Where science
& creativity meet

# ENGINEERING CONTROLLED FRAGRANCE RELEASE SYSTEMS FOR SUPERIOR PERFORMANCE

**Yabin Lei - July 13, 2022**

# OUTLINE

- Introduction
- Preparation and characterization of core modified fragrance capsules
- Physical properties of core modified fragrance capsules
- Performance of core modified fragrance capsules
- ECHA regulations and latest industrial efforts
- Future trends
- Acknowledgement

# INTRODUCTION: WHY ENCAPSULATE

- Prevent the loss of ingredients in harsh application media such as rinse conditioner
- Enable efficient transfer and deposition of fragrance ingredients onto substrate
- Provide long-lasting and controlled release on demand and key touch points
- Create consumer products with superior overall performance

# INTRODUCTION: APPLICATIONS OF FRAGRANCE CAPSULES

- Fabric care
  - Fabric Softener and detergent
- Hair Care
  - Shampoo and conditioner
- Personal care
  - Deodorant, body wash and lotion
- Home care
  - Air refresher and floor cleaner
- Fine fragrance
  - Perfume



Public

# INTRODUCTION: SOME CONSIDERATIONS IN FRAGRANCE ENCAPSULATION

- Hydrophilic and hydrophobic nature of fragrance
- Water solubility
- Vapor pressure
- Ingredient and monomer/cross-linker reactions
- Core solvent or diluents
- Core modifiers
- Fragrance loading
- Capsule/particle size
- Release profile
- Application

# INTRODUCTION: PERFORMANCE EVALUATION OF FRAGRANCE CAPSULES

- Encapsulation efficiency
- Technical performance (stability, deposition, release profile)
- Sensory performance and consumer benefits
- Long term storage stability including leaching from capsules and sensory performance of aged product
- Capsule-base interaction

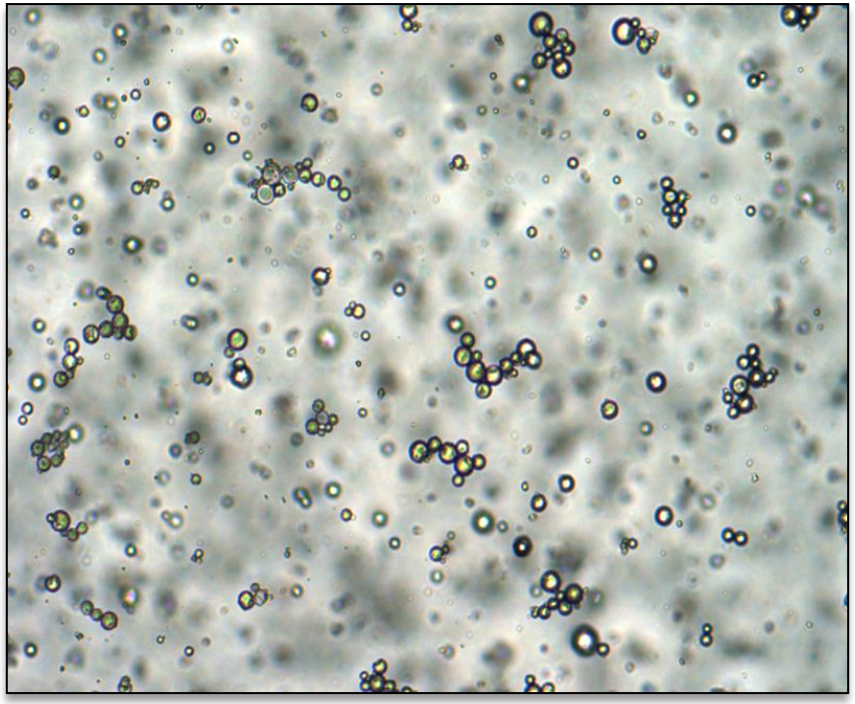
# INTRODUCTION: DELIVERY SYSTEMS OVERVIEW

- Emulsion & microemulsion
- Liposome
- Suspension
- Granulate (water dispersible/soluble granule)
- Spray-drying
- Aerosol
- Extrudate
- Microencapsulate (matrix & core/shell)
- Pro-fragrance, pro-drug & pro-pesticide

# INTRODUCTION: POLYMER-BASED FRAGRANCE DELIVERY SYSTEMS

| Polymer system | Encapsulation type | | Process/Comments |
|---|---|---|---|
| | Core/shell | Matrix | |
| **Spray dried products** | | √ | Drying. Frequently used for flavor delivery |
| **Polymer particles** | | √ | Various |
| **Melamine-formaldehyde** | √ | | Suspension polymerization |
| **Polyurea/polyurethane** | √ | | Interfacial polymerization |
| **Polyacrylate** | √ | √ | Free radical polymerization |
| **Layer-by-layer (oppositely charged polymers)** | √ | √ | Molecular self-assembly, potentially biodegradable |
| **Biopolymer (Gelatin-gum Arabic), non-cross-linked** | √ | | Coacervation, potentially biodegradable |
| **Biopolymer (Gelatin-gum Arabic), cross-linked** | √ | | Coacervation, potentially biodegradable |
| **Proteins and polysaccharides** | √ | √ | Various, potentially biodegradable |

# INTRODUCTION: STRUCTURAL FEATURES OF FRAGRANCE CAPSULES



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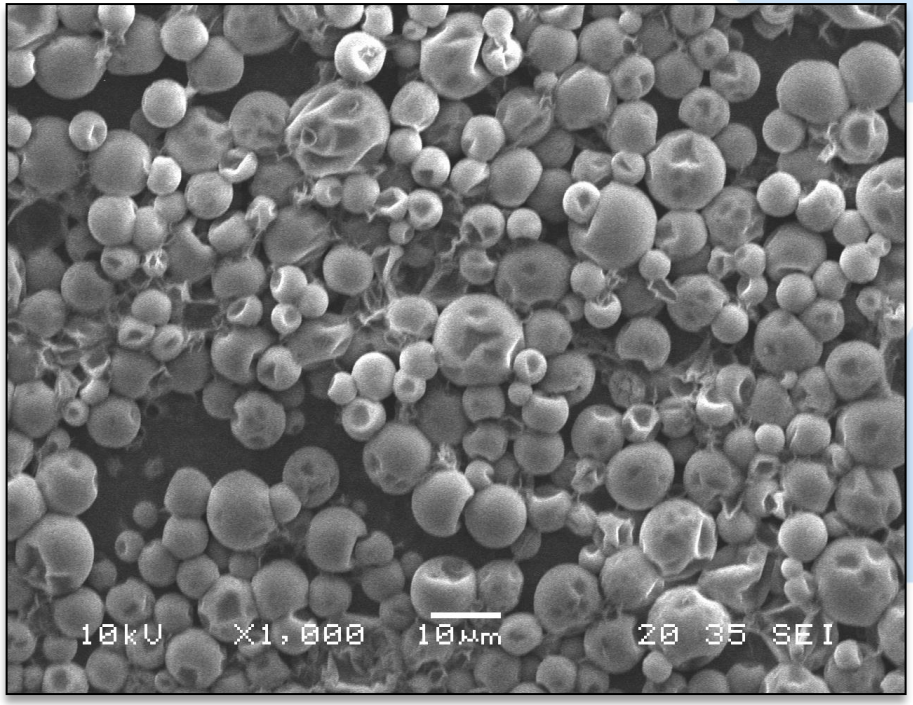
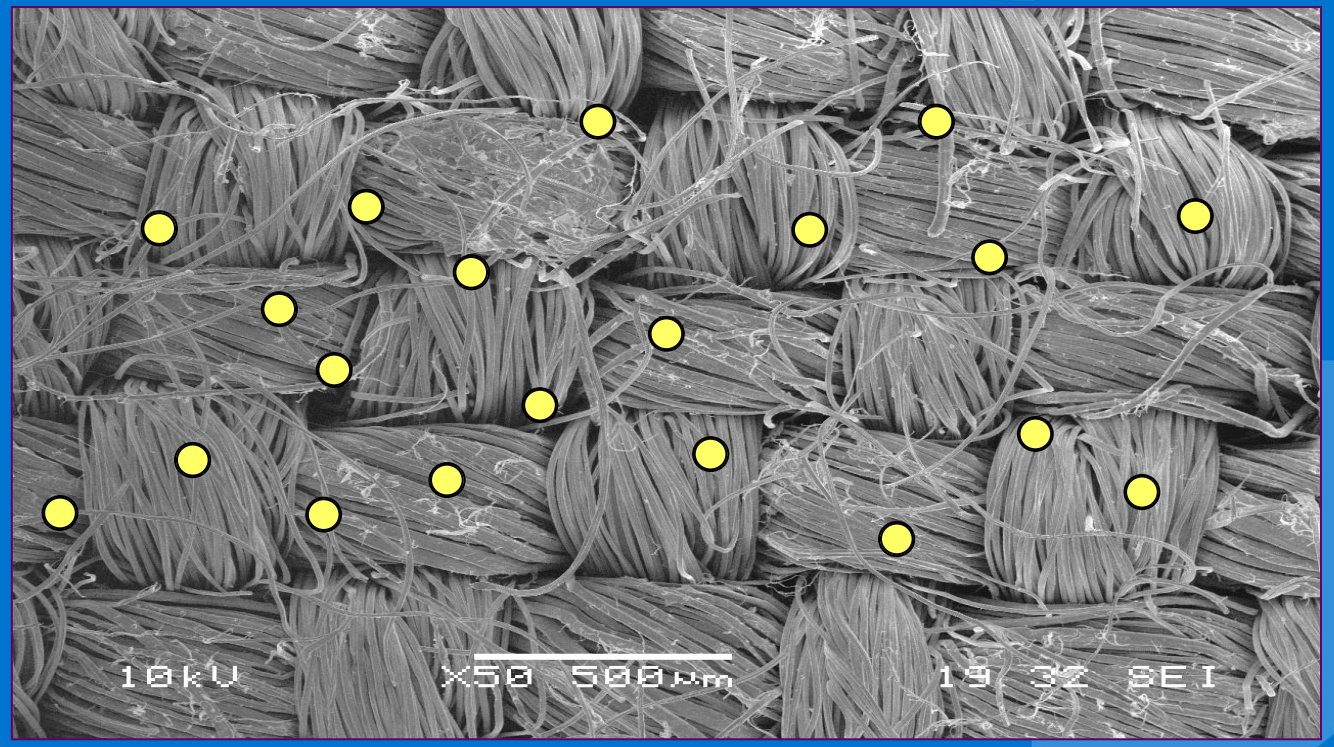



