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Functionalized Alginate Microparticles for Fluid Flow Visualization

ECOMMFIT
Experiments, Computation and Modelization in Fluid Mechanics and Turbulence

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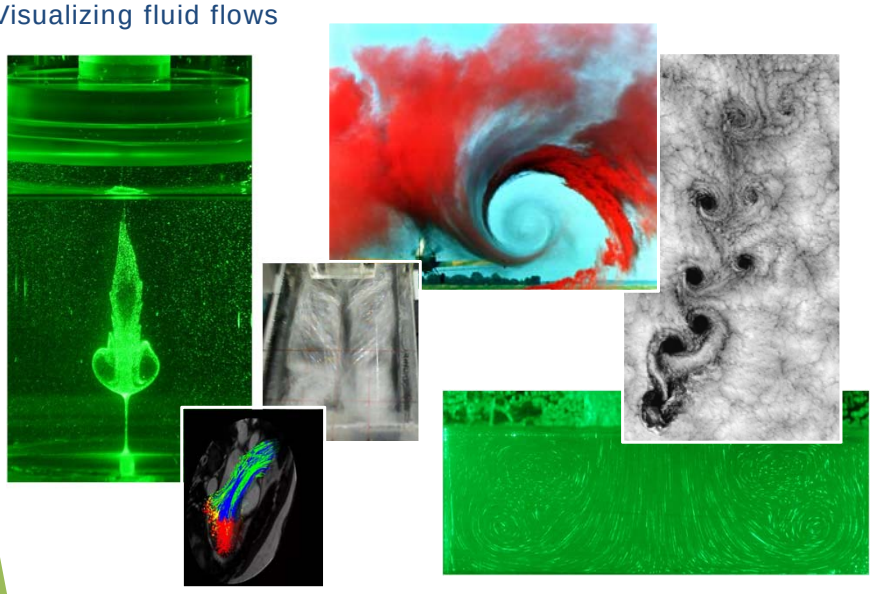
Index

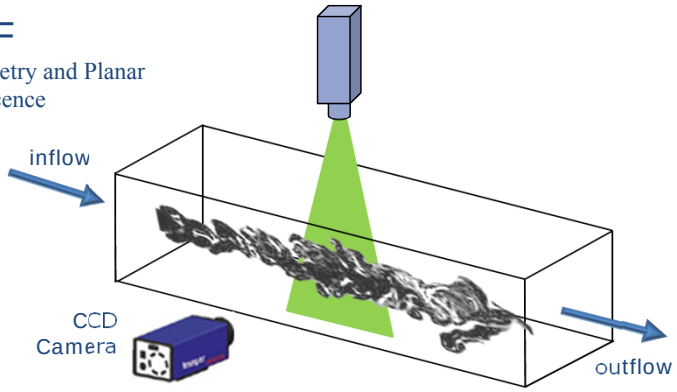
- Visualizing and measuring fluid flows
  - PIV and PLIF
  - Tracer particles
- Alginate particles
  - Preparation
  - Properties
- Applications
- Conclusions

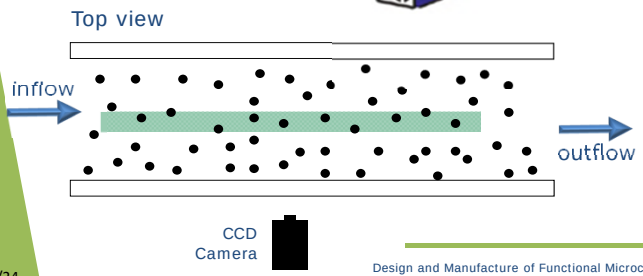
Visualizing fluid flows



PIV and PLIF

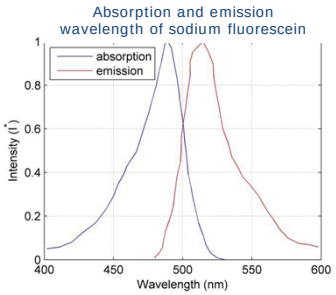
Particle Image Velocimetry and Planar Laser-Induced Fluorescence

