Microencapsulation and Its Applications in Herbicide Formulations

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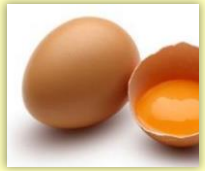
What Is Microencapsulation?

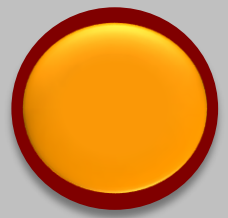
Capsules

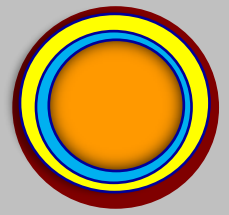



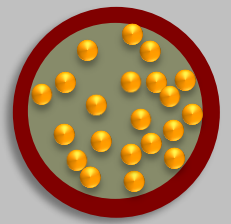

Macro (>mm)	**Micro**	Nano
	0.2–1000 µm	1–200 nm

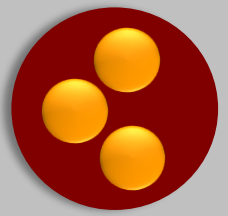
Microencapsulation is a technology of making micro-capsules which are solid particles or liquid droplets surrounded by a shell.

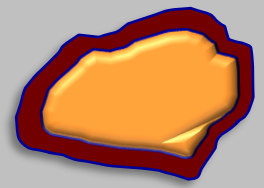
Types of micro-capsules

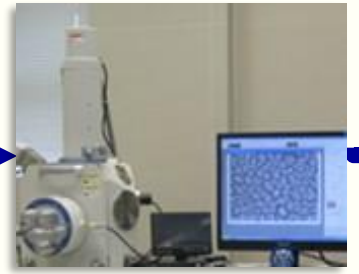
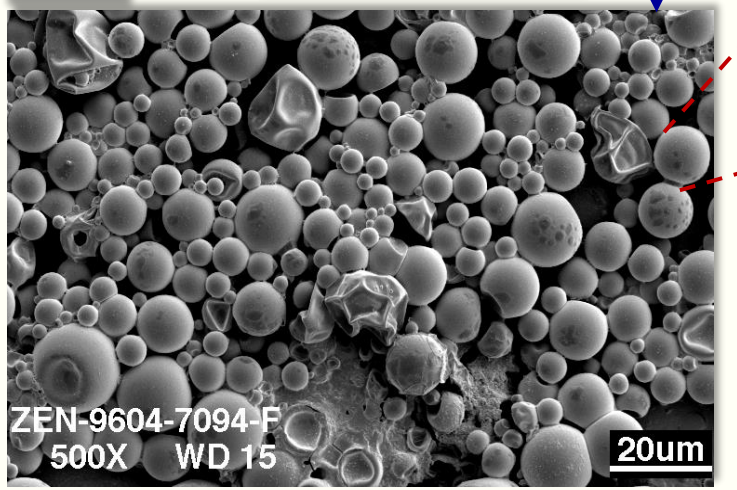

