Study of Transparent Silica Aerogel with High Refractive Index

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Introduction

Silica aerogel as a Cherenkov radiator

Unique refractive index

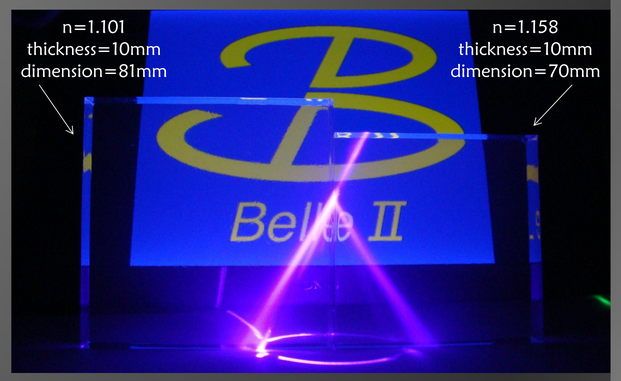
- n=1.0026-1.11 (conventional production method)
- n=1.05-1.26 (new production method)

cf. air (gas) : n=1.0003, water (liquid) : n=1.33

New aerogel production technique

Pinhole Drying (PD) method

- (ultra-) high refractive index → new PID window
- highly transparent → use in focusing RICH, (downstream aerogel requires high transparency because most of photons pass through the layer)
- hydrophobic → maintenance free



New Aerogel Production Technique – Pinhole Drying (PD) Method –

Production process

1. Alcogel (wet gel) synthesis & Aging
2. Pinhole drying
   - enclose the alcogel in a semi-sealed container
   - solvent evaporation from the alcogel body
   - shrinkage of the alcogel and increase in density (one week – a few months)
3. Solvent displacement (ethanol immersion)
4. Hydrophobic treatment & Rinse (ethanol immersion)
5. CO_2 supercritical drying

Refractive index control → (A) + (B)

(A) Mixing ratio of raw chemical solutions

(B) Degree of the pinhole drying (shrinkage)

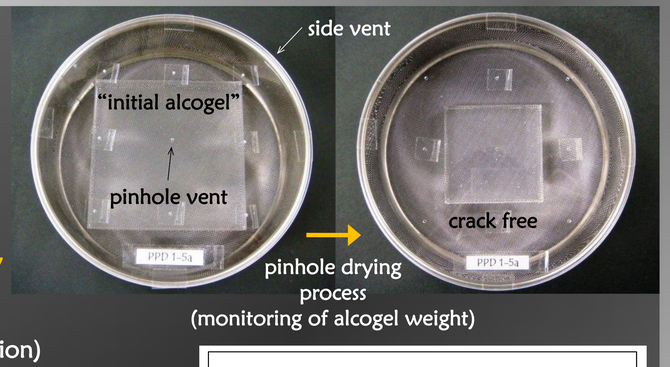
Initial alcogel selection

Solvent of synthesis

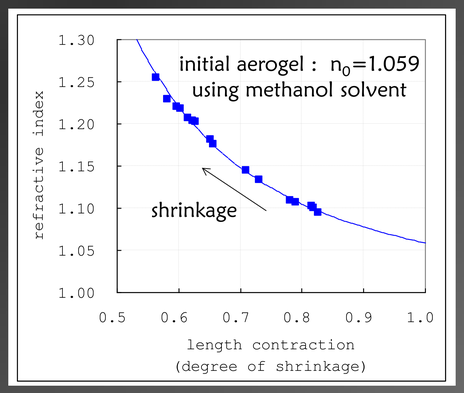
- methanol → produced in a short PD period
- N,N-dimethylformamide (DMF) → high transparency

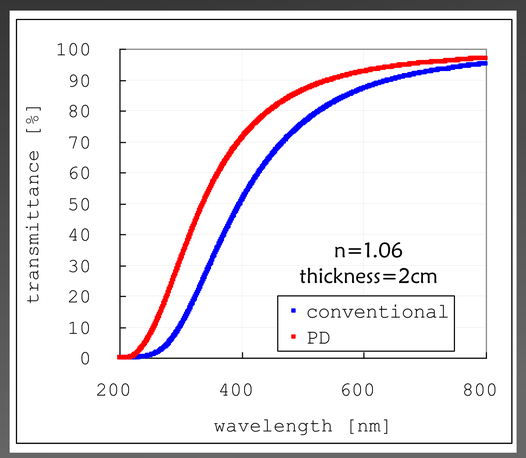
Initial refractive index

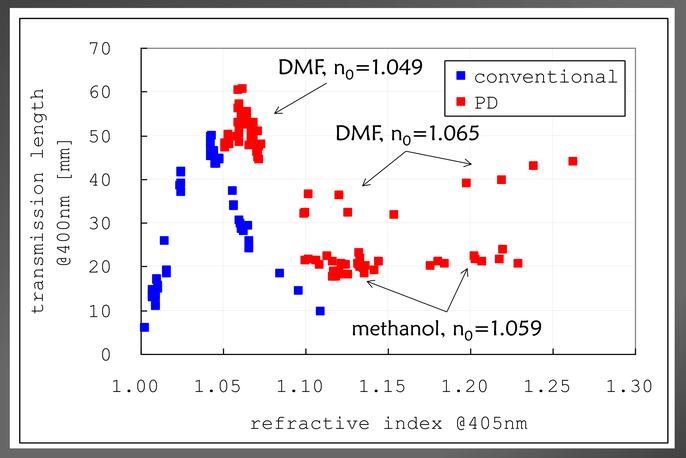
- high refractive index (n_0~1.06) → produced in a short PD period
- low refractive index (n_0~1.05) → high transparency



pinhole drying process (monitoring of alcogel weight)

