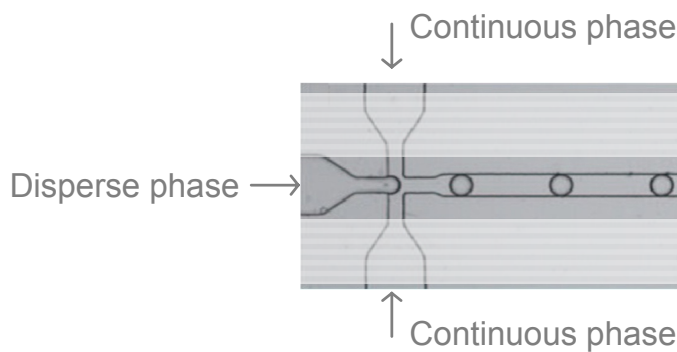


Droplet formation by flow control and surface tension

Control the drops

In microfluidic channels

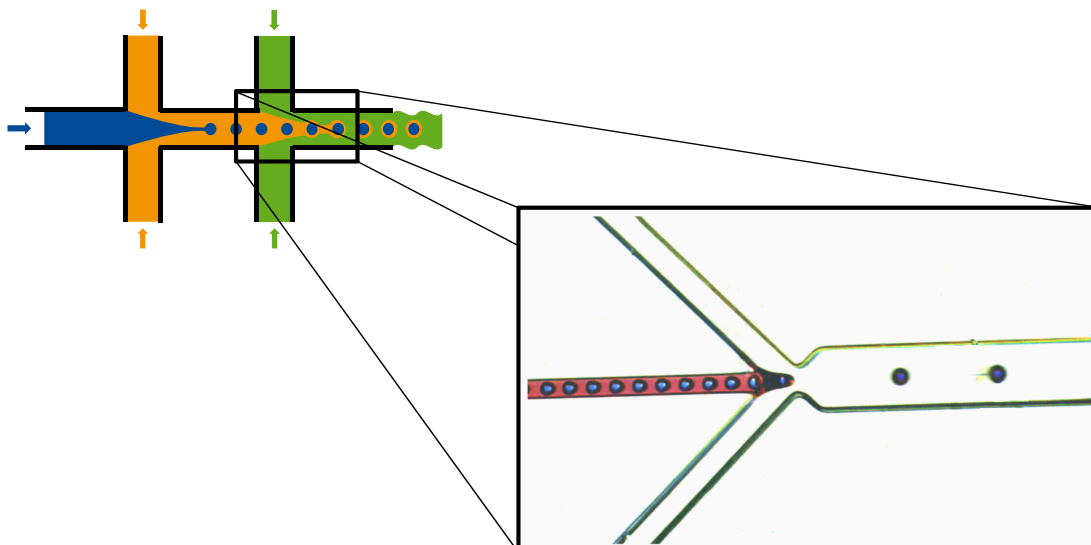
- 100% encapsulation efficiency
- Exact droplet size control: monodispersity
- Double emulsions and higher
- Low shear one step process
- Continuous process. Scale-up by parallelization



Weitz, Harvard

Double emulsion

Diameter: $\frac{1}{2}$ size human hair. Producing: >1000 drops/sec



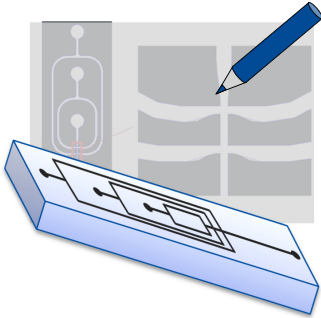
One-step preparation of double emulsions: core shell capsules or particles

Moving from milligrams to tons

Massive parallelization

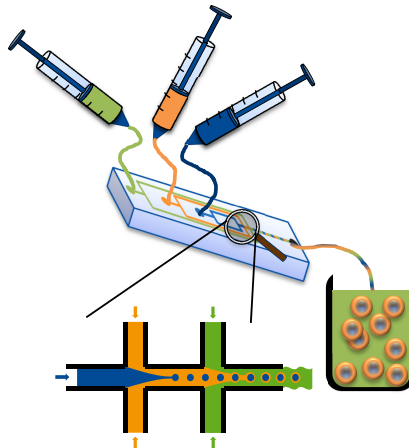
Lab scale

Manufacturing microfluidic devices



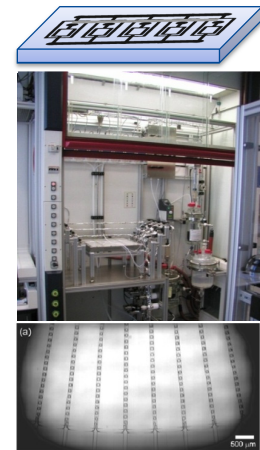
- chip design
- fabrication using different materials
- surface modification