Simple sphere

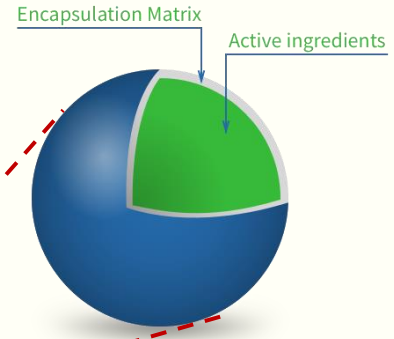

Multi-walled


Matrix core


Multi-core


Irregular shape

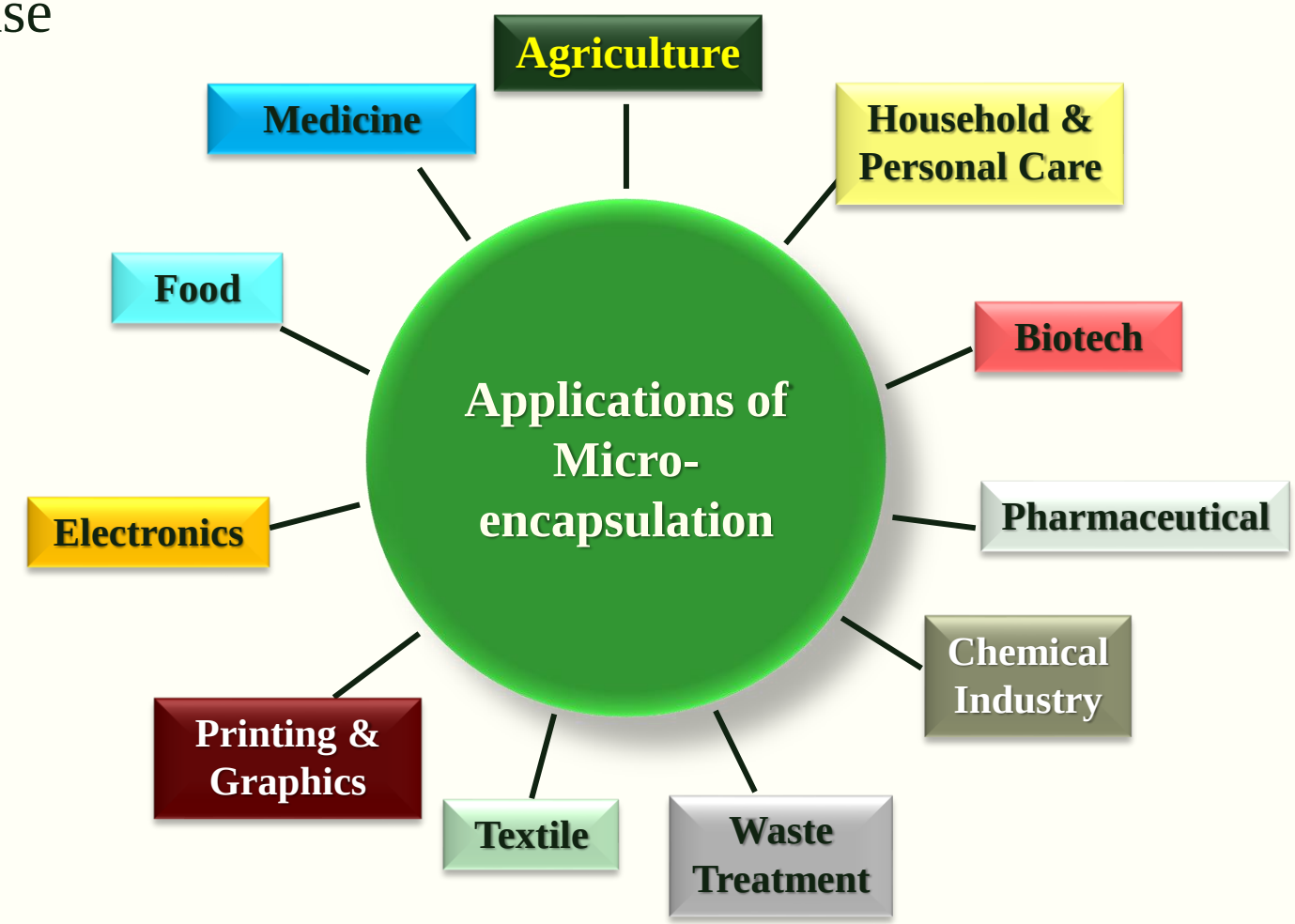






SEM image of microencapsulate

Benefits and Applications

- Controlled release or modulated release
- Protection: Separation of reactive components in mixtures
- Alter properties
  - Convert hydrophobic to hydrophilic
  - Make tacky liquid freely flowing solid
- Taste/odor masking
  - Fragrance release
- Add new functions
  - Reduce flammability, volatility (Safety)
- Targeted delivery
  - Deliver small amounts of potent actives efficiently