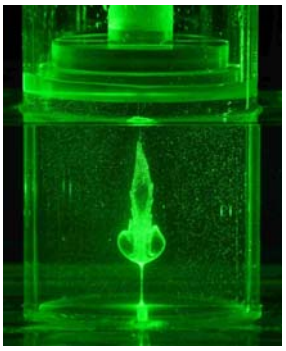


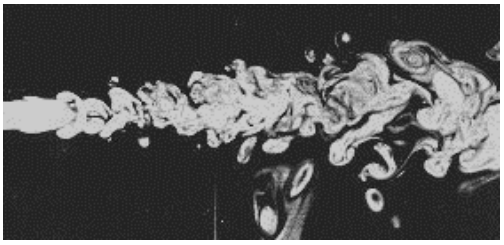


PLIF

- The fluid is stained with dye
- The light source excites the fluorescent dye. Part of the absorbed energy is spontaneously re-emitted causing fluorescence
- For measuring concentration or temperature

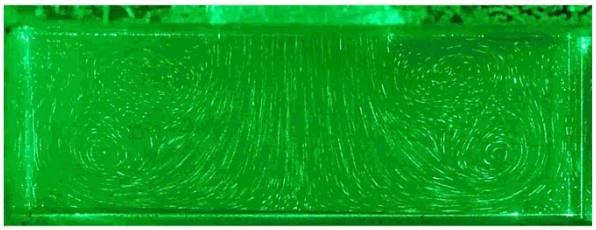




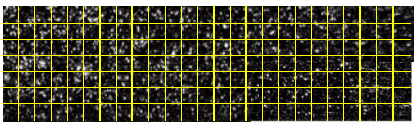


PIV

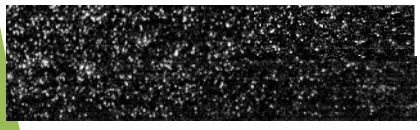
- Particles as tracers
- Velocity measurement

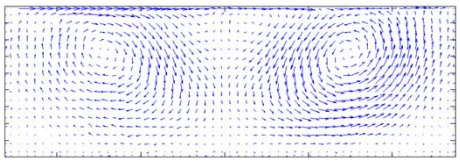


t1

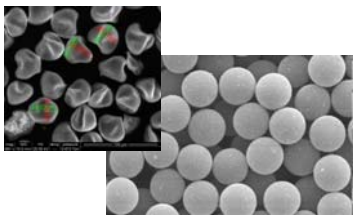


t2

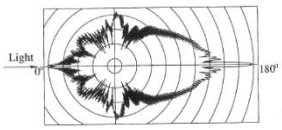




PIV. Tracer particles



- Inherent assumptions
  - Follow the fluid motion
  - No sinking or floating effects
  - Do not change the fluid properties
  - Are distributed homogeneously
  - Uniform displacement within interrogation area
- Size and shape
  - Spherical shape for better scattering the light
  - Small particles follow better the flow
  - Large particles scatters more light

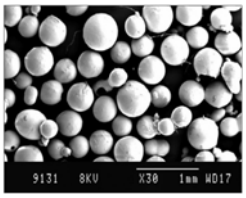


Light scattering by a particle in water (Raffel 1998)

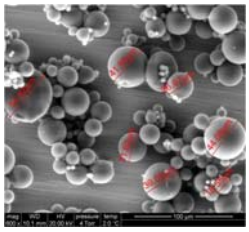
- Some particles used
  - Liquids(10-20 μm): Hollow glass spheres, polystyrene, aluminum, lycopodium, air bubbles,…
  - Gases (1-5 μm): polystyrene, aluminum, oil microdrops,…

Why alginate particles for PIV?

- They have been widely used in food and pharmaceutical industries to encapsulate drugs and proteins
- Easy to produce
- Good control of the size (from 1 to 100 μm)
- Smooth spherical shape
- Special substances can be added to functionalize de particles (Fluorescein, Rhodamine,…)
- Porous. Can be used in different fluids
- Soft. Can be used in systems with moving walls and contact walls



Alginate particles with products for treatment of colon infection

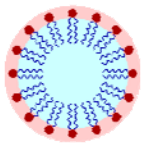


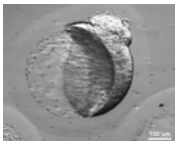
Preparation

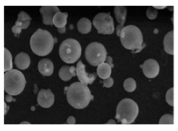
- Method
  - Emulsification / internal gelation
- Materials
  - water solution of sodium alginate
  - rhodamine B (optional)
  - iso-octane solution containing SpanTM 85
  - iso-octane and TweenTM 85
  - calcium chloride solution
- Production stages
  - Mixing and particle formation
  - Separation of particles by decantation
  - Cleaning
  - Drying and sieving

