Electronic Supplementary Material (ESI) for Materials Chemistry Frontiers.

ESI: Sized-controlled synthesis of $^{6}Li_2{}^{10}B_4O_7$ NPs for fast/thermal neutrons and gamma rays detection in plastic scintillation

Camille Frangville[a], Amélie Grabowski[a], Jonathan Dumazert[a], Eva Montbarbon[a], Clément Lynde[a], Romain Coulon[a], Amélie Venerosy[b], Guillaume H. V. Bertrand[a], Matthieu Hamel[a,*]

Matthieu.hamel@cea.fr
CEA, LIST, *Laboratoire Capteurs et Architectures Electroniques*
CEA Saclay
91191 Gif-sur-Yvette. FRANCE

$Li_2B_4O_7/PVP_{40k}$ hybrid aggregate drying methods prior curing

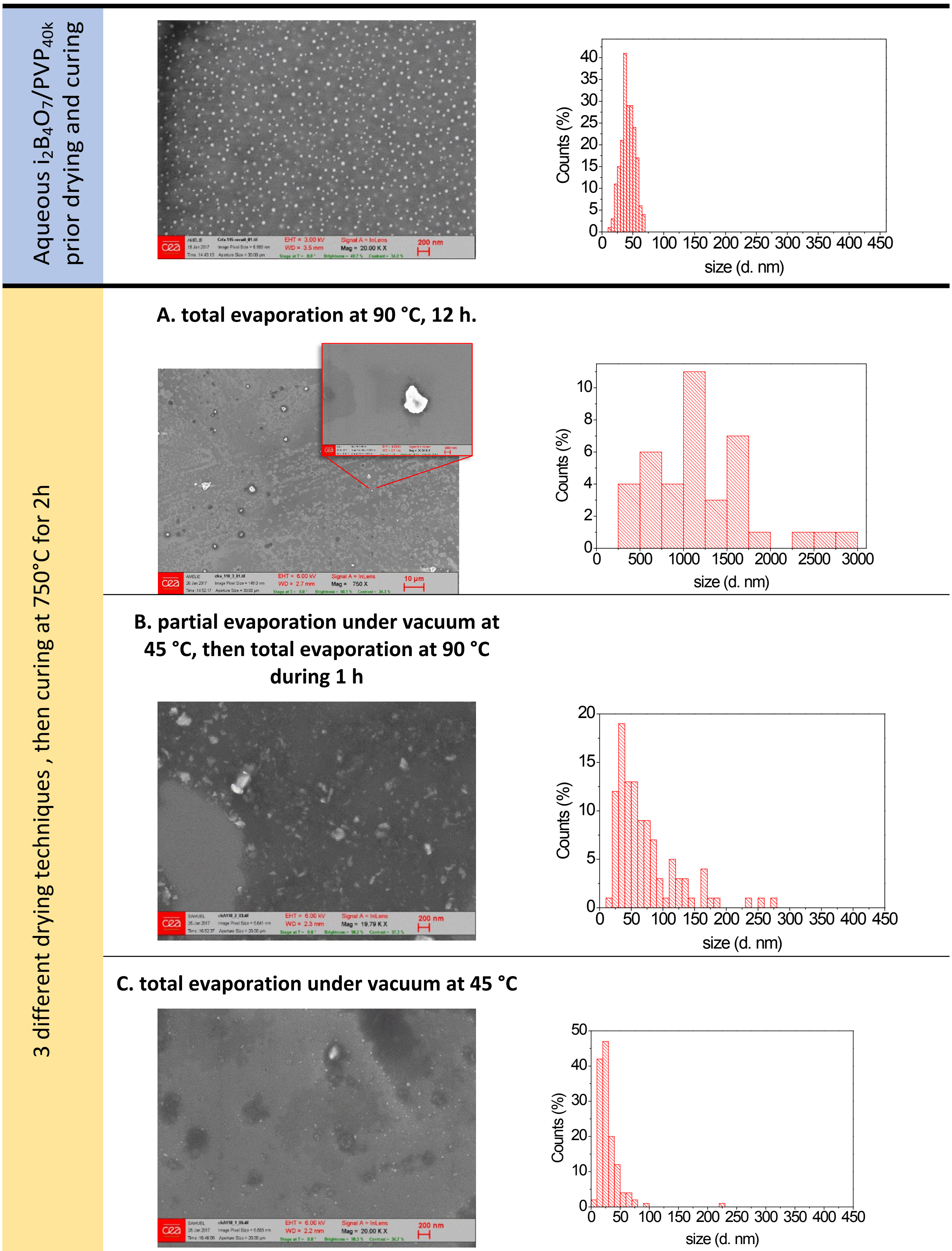


Figure SI-1. SEM images and polydispersity figures of various drying methods prior to curing. A: total evaporation at 90 °C, 12 h. B: partial evaporation under vacuum at 45 °C, then total evaporation at 90 °C during 1 h. C: total evaporation under vacuum at 45 °C. For all experiments, the final curing process is performed at 750 °C during 2 h.