History of Microencapsulation

Late 1800s

1872: Spray drying, Patent, Mr. Samuel Percy

Late 19th Century: Pan coating

1932: Spray dried flavors, England

1939: Carbonless copy paper R&D

1955: Dry loaded gelatin capsules, Green, US patent 2,712,507

1950:Fluid bed coating, Wurster

1960s: UF polymers (Matson patents, 1970)

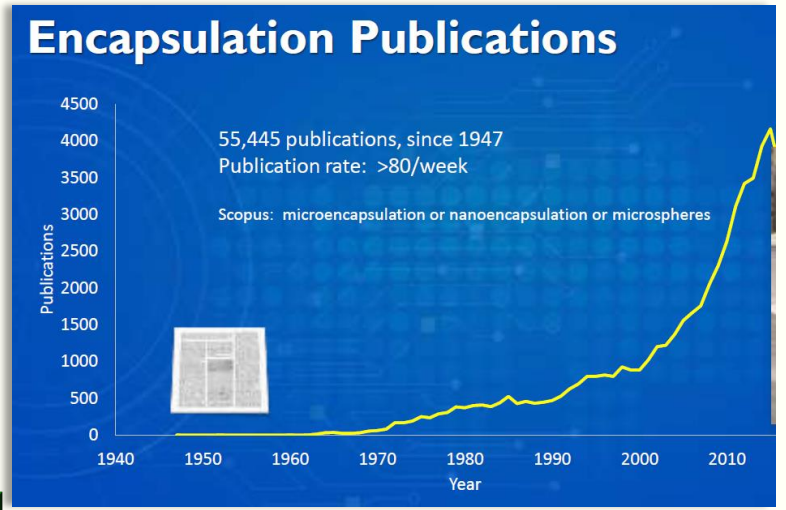
1962: Artificial cells, interfacial polymerization

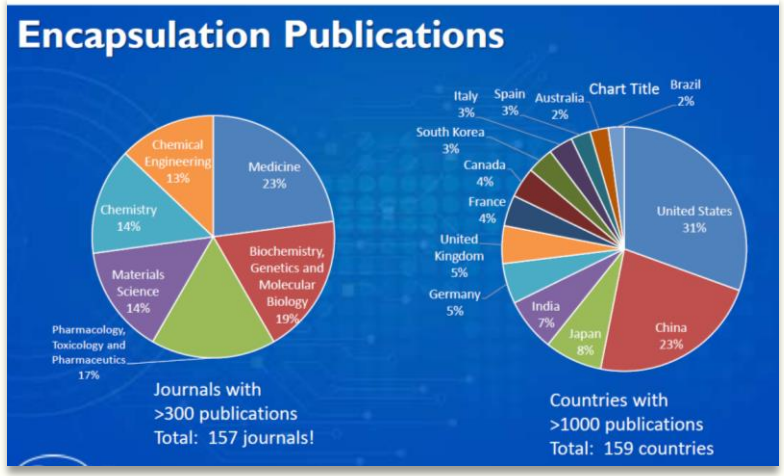
1973: Controlled Release Society

1967: 1st Microencapsulation course, Sparks

1976: Nanocapsulation

(SwRI)



