1. Abstract
We present the results of radioactivity contamination tests on a novel contamination-safe scintillation detector for alpha and beta radiation detection in water, as follow-up of the TAWARA RTM project. This detectors are large-area silicone-based scintillators with functionalized surface, representing an improvement in the realization of radioactivity monitors for water with high sensitivity and reasonable costs.

2. Intro

- Short path-length of alpha and beta in water
- Low detection limit (international legislations)
- Direct contact with water
- No protective layer 1) detector surface contamination
- If protective layer 2) passive layer contamination

Our solution: large area silicone-based scintillator with functionalized surface
- No need of passive protection layer/window
- Low surface contamination
- Can be easily decontaminated
- Flexible

3. Materials

- **Silicone matrix**: polydimethylsiloxane (DMS-V21)
  - After cross-linking → elastomeric material
  - Hydrophilic
  - Transparent in the range 330-2200 nm
  - Wide range of temperature (-10°C to 250°C)

- **Active silicone matrix**: polydimethylsiloxane Gelest P72-52311 + primary dopant: 2,5-diphenyl-oxazole (2.5%wt )
  - secondary dopant: Lumogen F Violet 570 (0.05%wt)

- **Passive silicone matrix**: passive layer contamination
  - Low detection limit (international legislations)

- **Fluorinated protective film**: nanometric trichloro[1H,1H,2H-perfluorocyclo]silane film
  - Fluorinated organic chain
  - Omnichromatic layer
  - Reduce surface contamination

4. Production @University of Padova

1. Mixing liquid silicone and cross-linking agent
2. Add ZnS:Ag powder
3. Pour the liquid mixture in a mold → 1 mm thick layer
4. Powder sedimentation overnight (p_{sed} > 1 g/cm³, \rho_{Ag} = 4.9 g/cm³) → 50 μm layer with 60%wt of ZnS:Ag
5. Silicone cross-linking in oven at 70°C, 1 h → solid elastomeric slab can be peeled off
6. Surface functionalization with fluorinated silane film by vapour phase deposition

5. Detection performance @University of Padova

6. Contamination tests @ ENEA

Samples 5 x 5 cm² square detectors:
1. passive silicone + ZnS:Ag
2. active silicone + ZnS:Ag + fluorosilane
3. active silicone + ZnS:Ag + Ag-beta detector
4. F Violet 570 (0.05%wt )
5. EJ-en 440 discs

- Couples of samples mounted back-to-back on plastic supports and sealed at the edges
- Sets of 8 couples are mounted on a rack attached to the moving arm of a dip-coater

- Contamination by immersion and motion inside an aqueous solution of Cs-137 or Co-60
  - Varying concentration (specific activity 1, 10, 100 kBq/L)
  - Varying bath time (30', 90', 150')

- After contamination, samples are rinsed with DI water and discs are cut out

Decontamination tests:
- A sub-set of samples is washed after contamination following different procedures
  - Immersion in a solution of CONTRAD 2000 for 30’
  - Immersion in a solution of HCl 0.5M for 30’
  - Immersion in a solution of CONTRAD 2000 for 30’ + rubbing with a soft towel
  - Immersion in a solution of HCl 1.5M for 30’

- Detector performances are not affected by the decontamination procedures

7. Contamination measurements @ ENEA

Residual contamination measured using a very low-background and calibrated gamma detection system

- Contamination level saturates after just some minutes
- Approx. linear growth of contamination with increasing specific activity
- Silicone-based detector less contaminate by a factor 10^2/20 with respect to commercial EJ-440
- Fluorinated film further decrease residual contamination

8. Conclusions

- Good detection efficiency for alpha and beta radiation
- High hydrophobicity, chemical resistance and long-term stability of the surface
- Negligible contamination level after exposition to radioactive aqueous solutions
- Possibility to cleanup the surface from possible residual contaminations using chemical cleaning agents without damaging the detector
- Low production cost

References