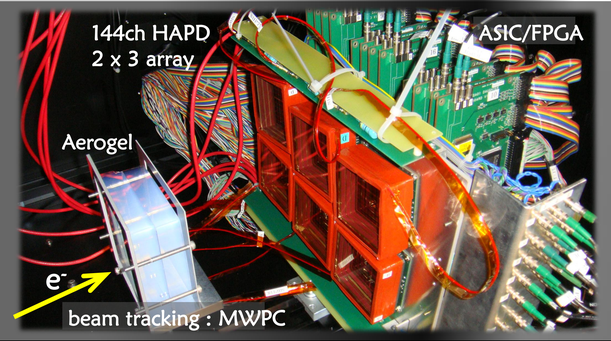






Performance of PD-aerogel – Beam Test Results –

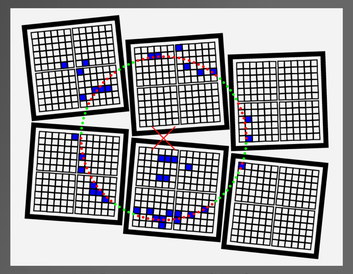
- @KEK Fuji Test Beam Line (FTBL) in Nov. 2009
- 2 GeV/c electron beams
- prototype aerogel RICH counter for the Belle-II end-cap apparatus
- new PD-aerogels, new HAPDs, new ASICs (realistic configuration)



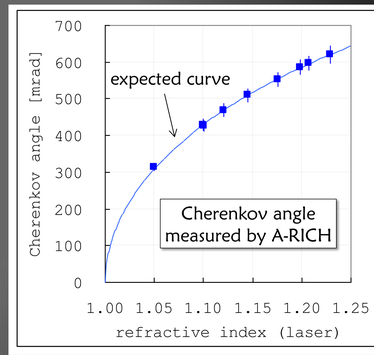
n=1.045-1.06 : 2cm x 2 layer focusing configuration

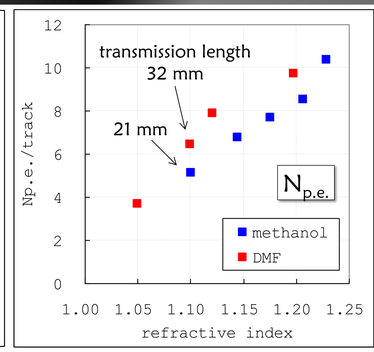
Aerogel configuration (refractive index)	Angular resolution (per single photon)	Photon yield ($N_{p.e.}$)	Angular resolution (per track)	π/K separation capability @4GeV/c
1.046 + 1.055	14.5 mrad	9.2	4.8 mrad	4.7σ
1.045 + 1.051(PD)	15.3 mrad	12.1	4.4 mrad	5.3σ
1.051(PD) +1.059(PD)	14.8 mrad	13.6	4.0 mrad	5.4σ

Ultra-high refractive index : 1cm single layer



RICH event display





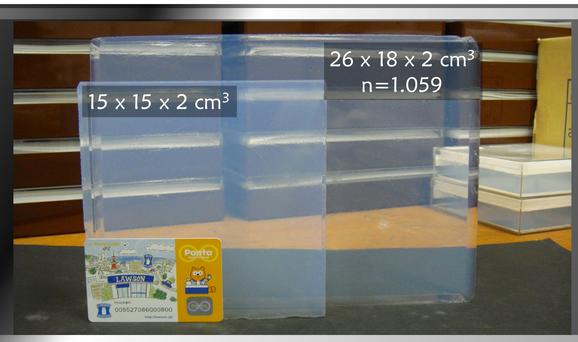
Studies for practical use

Large tile production

- n=1.045-1.06 (conventional production method)
- crack free sample : 26 x 18 x 2 cm^3 by Panasonic Co.,Ltd.

Neutron dose test

- Yayoi reactor at the Univ. of Tokyo in Mar. 2010
- dose level : 1 x 10^{12} n/cm^2 (Belle-II 10years)
- sample aerogel : n=1.062 (PD)
- → no change in both refractive index and transmittance



Summary

- New production method of silica aerogel has been invented: Pinhole Drying (PD) method.
- Refractive index of aerogel is well controlled in a range of up to n=1.26 by the PD method.
- The PD method can produce highly transparent aerogel (transmission length : up to 60 mm at n=1.06).
- Performance of PD-aerogel has been demonstrated by the beam test (π/K separation capability at 4 GeV/c : 5.4σ).
- Studies for practical use of aerogel have been conducted: Large tile production, Neutron dose test.

References

- [PD method] M. Tabata, *et al.*, Nucl. Instr. and Meth. (2010) in press; M. Tabata *et al.*, Proc. Nucl. Sci. Symp. IEEE 2005, p.816.
- [Aerogel by DMF solvent] I. Adachi, *et al.*, Nucl. Instr. and Meth. A 595 (2008) 180; I. Adachi, *et al.*, Nucl. Instr. and Meth. A 553 (2005) 146.
- [Focusing A-RICH] T. Iijima, *et al.*, Nucl. Instr. and Meth. A 548 (2005) 383.
- [HAPD] S. Nishida, *et al.*, Nucl. Instr. and Meth. A 610 (2009) 65; I. Adachi, *et al.*, talk in this workshop (ID=45).