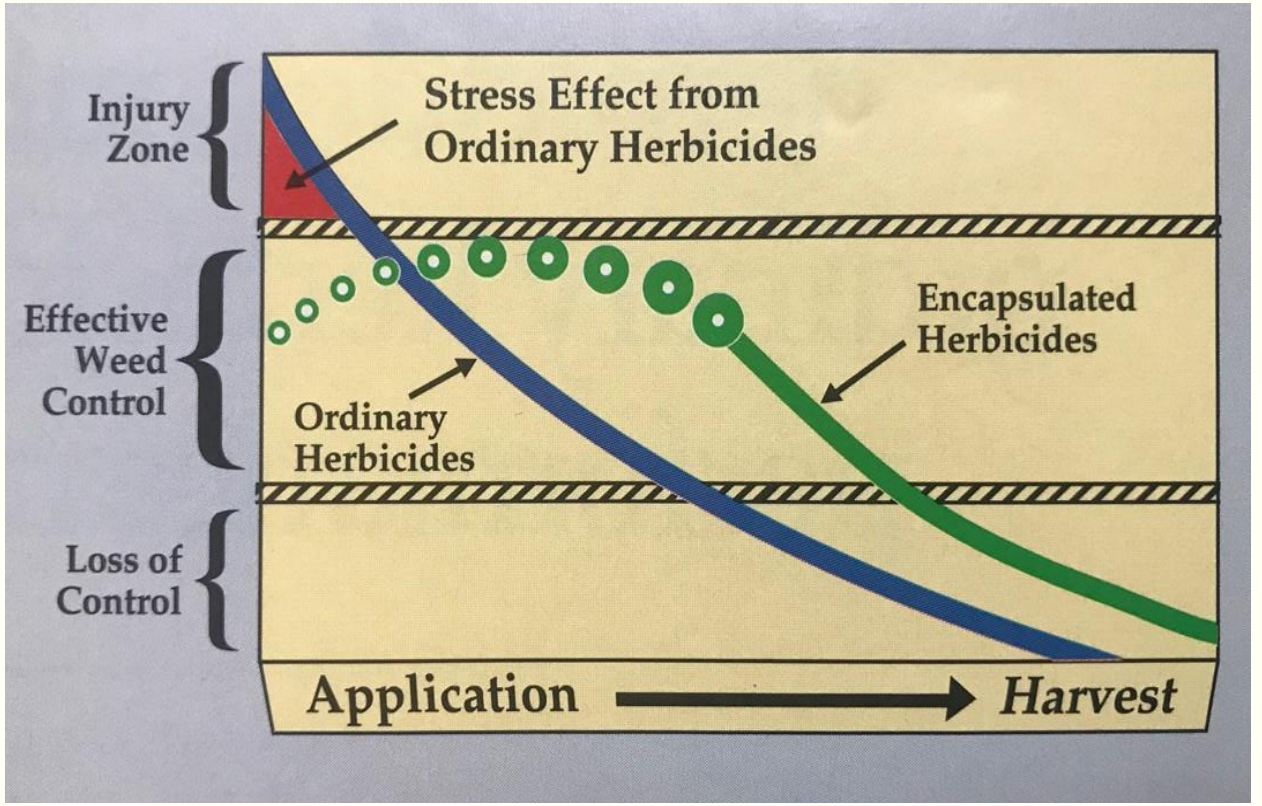


Microencapsulation Offers Multiple Benefits for the herbicidal Formulations

Controlled release
- **Longer activity for weed control**
- **Reduced crop injury**

Improves chemical stability and physical compatibility
- Separation of actives
- Convert hydrophobic to hydrophilic

Can improve other characteristics
- Reduce flammability, off-target movement, odor, irritation & tox profile



Comparison of encapsulated with "ordinary" herbicide for weed control and crop safety

Encapsulation Methods and Capsule Shell & Core Compositions

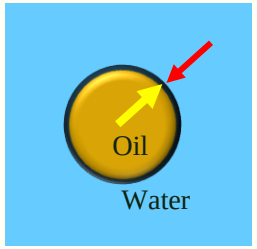
Encapsulation method

- Fluid bed coating
- Spray drying
- **In situ interfacial polymerization**
- Solvent evaporation
- Coacervation
- Phase separation
- Rotation disk
- Sol-gel method
- Pan coating
- Vibrating nozzle