SEM

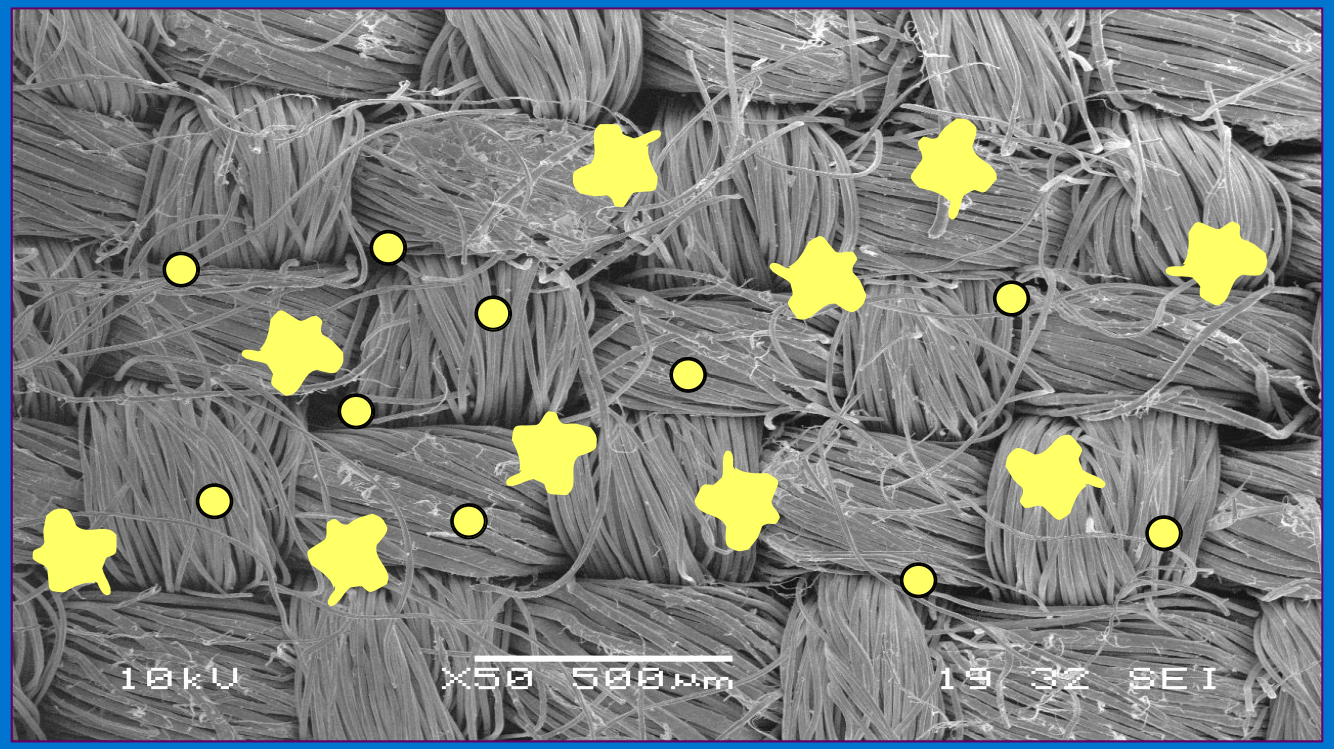
# INTRODUCTION: FRAGRANCE CAPSULE APPLICATION AND BENEFITS

Microscopic capsules that contain fragrance are deposited onto cloth or other surfaces…..

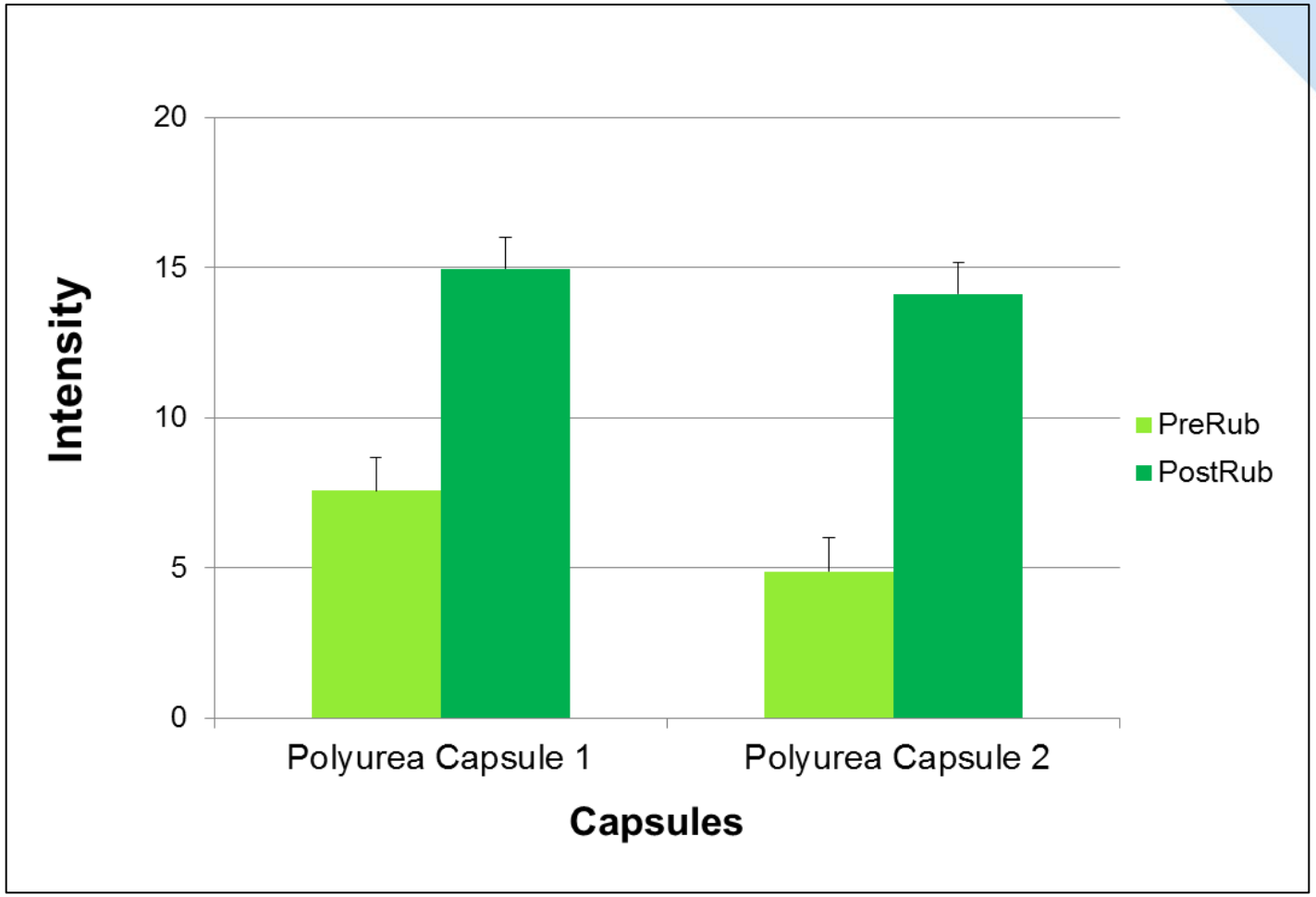


# INTRODUCTION: FRAGRANCE CAPSULE APPLICATION AND BENEFITS

The capsules release fragrance over time and provide a burst due to touch or motion…..