Enriched $^{6}Li_2{}^{10}B_4O_7$ NPs

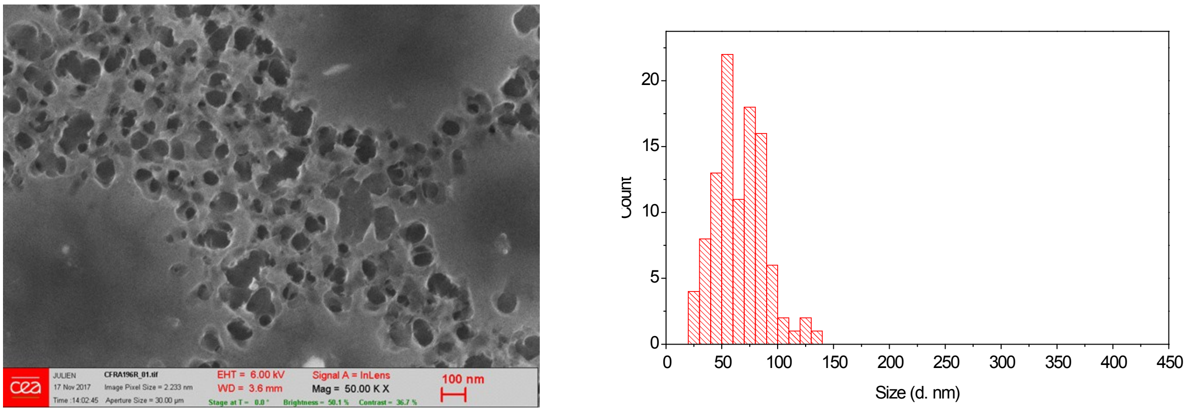


Figure SI-2. $^{6}Li_2{}^{10}B_4O_7$ NPs; left. SEM images, right. corresponding NPs size distribution.

$^{6}Li_2{}^{10}B_4O_7$ NPs loaded plastic scintillator

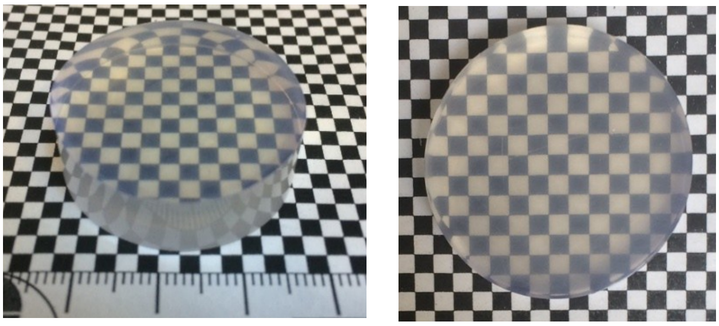


Figure SI-3. Pictures of a 0.3wt% $^{6}Li_2{}^{10}B_4O_7$ NPs loaded PS; diam. 32mm; height 11mm

Table SI-1. Characteristics of the lithium tetraborate-loaded plastic scintillator used in this study.

Diameter (mm)	31.8
Thickness (mm)	10.6
Weight (g)	9.1746
Density (g.cm^{-3})	1.09
Shore-D hardness	85
^{6}Lithium content (wt%)	0.0082
^{10}Boron content (wt%)	0.0256
λ_{em}^{max} **(nm)**	424
Transmission at 424 nm (%)	17
Decay time (ns; λ_{ex} = 274 nm)	2.17 (86.1) + 9.02 (13.9)
Decay time (ns; λ_{ex} = 368 nm)	1.80
Scintillation yield (ph.MeV^{-1})	3750

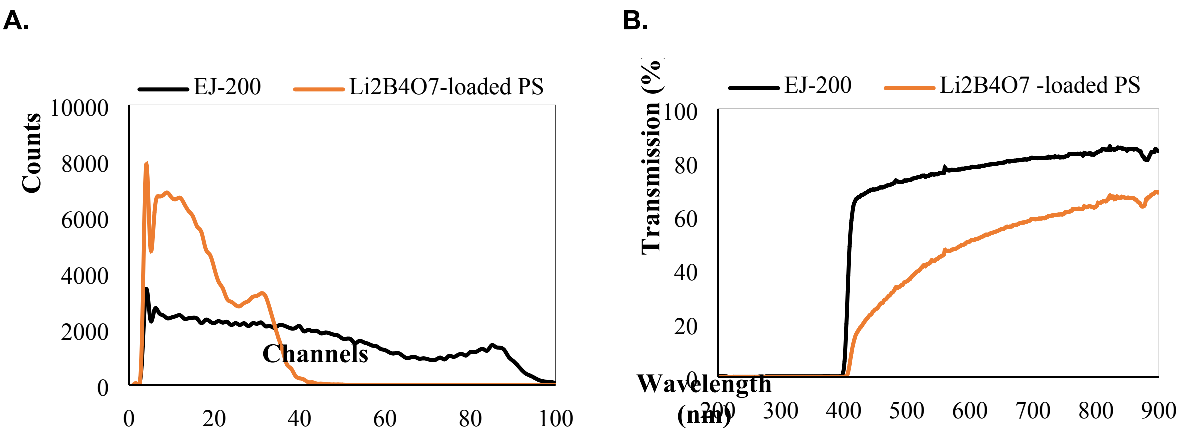


Figure SI-4. A.Pulse height spectra and B. Transmission spectrum of $^{6}Li_2{}^{10}B_4O_7$ –loaded PS and EJ200 (corresponding sizes)

$n_{thermal}$, n_{fast} and gamma detection

Table SI-2. ^{6}Li and ^{10}B thermal neutron captures.