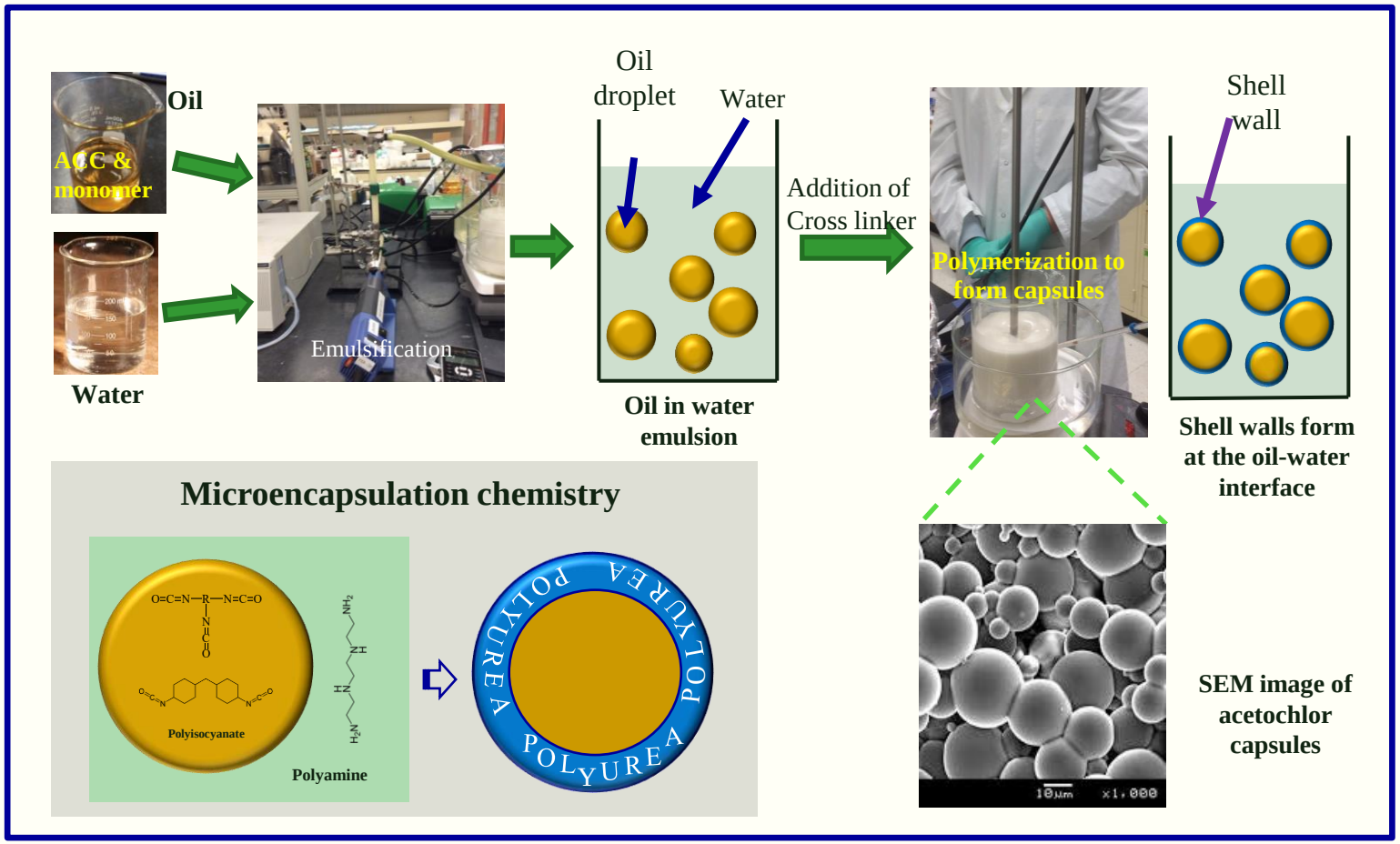
Shell materials: Compatible and non-reactive with core materials		Core materials
Melts	Waxes (vegetable or mineral), hydrogenated oils, PEG, PEG derivatives, polyethylene	Solids, liquids, gases ▪ Hydrophobic ▪ Hydrophilic
Water-based	Gelatin, starches, maltodextrins, alginates, chitosan, other polysaccharides, cellulosics, polyvinyl alcohol, polyacrylates; latexes; gelatin and gluteraldehyde; latexes, pseudolatexes	
Organic soluble	Cellulose ethers, polyacrylates, polylactic acid and its copolymers, enteric coatings	
Reactive coatings	Block copolymers from interfacial polymerization	

Microencapsulation through Interfacial Polymerization

Capsule is formed through the polymerization reaction in the interfaces between two phases (ex. oil droplet and water)