Production process

- Mixing and particle formation
  - A solution of water and sodium alginate, and optionally Rhodamine B, was dispersed in an iso-octane solution of SpanTM 85 using a magnetic stirrer.
  - A solution of iso-octane and TweenTM 85 was added into the emulsion and stirred. At this point the working solution contains spherical liquid droplets
  - Calcium chloride solution was added and mixed to form the solid particles
  - A sonication process was used to disaggregate and control the size of the particles
  - Surfactant hydrophilic-lipophilic balance, stirring velocity, alginate concentration and ultrasonic agitation affect the final diameter







Production process

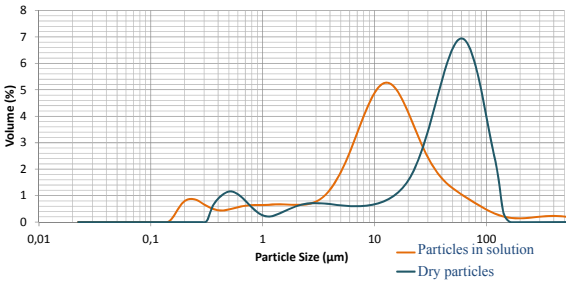
- Separation and cleaning
  - Microparticles are collected by decantation
  - The particles obtained are washed with water and decanted again
  - The process is repeated several times (3 to 7) until the greasy phase disappears
  - The final product are particles in aqueous solution

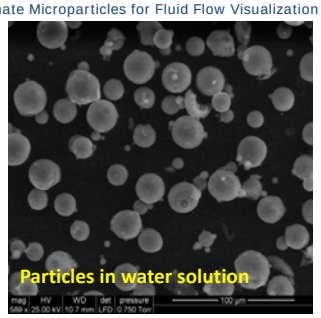
Production process

- Drying and sieving
  - Particles are ready to use in water
  - Drying is necessary for using the particles with different fluids but is a process not well defined
  - The process used consist in drying the particles with a heater under gentle and continuous stirring and crushing the particles with a mortar
  - Finally the particles are sieved
  - The process change de spherical structure of the small particles making some aggregates that ends with a wider band in particle size

Production process

- Drying and sieving

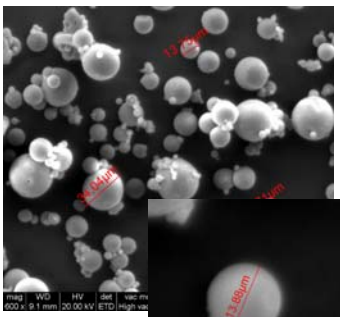


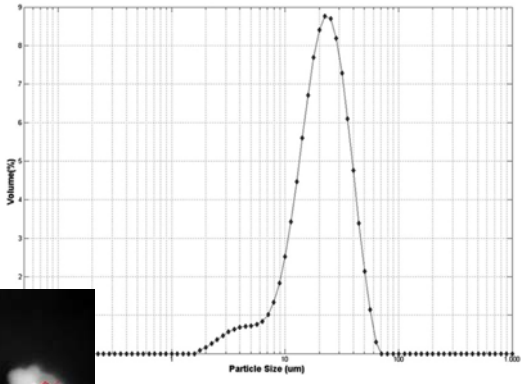


- The procedure is not good enough as it change the spherical structure of the small particles making some aggregates that ends with a wider band in particle size