Isotope	Thermal neutron capture reaction	25 meV cross section (Barns)	Natural isotopic abundance (%)
^{6}Li	$^{6}Li + n \rightarrow {}^{3}H\ (2.73\ MeV)\ +\ \alpha\ (2.05\ MeV)$	940	7.5
^{10}B	$^{10}B + n \rightarrow {}^{7}Li *\ +\ \alpha\ (1.47\ MeV) \rightarrow {}^{7}Li +\ \alpha\ (1.8\ MeV) +\ \gamma\ (0.48\ MeV$	3840	19.9

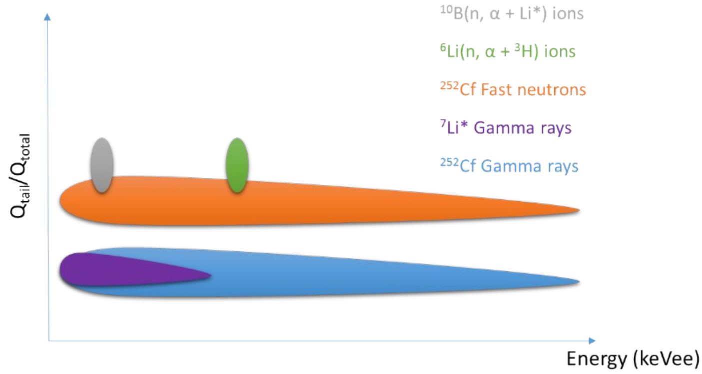
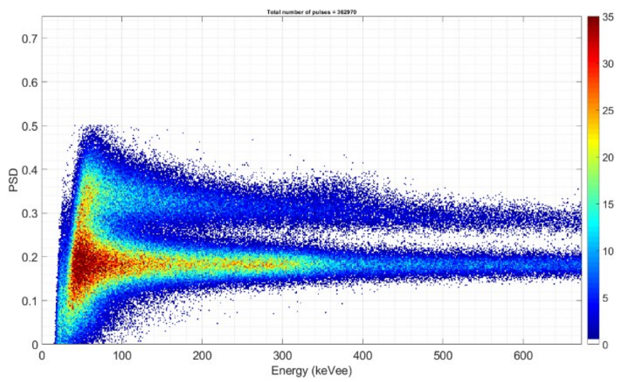
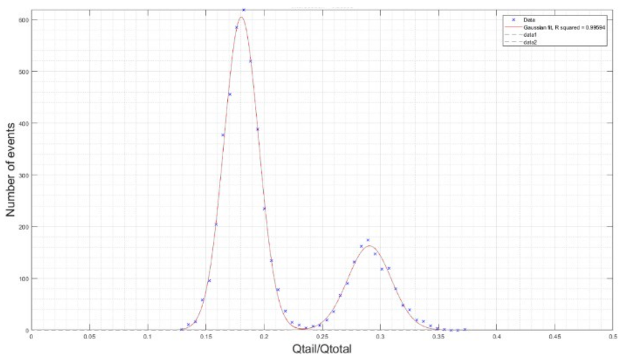


Figure SI-6. Ideal response of the NPs-loaded plastic scintillator towards a thermalized neutron source.

A.



B.



Energy range (keVee)	FoM value
230 – 270	1.15
270 – 310	1.21
310 – 350	1.15
350 – 390	1.16
420 – 460	1.36
460 – 500	1.40

Figure SI-7. A. Neutron/gamma pulse shape discrimination pattern of the $^{6}Li_2{}^{10}B_4O_7$ nanoparticles-loaded plastic scintillator. Partially thermalized and shielded ^{252}Cf source. B. Example of PSD cut [460;500 keVee] with the gamma (left) and the neutron (right) responses with corresponding FoM.

The quality of the PSD is quantitatively estimated from the calculation of the Figure of Merit (FoM), which has the following formula:

$$FoM = \frac{|\mu_n - \mu_\gamma|}{2.35(\sigma_n^2 + \sigma_\gamma^2)}$$

Where μ_n and μ_γ are the mean values of the neutron and the gamma ray contributions, and σ_n and σ_γ are the standard deviations of neutron and gamma distributions fit with Gaussian functions $N(\mu_n,\sigma_n)$ and $N(\mu_\gamma,\sigma_\gamma)$.