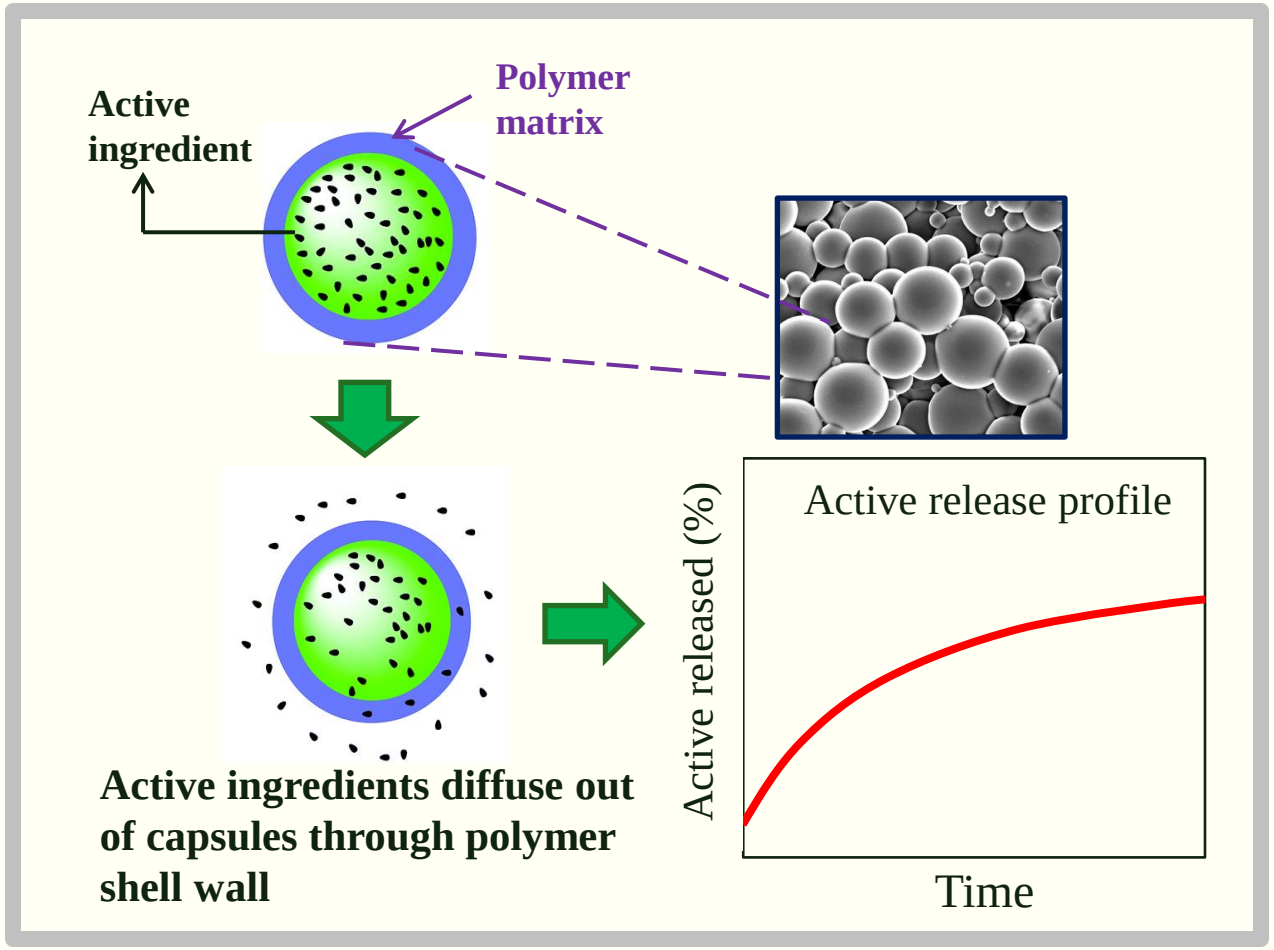


- 1935, Nylon (Carothers, DuPont)
- 1964, Chang, Science, 146: 524-525
  - "Semipermeable Microcapsules"
  - Encapsulation of cells
- Mathiowitz and Cohen, 1989
- Review: Microencapsulation by interfacial polymerization, 2015



Factors Affecting Active Release Rate from Capsules

The formulation performance is directly related to the release rate of the encapsulated actives



- **Capsule size**
- **Viscosity of the core materials**
- **Shell wall thickness**

- **Shell wall porosity (crosslink density)**
- **Concentration of encapsulated actives inside capsules**
- **Active solubility**

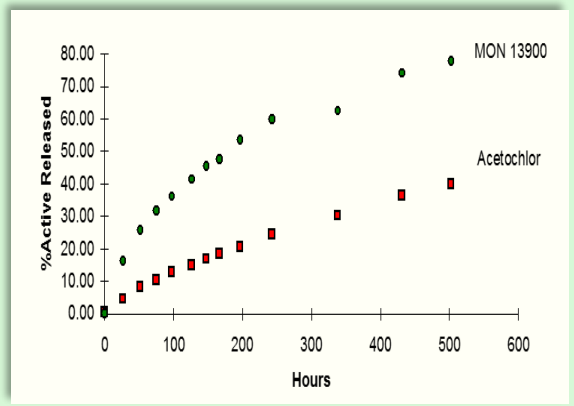
Increase of the left factors

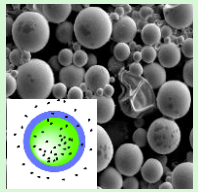
Increase of the left factors

Active release rate

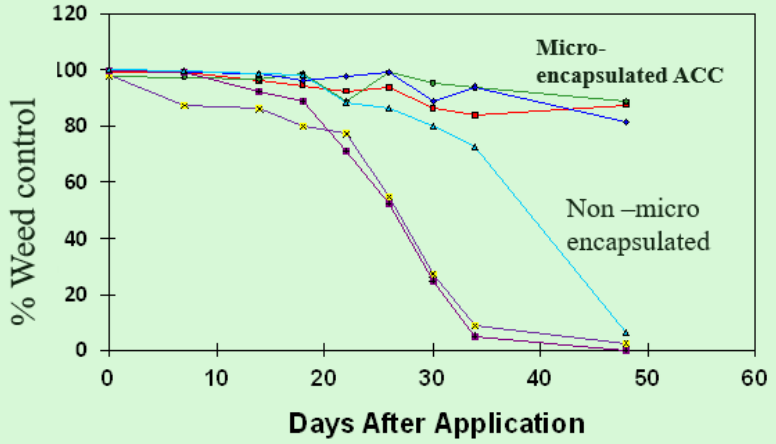
Microencapsulation Enhanced Performance in Weed Control

