Development and characterization of photo-polymeric scintillating microfluidic waveguides

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Motivation, approach and challenges

A novel type of particle detector based on scintillation, is currently being studied at CERN in close collaboration with EPFL. It consists of a single microfluidic channel filled with a liquid scintillator and is designed to define an array of scintillating waveguides each independently coupled to a photodetector \cite{1,2}. The microchannels can be fabricated, among other materials, in silicon or polymers. In the latter case, if the refractive index of the polymer is lower than that of the liquid scintillator, light can be guided along the microchannels by total internal reflection (TIR). This work presents the fabrication process of microchannels with different photo-polymer as well as the preliminary results obtained with the first set of such channels.

Fabrication process

1) Preparation of liquid polymer precursors
2) A flat plate and a plate with the microchannels were moulded by photo-polymerizing the precursors in PDMS moulds.
3) Microchannels were sealed by adhesive bonding \cite{3} of the two plates. In particular, a thin layer of liquid polymer precursor, used as glue, was UV-cured to obtain HBP and X-40 microchannels.

Process dynamics

\textbf{X-40} and \textbf{HBP} formulations (concentration of photo-initiator) were optimized by real-time photo- rheological \cite{4}, linear shrinkage and internal stresses \cite{5} analysis during polymerization. PMMA photoinitiator concentration was optimized by empirical experiences.

Radiation resistance

Samples of the three materials were placed into a 24 GeV proton beam. Their mechanical and optical properties at the emission peak of the scintillator were measured as a function of the deposited radiation dose.

Particle detection experiments with HBP microchannels

Accounting for its good radiation resistance and ease of fabrication, an HBP microchannel was produced. Attenuation length of such polymer structure filled with an organic liquid scintillator was measured by optically coupling it to a photodetector \cite{6}. A radioactive source was scanned along the microchannels to determine the light yield and attenuation of the HBP detector.

Conclusions

- A fast and repeatable process flow for the production of scintillating microfluidic waveguides was developed successfully for X-40 and HBP photo-polymer.
- The concentration of photoinitiator in the formulations with fastest reaction and minimal shrinkage and internal stresses (2\%wt for X-40 and 1.5\%wt for HBP) were optimized using photopolymerization.
- PMMA underwent severe damages after an irradiation dose of 10^5 Gy whereas X-40 and HBP were stable up to an irradiation dose of 10^6 Gy.
- Preliminary experimental results obtained with HBP microchannels demonstrate the feasibility of scintillating microfluidic waveguides with photo-polymer.