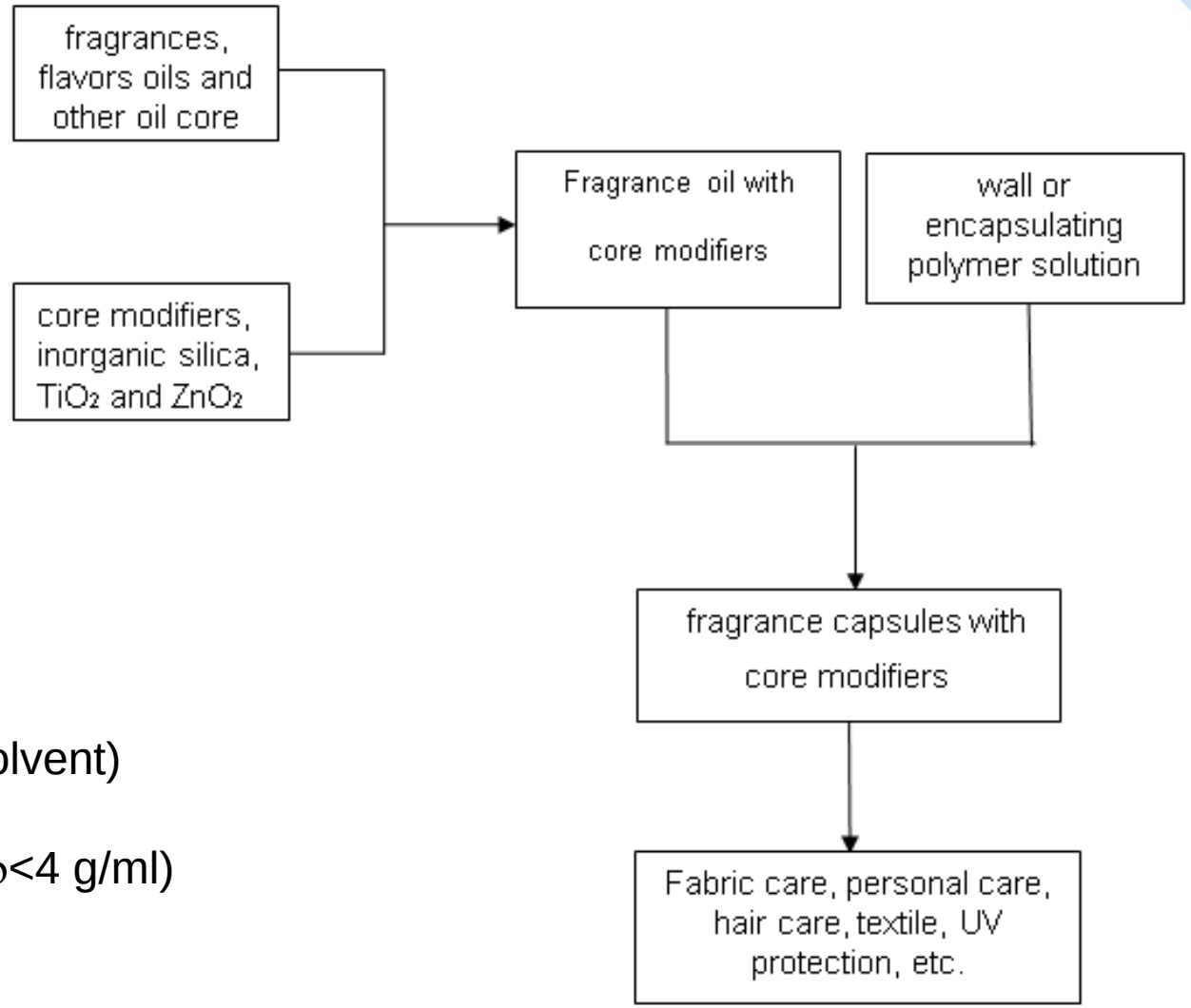
# EXAMPLE: SENSORY PERFORMANCE OF FRAGRANCE CAPSULES IN FABRIC SOFTENER BASE



# FRAGRANCE CAPSULE: CORE ENGINEERING

- Improved encapsulation efficiency
- Broader fragrance pallets (more hydrophilic ingredients)
- Enhanced stability and performance
- Controlled physical property
  - Capsule size and viscosity
  - Tunable density (better compatibility with base)
  - Better suspension in base (LD)
- Tunable release profile
- Increased deposition and better performance
- Employ either liquid (solvent and polymers) to solid materials (inorganics)

# PREPARATION AND CHARACTERIZATION OF FRAGRANCE CAPSULES WITH CORE MODIFIERS OR DENSIFICATION AGENT



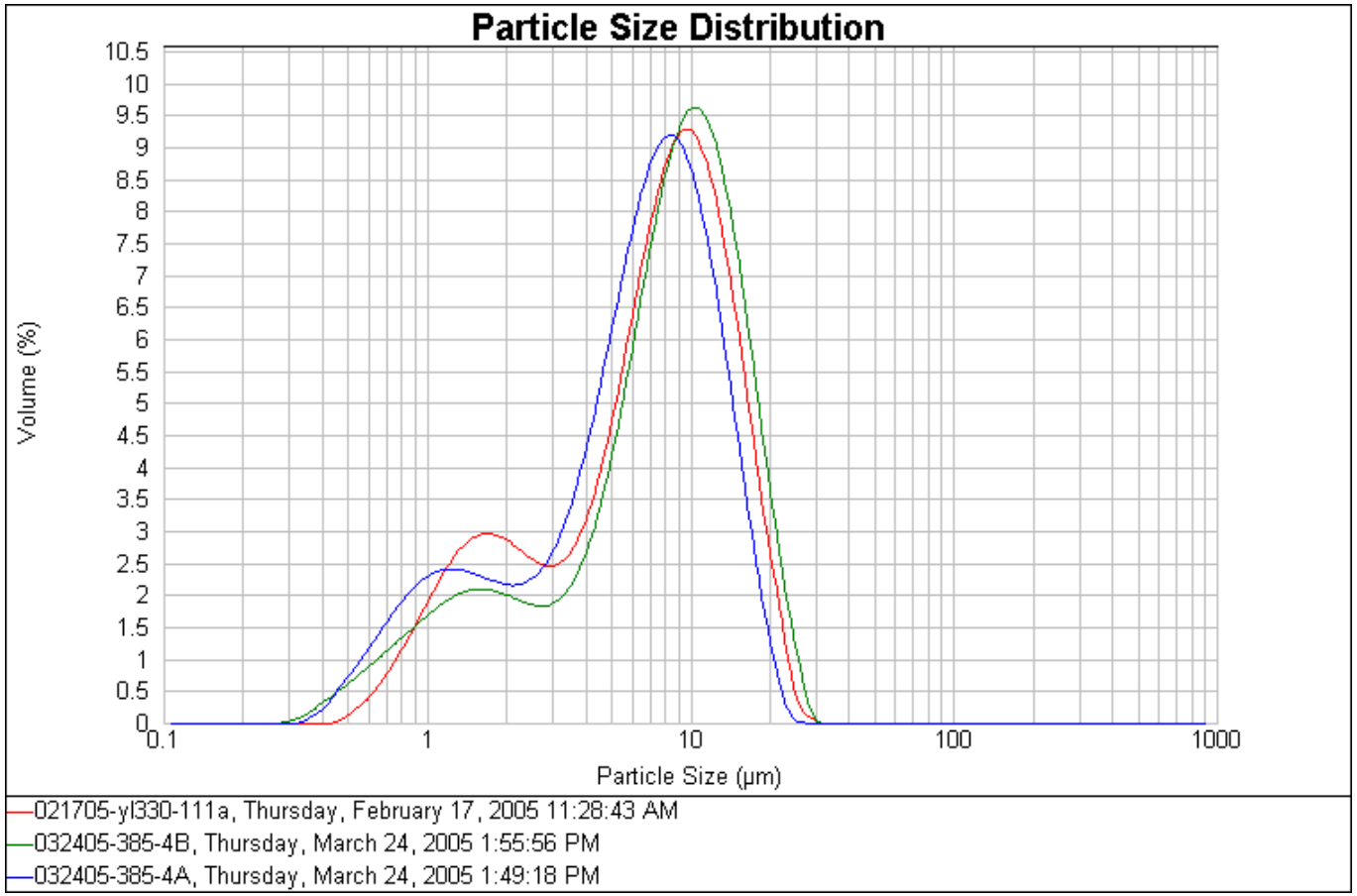

Core modifiers:

- ❑ Inorganics
- ❑ Organics (solvent)
- ❑ Particulates
- ❑ Density ($1<\rho<4$ g/ml)

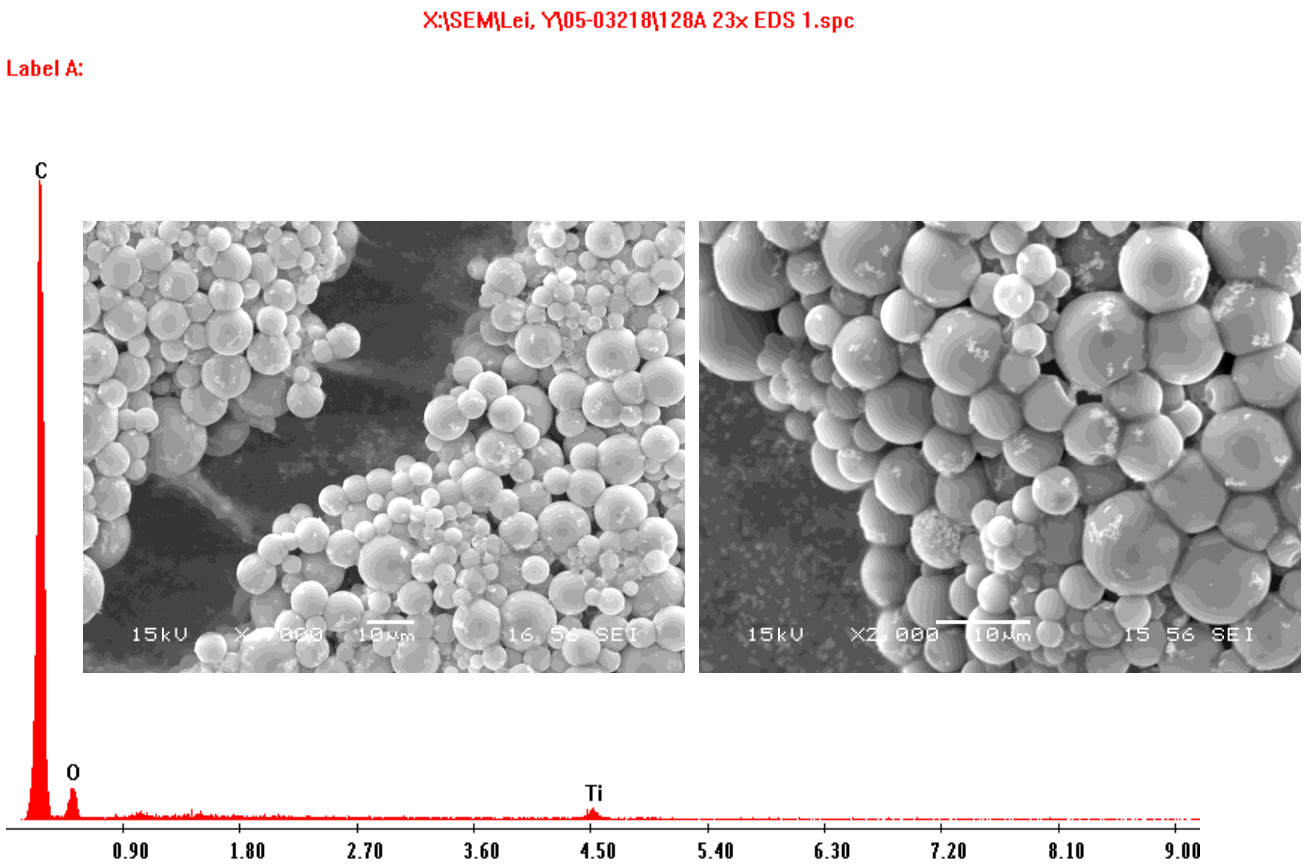
# ENCAPSULATION OF FRAGRANCE WITH DENSIFICATION AGENTS (DA)

| Component （g) | 385-4A | 385-4B |
|---|---|---|
| Fragrance | 190 | 105 |
| Hydrophobic $TiO_2$ | 20 | 20 |
| Neobee | 0 | 85 |
| Total | 210 | 210 |
| Free oil (%) | 0.3 | 0.15 |

