Characterising fluid flow using Positron Emission Particle Tracking

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Positron Emission Particle Tracking (PEPT)

- Non-invasive technique for measuring flow within opaque multiphase systems.
- Positron emitting particle matching physical properties material of interest.
- Back-to-back gamma rays emit from positron/electron anihilation (Fig 1.).
- Gamma rays penetrate through system under study before being recorded by positron camera (Fig 2.).
- Three dimensional particle position determined algorithmically at high temporal resolution.
- Kinematics and dynamics of tracer particle behaviour determined from the trajectory (Fig 3.)

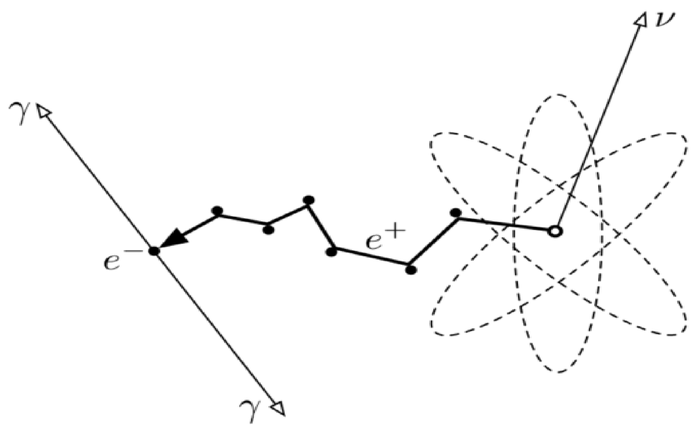

Figure 1: Positron emission and annihilation with electron producing a pair of nearly collinear 511 keV gamma rays.

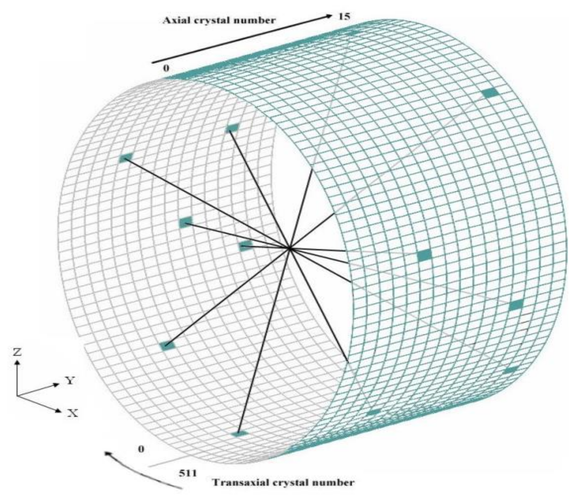

Figure 2: PET scanner recording emitted gamma rays from resultant positron annihilation.

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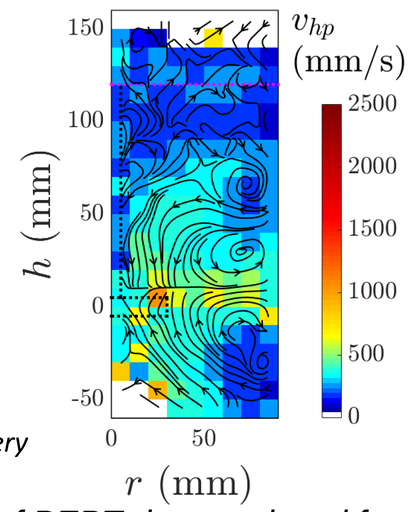

Figure 3: Example of PEPT data analyzed for determining velocity field of particles in flotation cell [1].

Tracer development for flow studies.

Sodium alginates are water soluble polymers typically derived from alginic acid. When exposed to multivalent ions in solution they are capable of forming hydrogels. The alginates form hydrophilic polymers with a high water content when dissolved. A ^{68}Ga eluate supplied by a ^{68}Ge/^{68}Ga generator is evaporated and re-dissolved in 100 – 200 µL de-ionised water, the solution is again dried to incipient dryness. Adding a dilute sodium alginate solution to the nearly-dried ^{68}Ga salt forms the three-dimensionally cross-linked networks constructs giving rise to the gel-based network commonly called “egg-box” as shown in Figure 4. This forms a nearly neutrally buoyant positron-emitting particle that can be used to characterize the flow for a system of interest.