Properties

- Size distribution

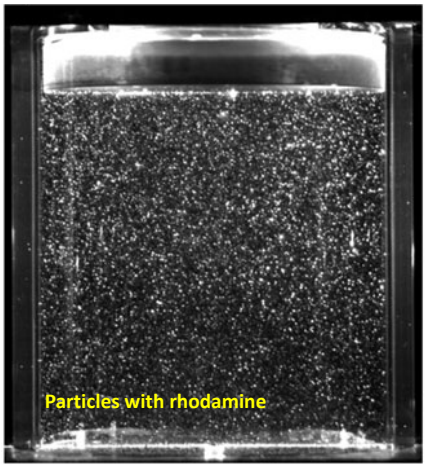


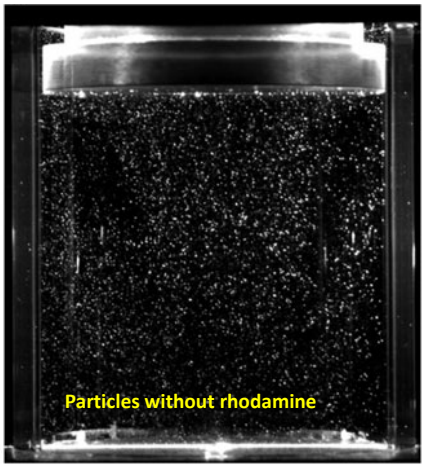


Properties

- Addition of rhodamine

Both images have the same experimental conditions: concentration of particles (0.05 g/l), sensor gain, acquisitions rate (100 Hz) and exposure (5000 ms)



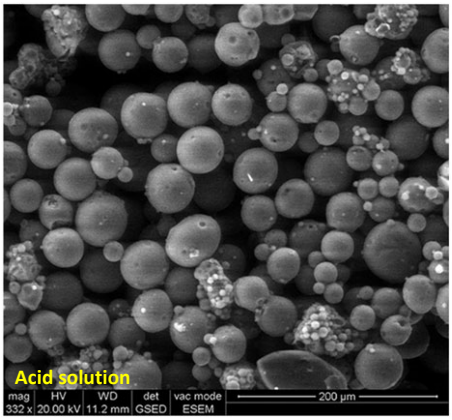


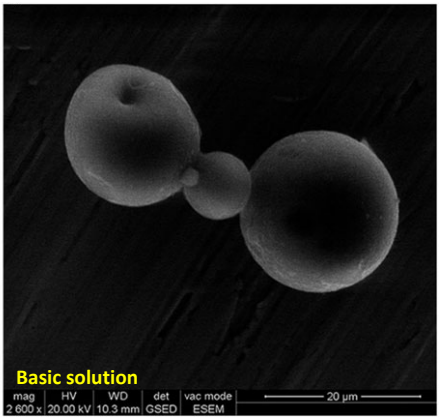
Properties

- Degradation in aggressive mediums

The particles have been maintained in an acid fluid (acetic acid, pH = 4) and in a basic fluid (ammonium hydroxide, pH = 10) during 2 days.

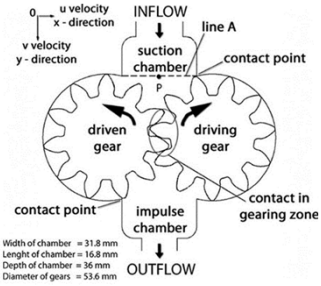
The microparticles preserve the same shape and aspect, and degradation cannot be appreciated

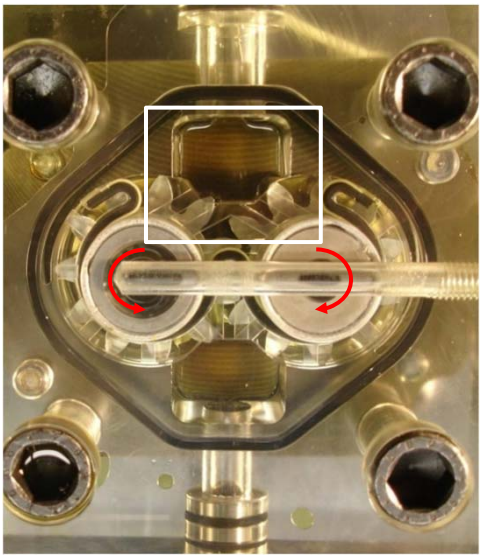




Applications

- Flow in a gear pump
  - Fluid: oil
  - Alginate particles of 10 µm
  - Analysis of the flow in the suction chamber