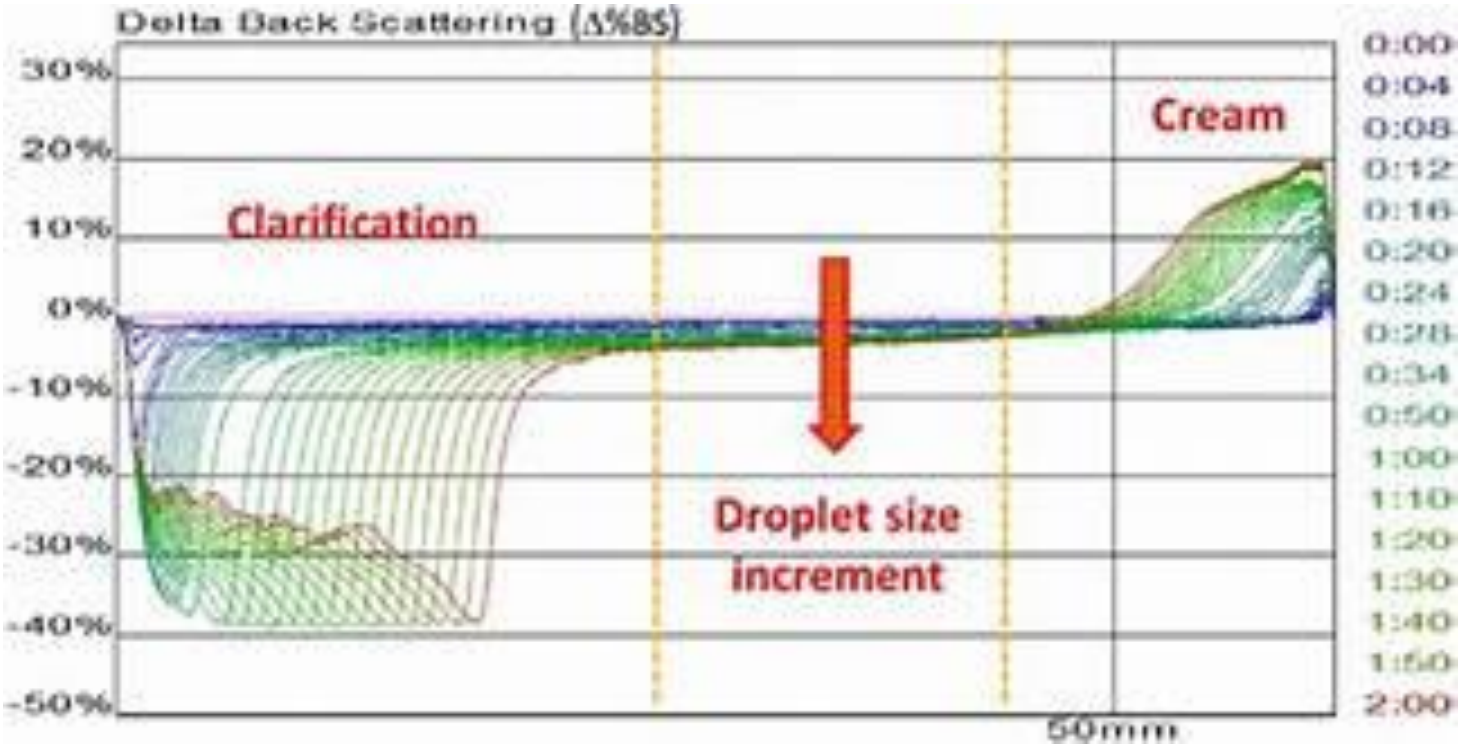
# PARTICLE SIZE DISTRIBUTION OF CAPSULES MADE WITH DA



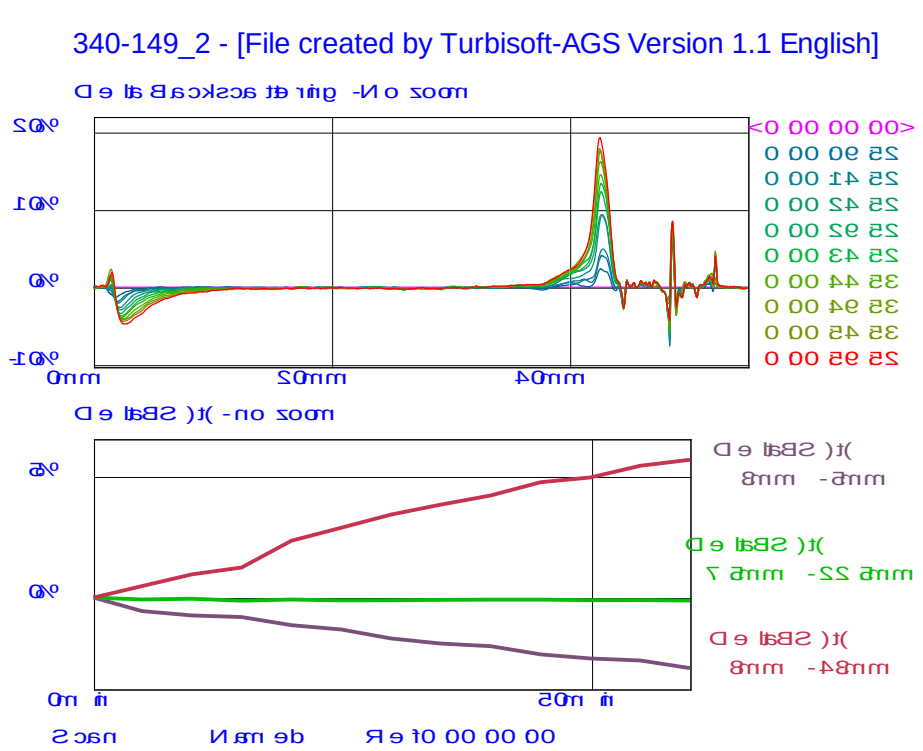
# CHARACTERIZATION: SEM AND XRD OF CAPSULES WITH DA

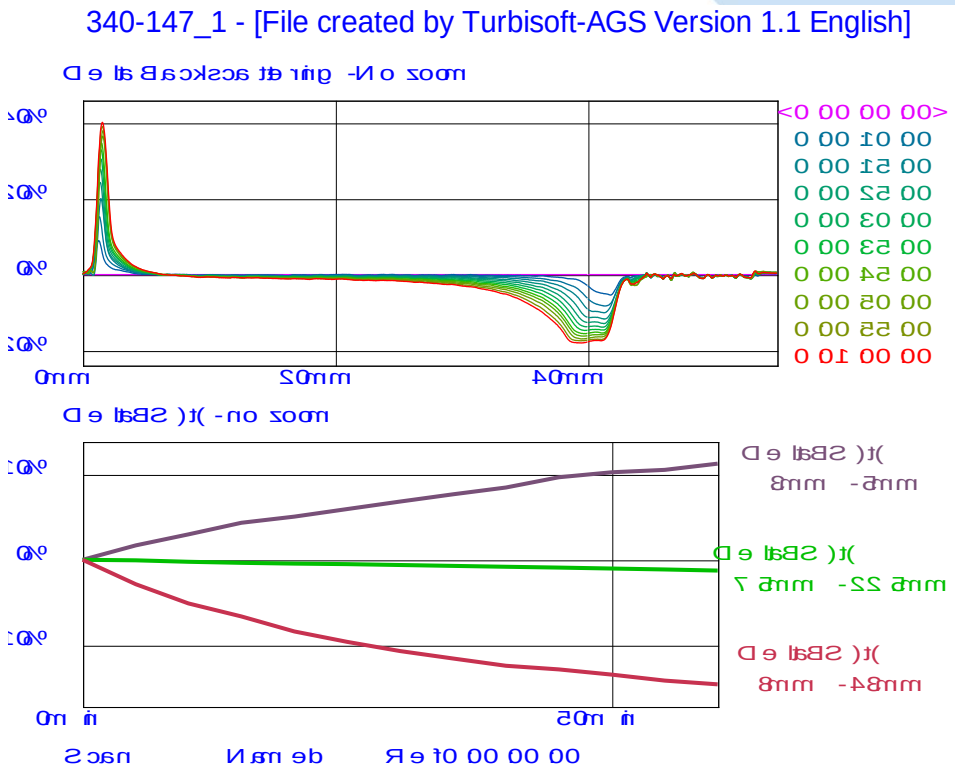


# ILLUSTRATIVE TURBISCAN BACKSCATTERING PROFILE OF SUSPENSIONS OR EMULSIONS

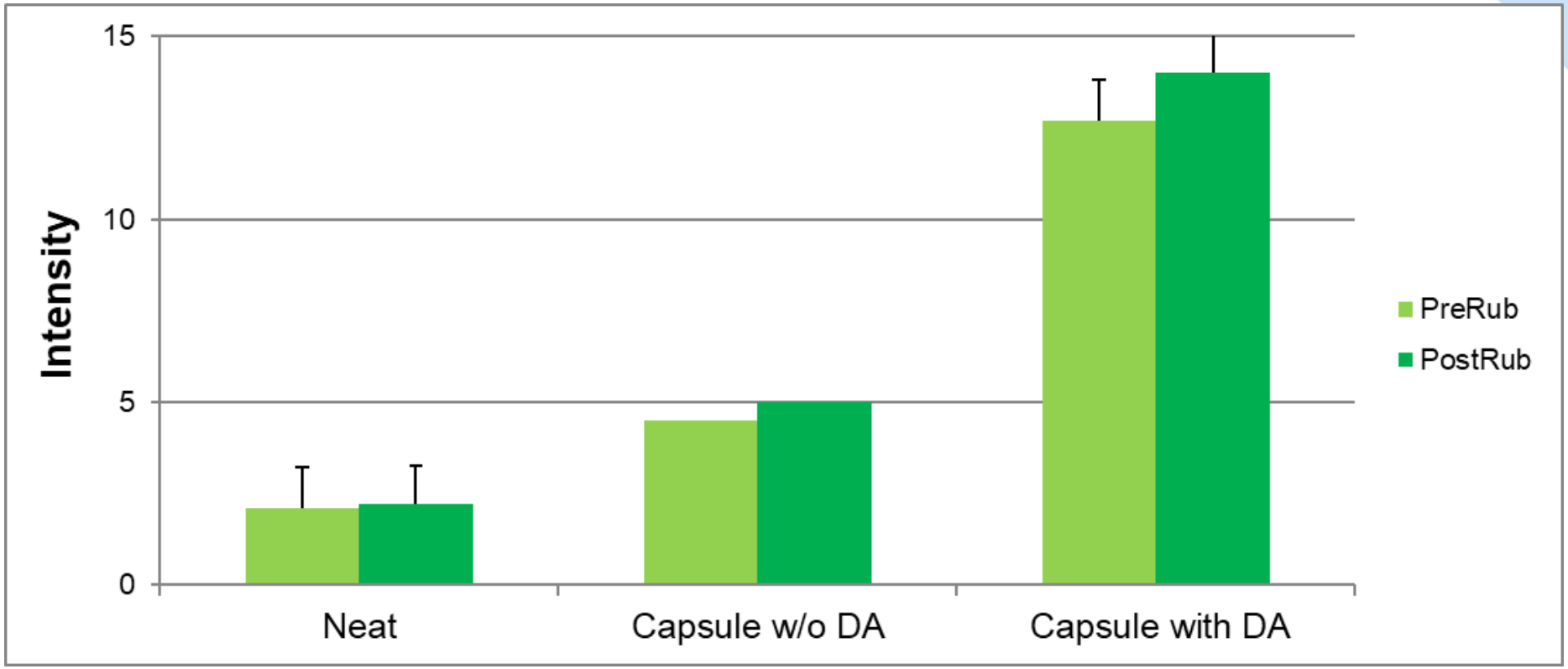