Ø range [mm]	Activity [µCi]
0.5-0.8	250
0.8-1.1	1100
1.0	480
0.6-1.0	2100
0.8-1.0	1600
1.0	1100
0.2-0.3	430

Table 1: Preliminary tests on producing ^{68}Ga PEPT tracers using alginate based polymers.

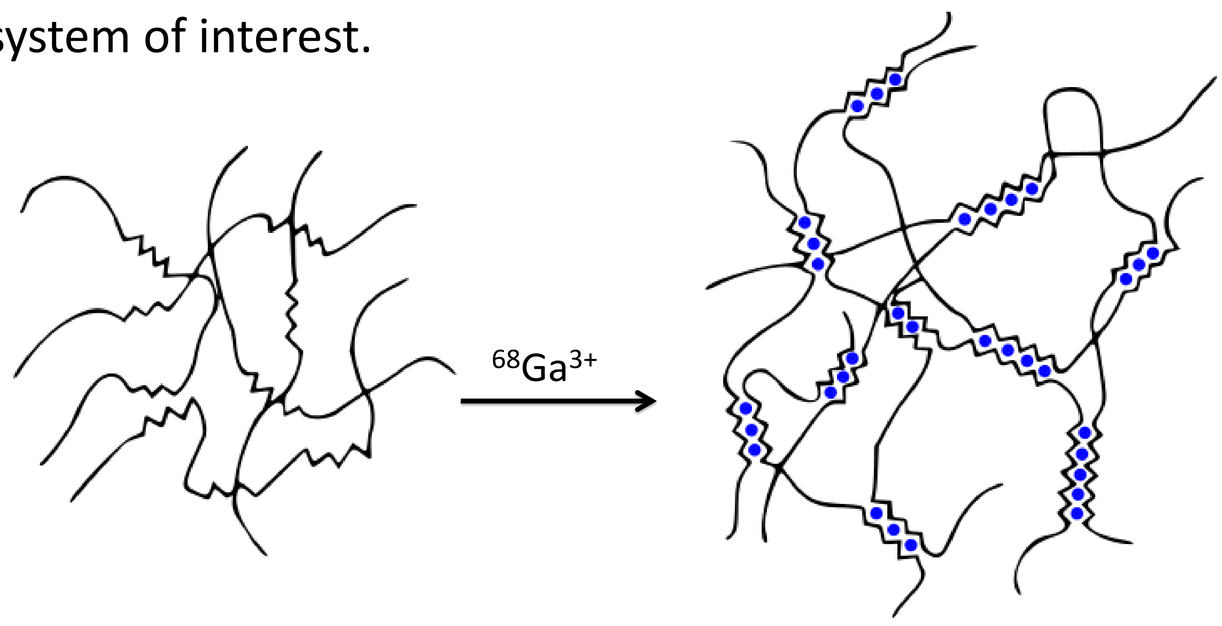

Figure 4: Illustration of $^{68}Ga^{3+}$ (represented as blue dots) binding with α-L-guluronic acid groups (represented by the zig-zag) pattern to form “egg-box” three dimensional network from the linear alginate polymers..

Table 1 confirms the alginate based tracers are sufficiently radioactive for tracking with PEPT. It was determined that the pH of the initial ^{68}Ga solution used for cross-linking as well as the concentration of sodium alginate solution were critical in tracer production. The activities of the initial tests are sufficient for use in PEPT although the method requires further development to reduce activity leaching as well as reduce the average size of each particle. Future work will include using this tracer type to determine the degree of representation they have to fluid flow being analysed through comparison with other tracking techniques.

Conclusion

The quality of information collected from PEPT experiments relies directly on the ability of the tracer to represent the media being investigated. The typical scale of particles of interest are on the mm scale and smaller. Further development into increasing activity per unit volume of these alginate tracers is motivated by the requirement to make the flow follower to match the scale or turbulent flow. This will further expand the possible fundamental studies and validation of models for Newtonian fluid flow.

[1] Buffler, A. et al. (2011) PEPT Cape Town the first year of research. Southern African Institute of Mining & Metallurgy Western Cape Branch: MinProc 2011 Conference MinProc Conference: Proceedings of the conference, South Africa.