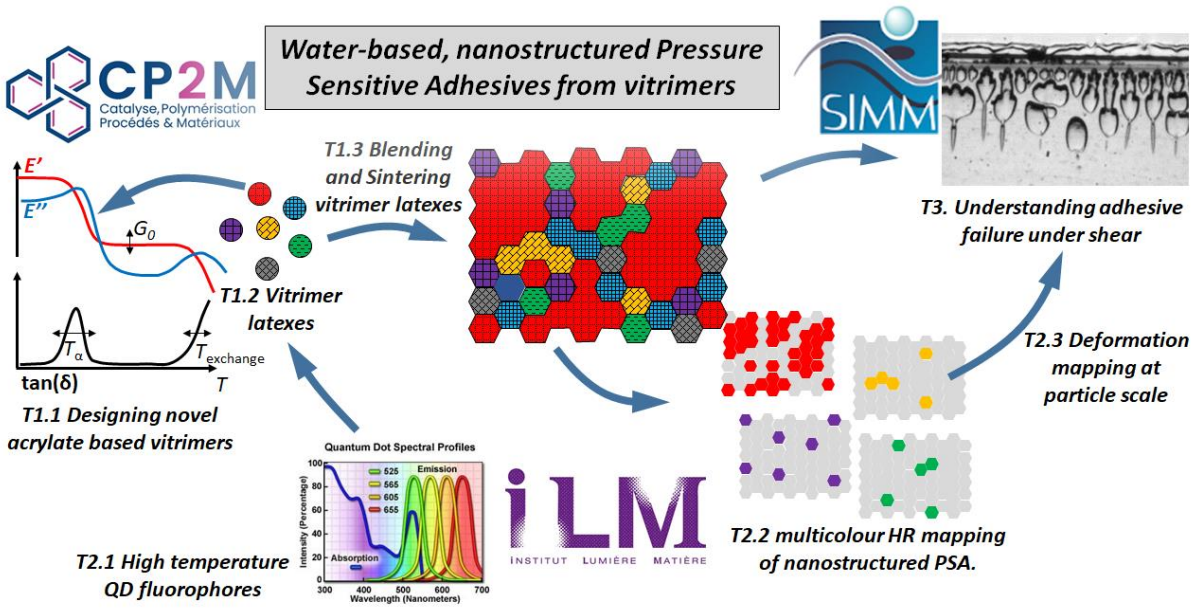
Shear debonding of novel vitrimer based adhesives

PhD thesis offer in the SIMM laboratory (start October 2022)

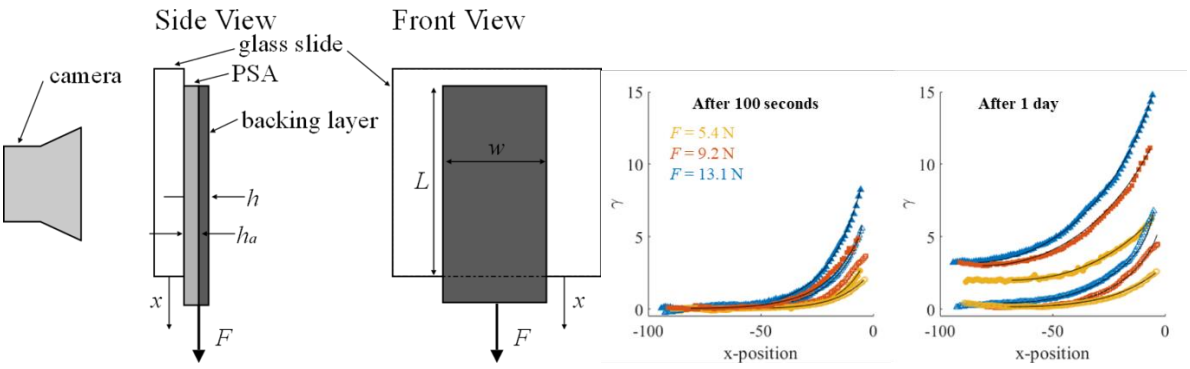
Context

The VITRIPSA ANR project is coordinated by Damien Montarnal at the CP2M lab in Lyon. The overall project aims at synthesizing nanostructured waterborne soft adhesives (PSA) from vitrimer-like particles. After short annealing times dynamic bond exchanges at interfaces will connect the crosslinked particles together forming a nanostructured film with good overall mechanical and adhesion properties. More extended annealing at high temperatures will then provide extensive interdiffusion between nanostructured domains to reach phase randomization and afford irreversible changes in the PSAs viscoelastic properties. Three approaches will be developed: i) (Lyon-CP2M) synthesis of a **library of vitrimer latexes** with **tunable structure, crosslinking density and T_g**, that can be mixed and quickly sintered (a few minutes at 90°C) through interfacial reaction into a **nanostructured crosslinked PSA**, ii) (ILM Lyon) **mapping of local deformations** of the individual domains (100-300 nm) through **correlation of colour-filtered confocal images**, and iii) (ESPCI-SIMM) **characterization of PSA properties and in particular resistance to shear over long times and low loads**, a poorly understood property crucially depending on the optimization of the stress transfer between particles.



Objective of the thesis

The key limitation of emulsion made adhesives is their classical weakness in long-term shear resistance. In conventional shear tests, a fixed weight is attached to a tape and the time to failure is measured and the stress is assumed to be homogeneous in the tape. This test is actually complex and recent theoretical models predict that the strain should be far from homogeneous in the adhesive layer while preliminary experiments shown below demonstrate that the strain is indeed not constant neither spatially nor temporally. Catastrophic failure occurs by crack propagation from the localized defects initiated in the high stress area of the tape. In order to bring an advanced understanding of such events, a multi-scale approach is needed.



Left: Shear measurement experiment setup. Right : strain (γ) as a function of position along the tape after 100s and after 1 day

A key novelty of the adhesives targeted within VITRIPSA will be the change of properties upon extended annealing and homogenization of crosslink densities in low T_g phases. This evolution of the strain field will lead at some point to extensive localized damage and the formation of cavities or cracks that propagate a shear crack either in the bulk or along the substrate/adhesive interface. The PhD student will develop and use a new optically instrumented shear test to carry out load or displacement controlled shear tests up to 150°C while maintaining the capability of the digital image correlation (DIC) strain field measurement.

Predicting the onset of such a shear crack as a function of molecular structure is a major challenge of the thesis and digital image correlation (DIC) measurements will be combined with real time high speed optical observation of localized damage in the late stages for selected formulations of adhesives that present a very different shear resistance.

The work will be carried at the SIMM lab of the ESPCI under the supervision of Matteo Ciccotti and Costantino Creton, and will be in close collaboration with a PhD student a the CP2M lab in Lyon and another PhD student at the ILM lab in Lyon as part of the VITRIPSA ANR project (2021-2025).

Seeked profile

Master's student in materials science or soft matter physics able to work in a team and with a pronounced taste for a pluridisciplinary approach combining materials science, soft matter physics and mechanics.

Contact

Matteo.Ciccotti@espci.psl.eu , Costantino.Creton@espci.psl.eu

References

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2. Hui, C.-Y., et al., *Mechanics of an adhesive tape in a zero degree peel test: effect of large deformation and material nonlinearity.* Soft Matter, 2018. **14**(47): p. 9681-9692.
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