# DISPERSION PROPERTIES OF CAPSULES WITH DA

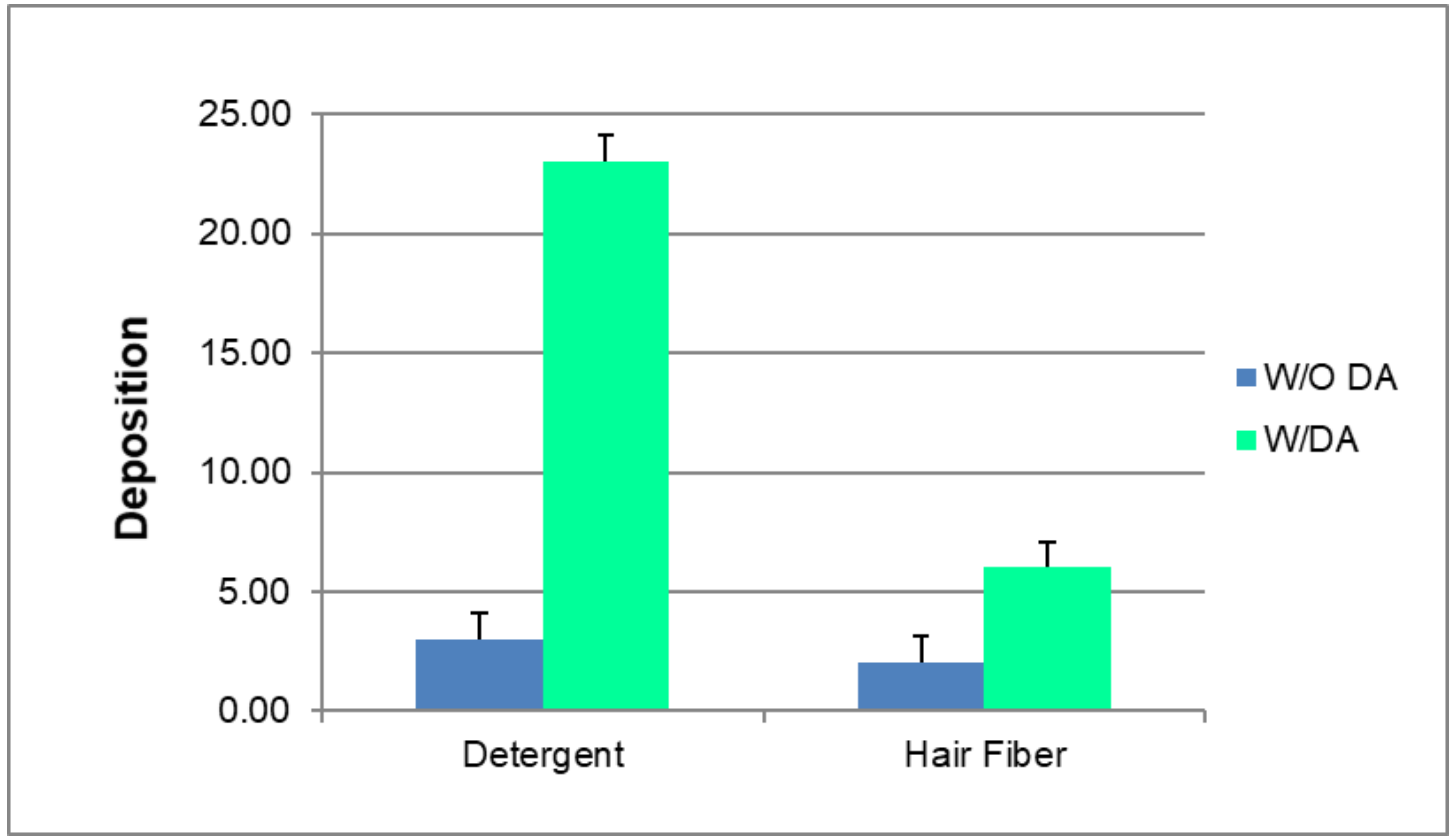


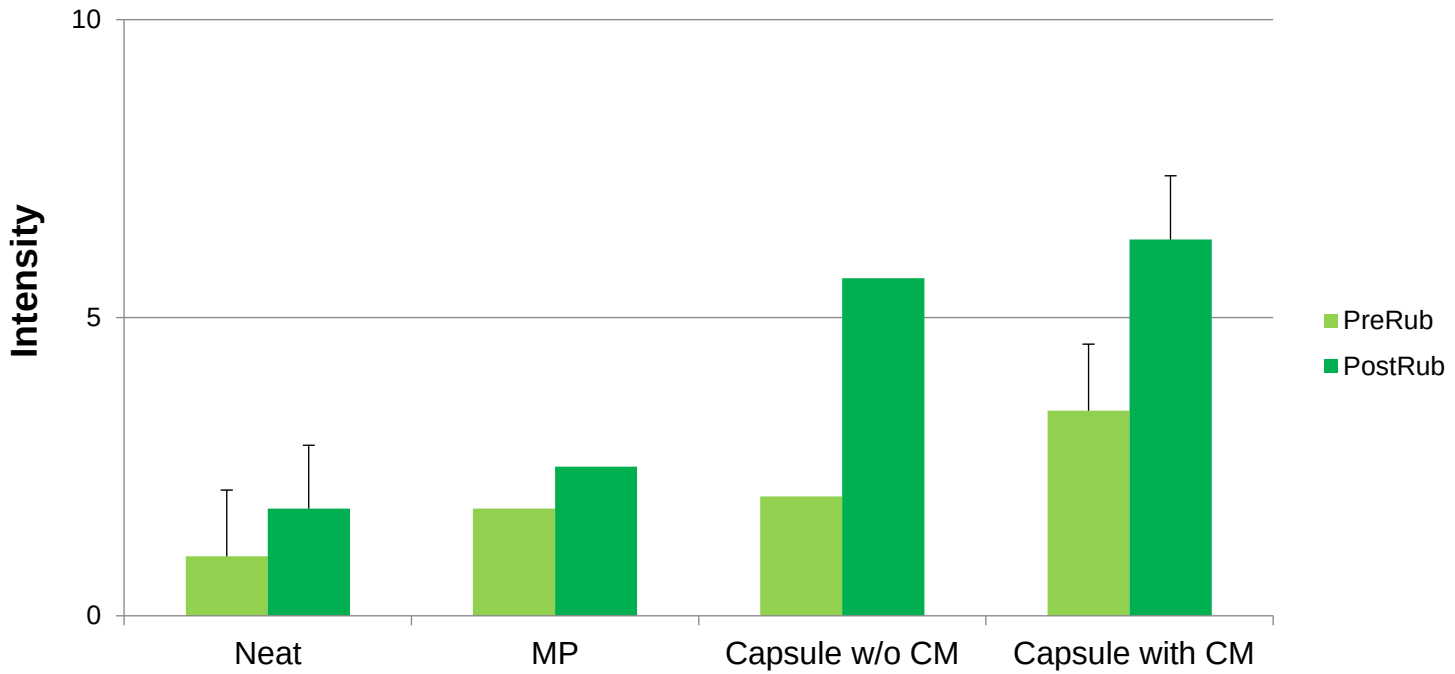
# COMPARISON OF SENSORY PERFORMANCE OF FRAGRANCE CAPSULES WITH AND WITHOUT DA IN LIQUID DETERGENT



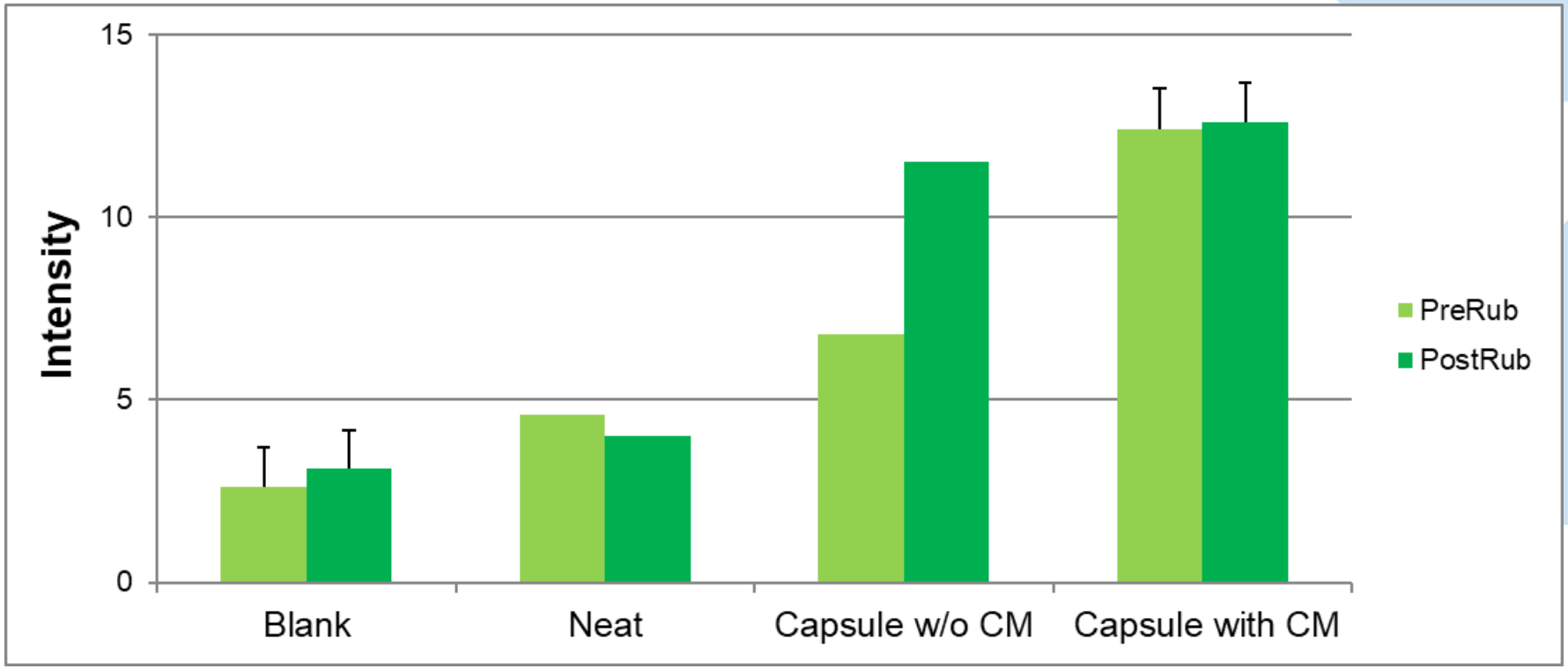
# COMPARISON OF DEPOSITION FRAGRANCE CAPSULES WITH AND WITHOUT DA IN LIQUID DETERGENT AND HAIR