Extended weed control, reduced crop injury and expanded its application scope

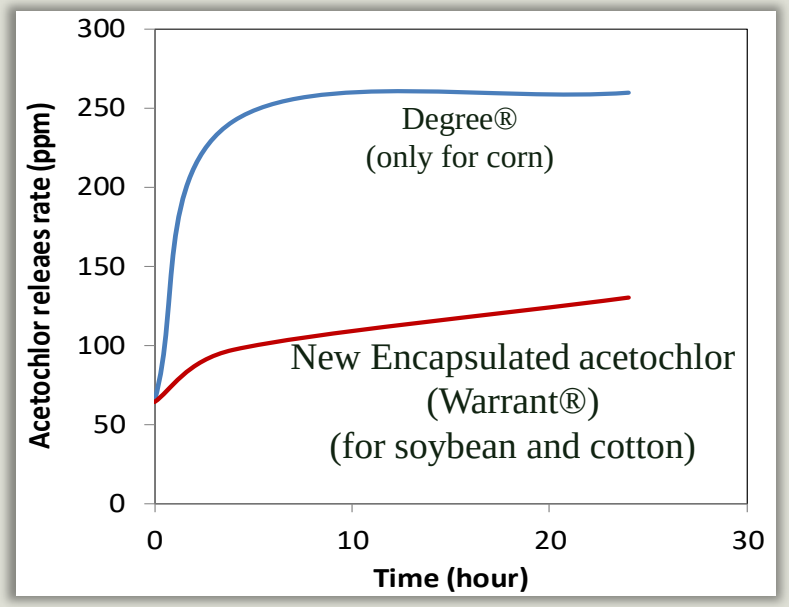




- Diffusion release mechanism
  - Controlled over time

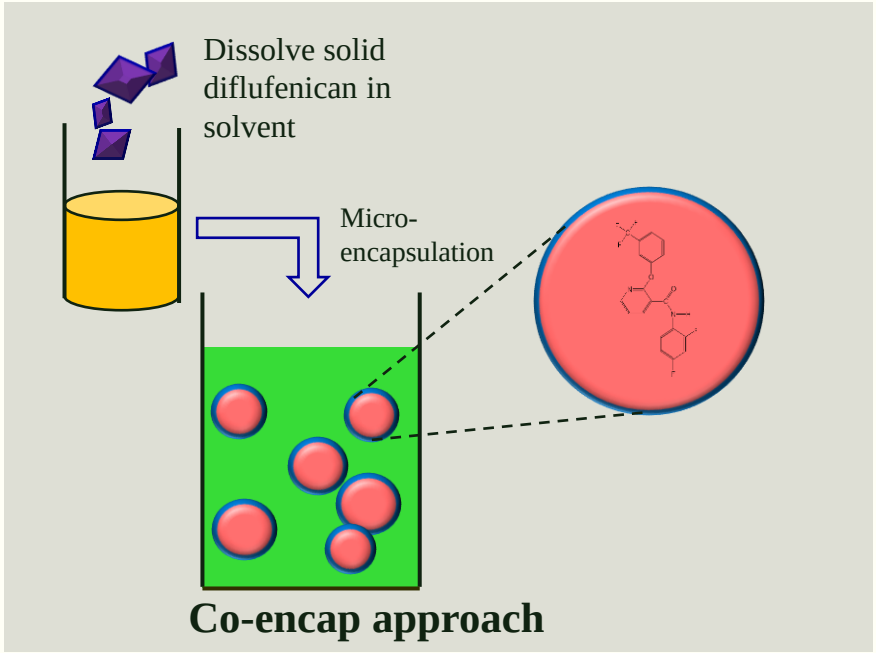


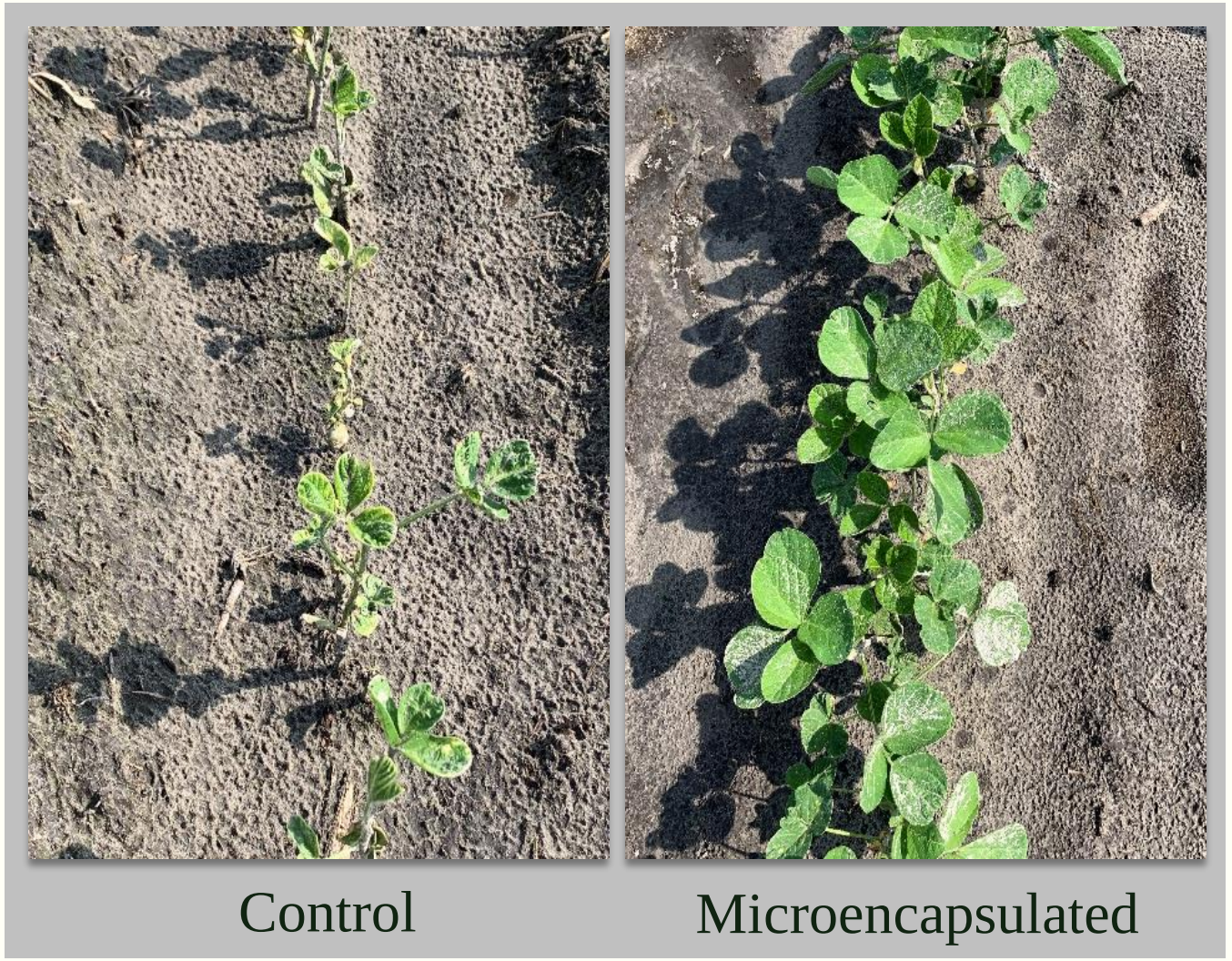
- **Microencapsulated acetochlor demonstrated better performance for corn**
- **Microencapsulated acetochlor application to soybean and cotton**



Microencapsulation Improved Herbicide Performance in Weed Control – Diflufenican as an Example

- Diflufenican is effective in controlling tough weeds in crop fields
- Application of diflufenican has concerns due to crop injury
- Crop injury can be managed through controlled release of diflufenican