Formulation design



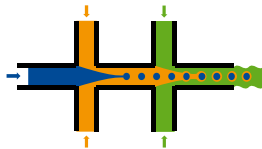
Pilot scale

Parallelization and transfer into mini pilot plant

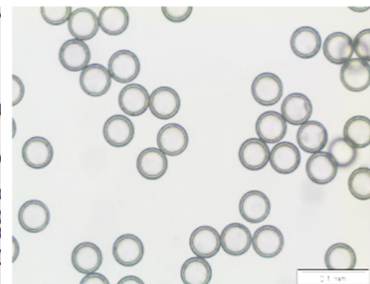
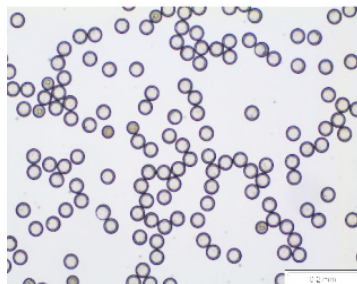


Toolbox to tune applicability and release profile

Particle size

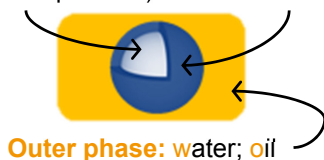


Channel size



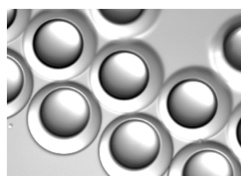
Composition

Core: water; oil (solution / suspension) **Shell:** oil; polymer; wax

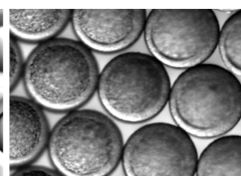


Outer phase: water; oil

w/o/w



w/x/w

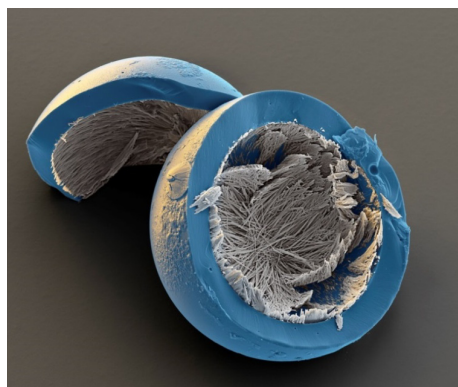
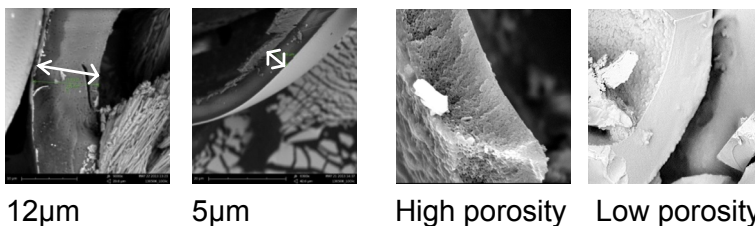


w/p/w



Nano-structure key for controlled release

Shell thickness and nano-structure

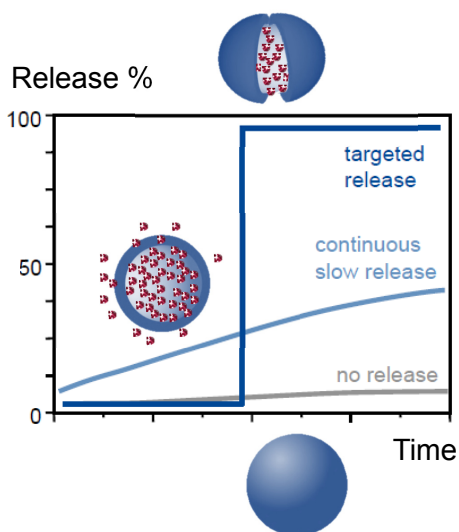


- Shell thickness: fine tuned by adjusting flow rates
- Shell nano-structure: porosity fine tuned by composition and cross-linking conditions

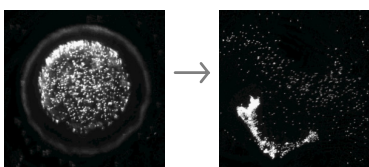
Both parameters are key for release profile

Release profile

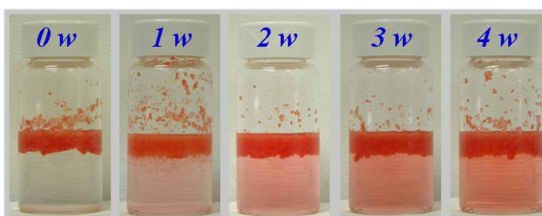
Stable formulation: After application triggered or slow release



Triggered release: temperature, osmotic pressure, mechanical pressure



Continuous/slow release: nano-structure of shell porosity



Better control and more possibilities

to meet customers' needs and protect the environment



At BASF, we develop new formulation technologies which allow

- high degree of control in composition and shell properties (nano-structure)
- using mild processing conditions (no shear), continuous process and high versatility (multiple emulsions) to achieve the encapsulation
 - of a broader spectrum of actives (including water soluble actives in water) and
 - temperature or shear sensitive systems like enzymes and microorganisms

With the target of

- selective application of actives to better meet our customers' needs and to preserve the environment (saving resources)

13

BASF Research Press Conference
on May 27, 2014

Nanotechnology

Small dimensions – great opportunities