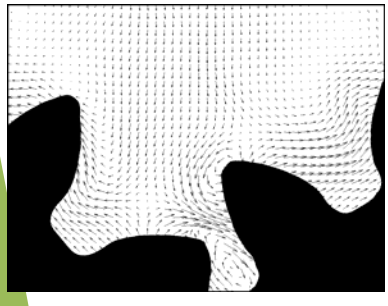


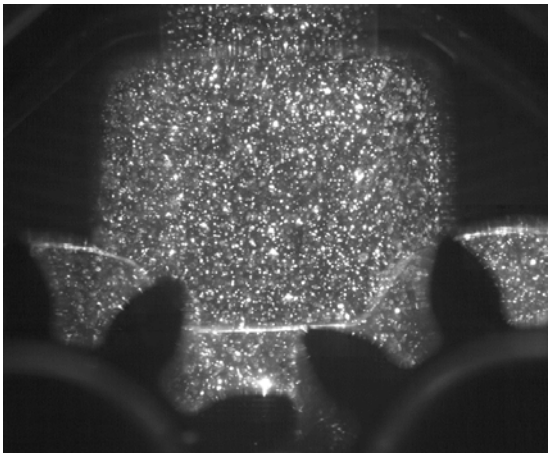


Functionalized Alginate Microparticles for Fluid Flow Visualization

Applications

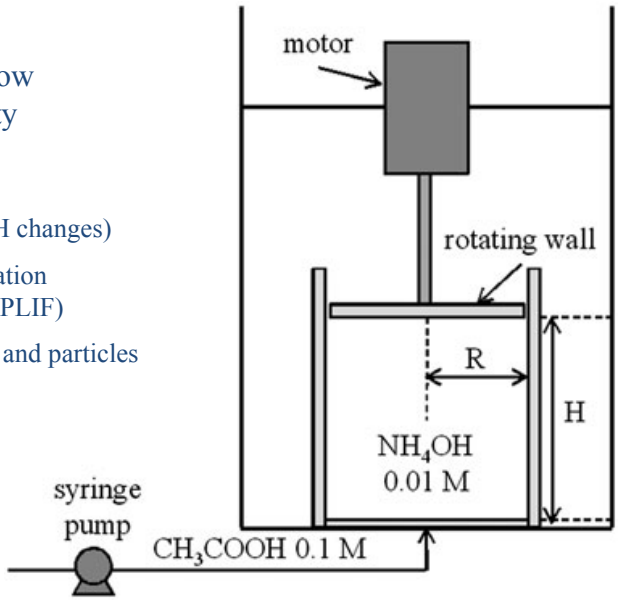
- Flow in a gear pump





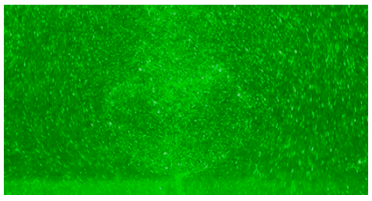
Applications

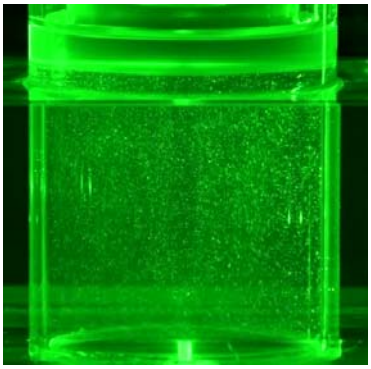
- Confined reactive flow in a cylindrical cavity
  - Fluid: water solutions
  - Acid-base reaction (pH changes)
  - Velocity and concentration measurements (PIV + PLIF)
  - Fluid with fluorescein and particles with rhodamine