# COMPARISON OF SENSORY PERFORMANCE OF CAPSULES WITH AND WITHOUT CORE MODIFIERS IN HAIR CONDITIONER



# COMPARISON OF SENSORY PERFORMANCE OF CAPSULES WITH AND WITHOUT CORE MODIFIERS IN FABRIC SOFTENER



# SUMMARY

- Stable fragrance capsules could be prepared using a range of core modifiers
- The inclusion of densification agent or/and core modifiers:
  - Can significantly improve the dispersion of capsules in base
  - Enhance the sensory performance of capsules in difficult applications via increased deposition
  - Modulate the release profile of capsules in different applications to meet consumer demands
- The concept may be applicable to other delivery platforms and applications

# MICROPLASTICS REGULATIONS: RECENT DEVELOPMENTS

- 18 FEBRUARY 2022: California 2787 Bill is introduced prohibiting the sale of consumer products with intentionally added microplastics. Recently this bill was terminated but will be proposed again once ECHA microplastics restriction is finalized (goal was to align)
- APRIL 2022: Plastic Soup Foundation publishes report on microplastics in cosmetic products that gets a lot of media coverage, increasing pressure on EU Politicians to move forward with Microplastics Restriction after 1 year of standstill
- 13 APRIL 2022: Commission responds to questions of EU Parliament who are very critical about the 1-year delay, confirming that draft Restriction proposal is now starting internal consultation (DG Grow / DG Envi, Legal, etc.)
- In general, there are increasing pressure globally to restrict microplastics; the scope for any one regulation varies substantially as do definitions, exemptions, timing etc.

# MICROPLASTICS REGULATIONS: RECENT DEVELOPMENTS

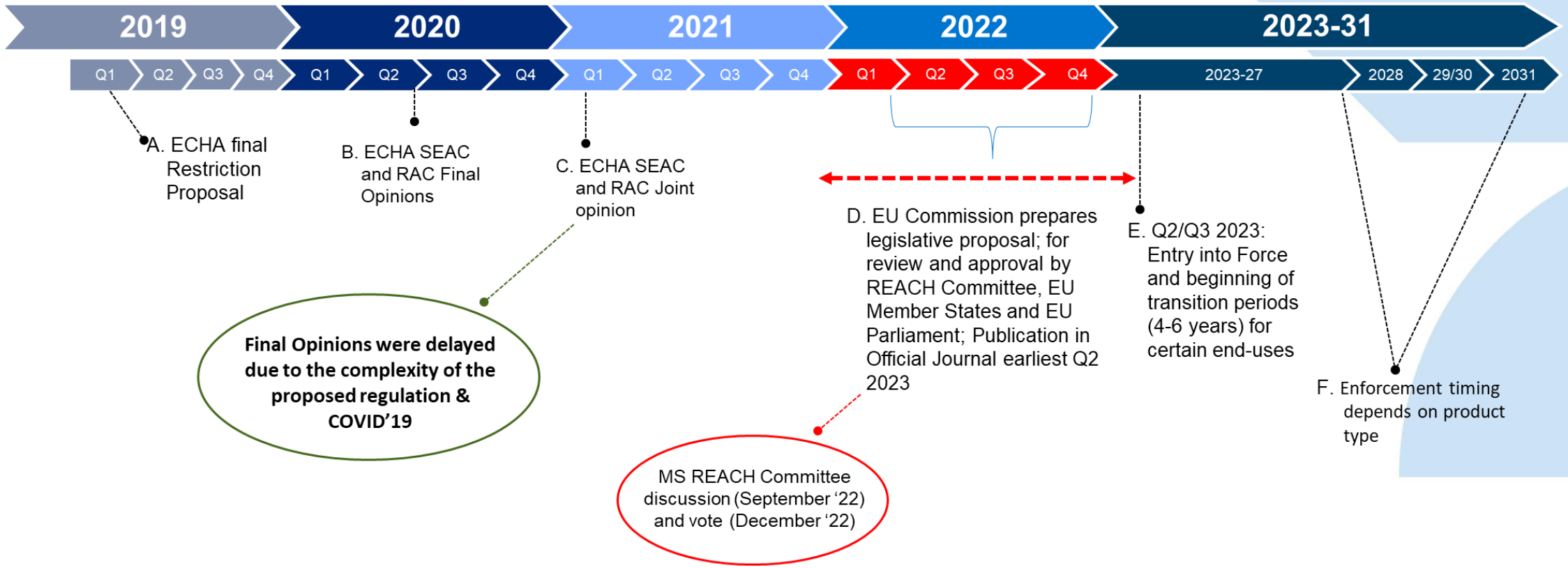
- Proposed Definition:
  - ‘Microplastic’ means particles containing solid polymer, to which additives or other substances may have been added, and where ≥ 1% w/w of particles have (i) all dimensions 0.1µm ≤ x ≤ 5mm, or (ii) a length of 0.3µm ≤ x ≤ 15mm and length to diameter ratio of >3

- Microplastics shall not, from [entry into force (EiF)], be placed on the market as a substance on its own or in a mixture as a microplastic in a concentration equal to or greater than 0.01% w/w.

- Key exemptions:
  - Natural Polymers
  - Polymers that are biodegradable according to proposed criteria
  - Need to demonstrate biodegradability of all polymeric components if the polymer is a blend (blend is only vaguely defined)
  - Polymers with water solubility > 2 g/L

- Transition period:
  - Ranges 4-8 years from EiF depending on product type

# MICROPLASTICS REGULATIONS: RECENT DEVELOPMENTS



# RECENT ADVANCES IN MORE SUSTAINABLE DELIVERY SYSTEMS BY PATENT PUBLICATIONS

| Company | Total Publications | Materials |
|---|---|---|
| Firmenich | 24 | Poly(ester-urea), polyaminoester, silk fibroin, sodium caseinate and whey protein, chemical cross-linkers |
| Givaudan | 13 | Matrix comprises a starch and a hemicellulose. chitosan, alginate, polyvinylalcohol or tamarind kernel, gelatin, isocyanate |
| IFF | 29 | Proteins, amino acids and polysaccharides, chemical cross-linkers |
| Takasago | 4 | α,β-unsaturated carbonyl compounds (acrylate), multifunctional amine, and solid colloidal particles |
| Encapsys | 13 | Polyacrylate, poly(beta-amino ester), polyurea (chitosan and isocyanate), polypetides/poly-chloroformate (polyurea), methacrylate polysaccharides |
| Calyxia | 11 | Polyacrylate, biopolymer |
| Gem Innov | 5 | Poly(Beta-Amino) Ester |

# RECENT ADVANCES IN MORE SUSTAINABLE DELIVERY SYSTEMS BY PATENT PUBLICATIONS

| Company | Total Publications | Materials |
|---|---|---|
| Procter and Gamble | 672 | poly(vinyl alcohol), chitosan, chitin, pectin, carrageenan, xanthan gum, tara gum, gelatin, konjac gum, alginate, hyaluronic acid, amylose, lignin, dilutant gum, and mixtures thereof; |
| Procter and Gamble | 25 | biopolymer backbone derivatized with a polymerizable functional groups |
| Unilever | 105 | Fabric spray with hydrolyzed plant protein and free perfume; a chitosan-amino acid salt out shell where inner shell is polystyrene, polyvinyl alcohol, polyacrylate, |
| Colgate | 22 | Biodegradable polylactic acid-based polymer for oral care |
| Henkel | 46 | Bacterial spores, pH-sensitive nanocapsules with acrylate chemistry |

# FUTURE TRENDS IN FRAGRANCE ENCAPSULATION

- Green and sustainable chemistry
  - Biodegradable systems to meet ECHA requirements
  - Renewable and naturally derived
  - Benign chemistry
- Tailored fragrance release
  - Diffusive
  - Triggered fragrance release (light, temperature, pH and moisture)
- New format
  - Fabric softener pods
- Expanded applications areas and consumer benefits

# IFF | OUR PURPOSE

## APPLYING SCIENCE AND CREATIVITY FOR A BETTER WORLD

With the beauty of art and the precision of science, we are an international collective of thinkers who partner with customers to bring scents, tastes, experiences, ingredients and solutions for products the world craves.