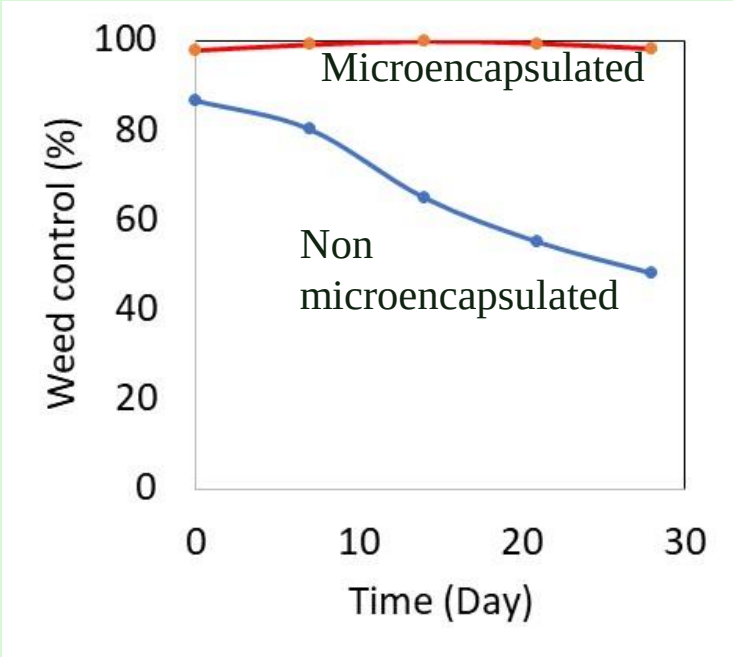


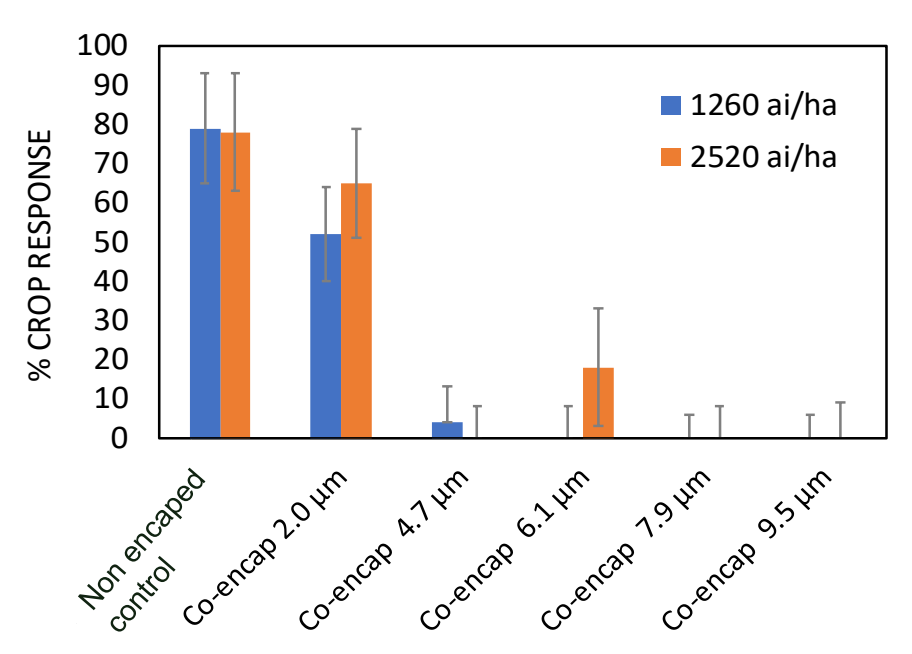


Microencapsulation Demonstrated Extended Weed Control and Better crop Safety

- Metribuzin provides a good option for controlling some resistant weeds
- Metribuzin is labeled for PRE application in both soybean & corn fields, but crop injury is a concern

- Micro-encapsulating metribuzin is an approach to improve its performance
  - ➢ Longer weed control
  - ➢ Less crop response



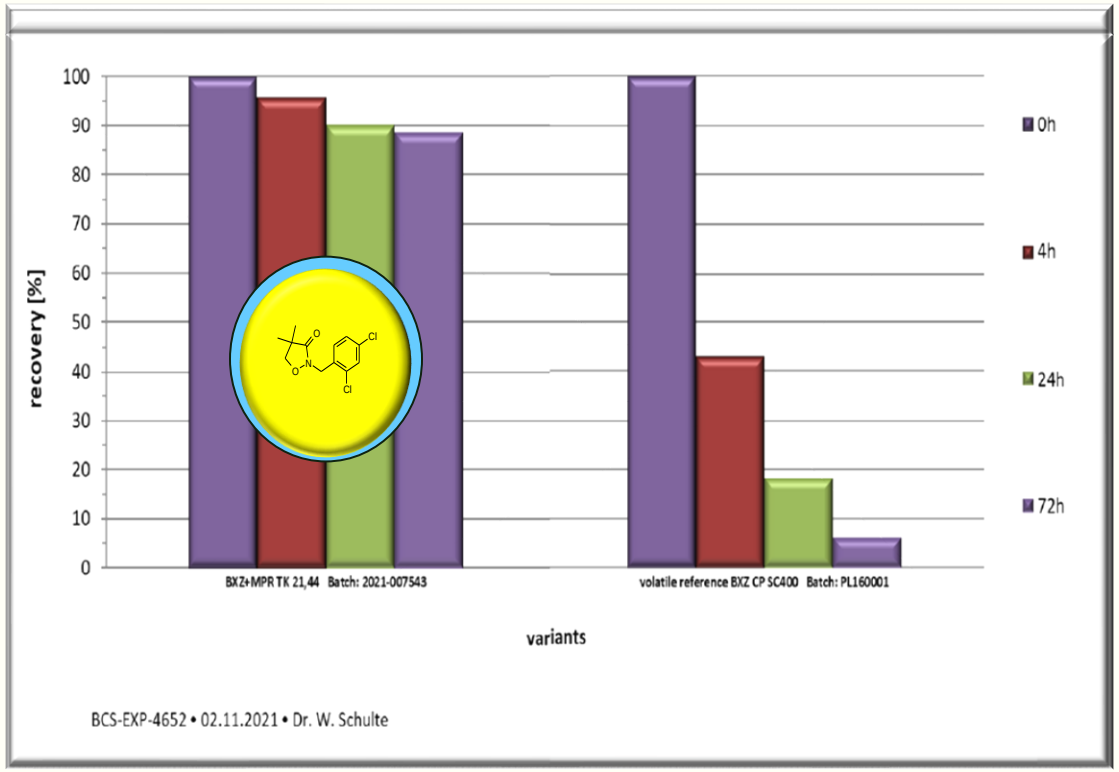


Microencapsulation Improved Formulation Properties (BCS-CY69849)

- Active has high vapor pressure (2.3 mPa) → risk of volatility
- Low melting point (81°C) → agglomerates in SC
- Selectivity → risk of phytotoxic

Microencapsulation is the solution


new CS-facility in FT-PP



Microencapsulation Is a Powerful and Beautiful Tool in Delivering Herbicides

- Enhance and improve active performance
  - ➢ Extended activity after application
  - ➢ Managed phytotoxicity
    - – Expand crop scope
    - – Expand application windows (Pre & Post)
- Increase compatibility among ingredients in formulations and in applications
- Rejuvenate actives for having differentiated features and new purposes