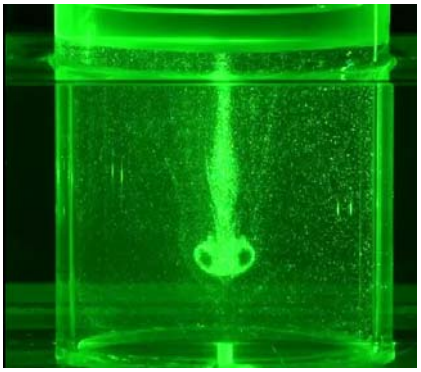


Applications

- Confined reactive flow in a cylindrical cavity



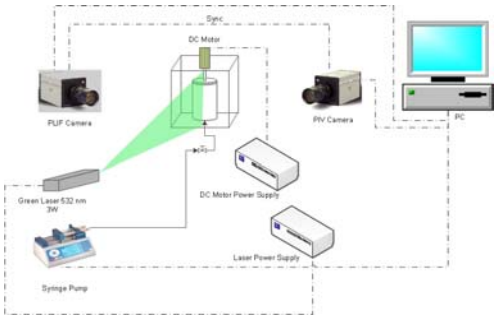


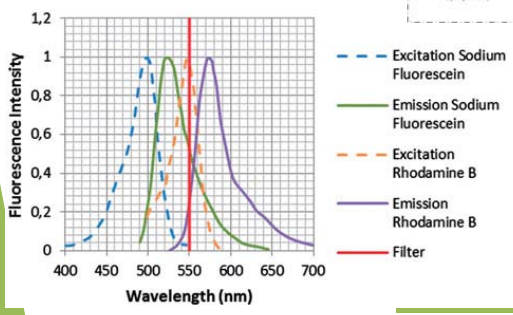


Images: Ildefonso Cuesta

Applications

- Confined reactive flow in a cylindrical cavity
  - The signal emitted by the tracer particles and by the fluorescence dye need to be separated





- As rhodamine and fluorescein have different emission wavelength, a filter can be used to separate both signals.

Applications

- Confined reactive flow in a cylindrical cavity

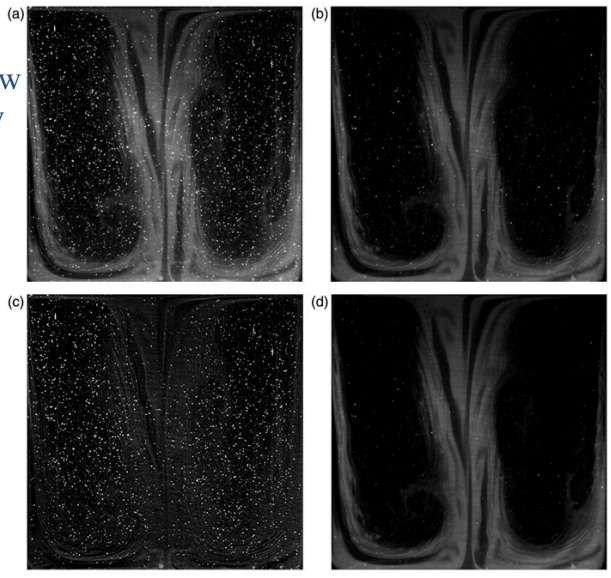
PIV and PLIF images at Re=1000 and t=10 min

(a) Original PIV image (particles + fluorescein)

(b) Original PLIF image

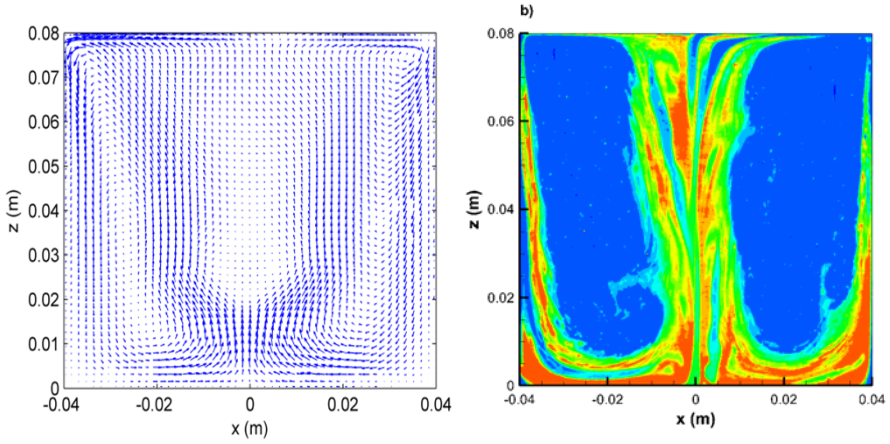
(c) Final PIV image

(d) Final PLIF image



Applications

- Confined reactive flow in a cylindrical cavity



Conclusions

- Alginate microparticles can be used as a tracer particles for flow visualization and measurement
- The porous structure of the particles allow their use for fluids with different densities
- Alginate microparticles have soft a structure. Thus they do not cause any damage to the inner contact surface of the machines
- The diameter of the alginate microparticles made with the internal gelation technique can be easily controlled just changing preparation techniques.
- It has been demonstrated that alginate microparticles has a good chemical resistance in acid–base media, such as acetic acid and ammonium hydroxide in different concentrations.
- The tracer particles functionalized with Rhodamine B allows apply PIV in complex experimental analysis like in synchronized PLIF applications.