As a global leader in food, beverage, health, biosciences and sensorial experiences, we do a lot and continually innovate to do it better.

**3,000+**
scientists, engineers, technologists and application professionals

**600+**
flavorists, scent design managers and perfumers, chefs

**130+**
research, technology and innovation centers

**20+**
regional creative and application centers

**40+**
strategic university partnerships

**12,000+**
patents granted and filed

# THE NEW IFF

## A COMPELLING COMBINATION

**iff** — A global leader in taste, scent and nutrition

**Broader**
Set of Ingredients and Solutions

**Deeper**
Innovation and R&D Platform

**Shared**
Focus on Consumer-Oriented End Markets

**~$11B**
Expected Annual Revenue[1]

***~$2.5B***
Expected Annual EBITDA[1 2]

**DuPont Nutrition & Biosciences** — Leading value-added ingredients & solutions provider

**THE NEW IFF**

### STRATEGIC RATIONALE

- **BROADENS CATEGORY EXPOSURE**
- **EXPANDS R&D CAPABILITIES & EXPERTISE**
- **DIFFERENTIATED INTEGRATED SOLUTIONS**

### VALUE PROPOSITION

- Expands breadth of capabilities
- #1 or #2 position across complementary high-value ingredients

- Best-in-class R&D and innovation capabilities and strongest industry pipeline to develop proactive solutions
- Talent with both creative and scientific expertise
- Top quartile R&D spend annually in industry (5.6% of sales), with a significant patent portfolio as a combined company

- Stronger & broadest differentiated product offerings
- Ability to improve speed-to-market
- Greater simplification of supply chain

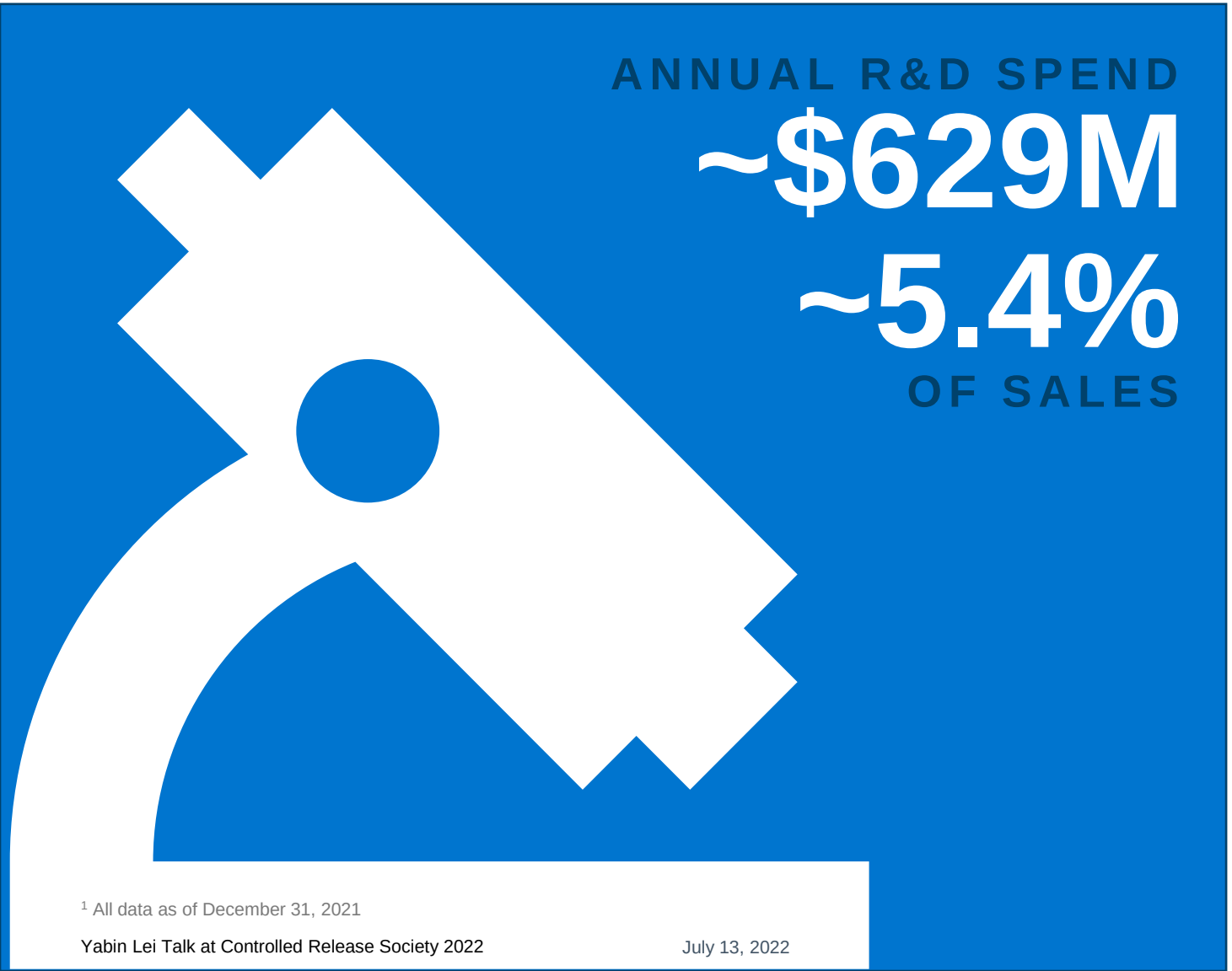
# THE NEW INDUSTRY-DEFINING LEADER

## Scale & portfolio strength creates competitive advantage as industry transforms

| **$11.7B** pro-forma revenue | **1.5X** pro-forma R&D investment | **#1 or #2** in core categories | **20.8%** pro-forma EBITDA margin | **~48%** pro-forma sales to small, medium & private label customers[3] | **~43%** pro-forma emerging market revenue |
|---|---|---|---|---|---|
| Net sales of +$11B. Combined sales grew +10% | Industry-leading R&D investment with an annual budget 1.5x the size of peers | Leader in nutrition, cultures, enzymes, probiotics, soy proteins, flavor & fragrances | Best-in-class financial profile including synergies benefits | 45,000+ customers; Majority in high-growth segments | Truly global footprint with significant exposure to high growth markets |

# IFF RESEARCH & DEVELOPMENT

## Building competitive advantage takes commitment and a proven strategy




- Goal is to develop differentiated solutions that drive consumer preference based on consumer insights
- We do so by prioritizing our investments & spending on the highest return opportunities
- Accelerating the rate & impact of innovation through our first in class innovation pipeline

[1] All data as of December 31, 2021

# INDUSTRY LEADING R&D PLATFORMS & CAPABILITIES

## Innovation supporting divisional growth strategies

### R&D PLATFORMS

- DELIVERY SYSTEMS
- HEALTH & WELLNESS
- MODULATION
- TASTE INGREDIENTS
- SCENT INGREDIENTS
- COSMETIC ACTIVES
- FUNCTIONAL FOOD INGREDIENTS
- PRESERVATION
- BIOBASED ACTIVES, ENZYMES & POLYMERS
- PROTEIN SOLUTIONS

### ENABLING CAPABILITIES

- SENSORY & CONSUMER SCIENCES
- CLINICAL RESEARCH
- ANALYTICAL SCIENCE
- DATA SCIENCE & AUTOMATION
- MATERIAL & APPLICATION SCIENCE
- NATURAL PRODUCT & CROP SCIENCE
- PROTEIN & PATHWAY ENGINEERING
- PROCESS ENGINEERING
- MOLECULAR BIOLOGY & GENOMICS
- APPLIED MICROBIOLOGY
- CHEMICAL & BIOCHEMICAL SYNTHESIS

### CHEMISTRY, BIOLOGY, MATERIAL SCIENCE & ENGINEERING

**Sustainability, Regulatory & Safety**

**Intellectual Property**

# ACKNOWLEDGEMENTS


- IFF Delivery and Material Technology Group
- IFF Global Analytical and Sensory Group
- IFF Materials Characterization Lab