

THE "BLACK MATERIALS" OF ANCIENT EGYPT: FROM MOLECULES TO RECIPES

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Black Materials

Materials employed in ancient Egyptian funerary practices, found on mummies, wrappings, coffin elements, and ritual objects. **Complex mixtures** of natural **organic and inorganic** substances of varied origins.

- Waxes
- Resins
- Animal fats
- Oils
- Gums
- Pitches
- **Bitumen**



Head of the mummy of a bearded man (Late Period), Chateau-musée, Boulogne-sur-Mer, France. Photo Credits: Frédérique Vincent.

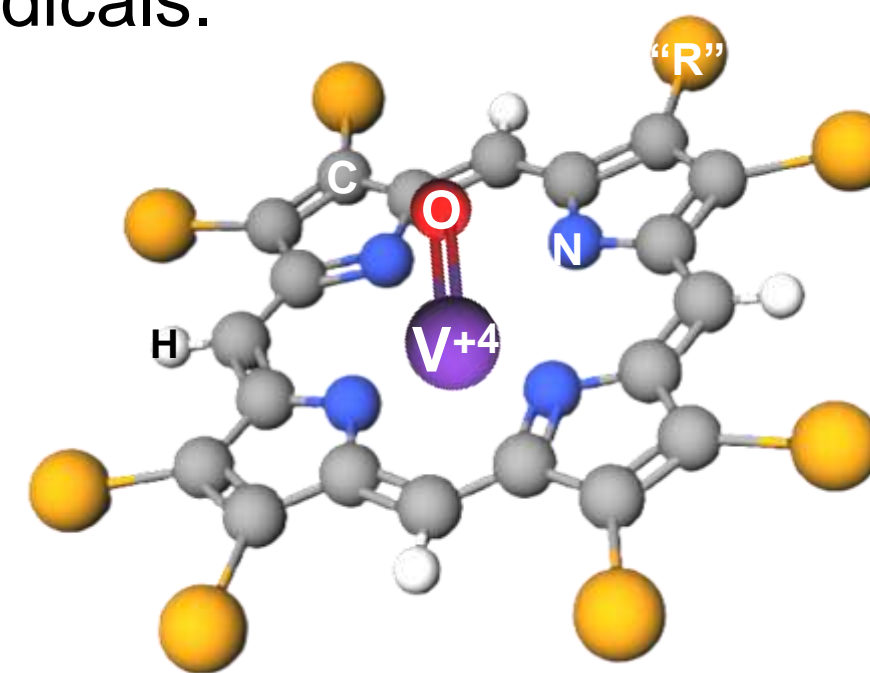
Bitumen

Component of petroleum.

Was increasingly used from the New Kingdom to the Ptolemaic/Roman period.

Contains **vanadyl porphyrins** and carbonaceous radicals.

Internal
paramagnetic
probes

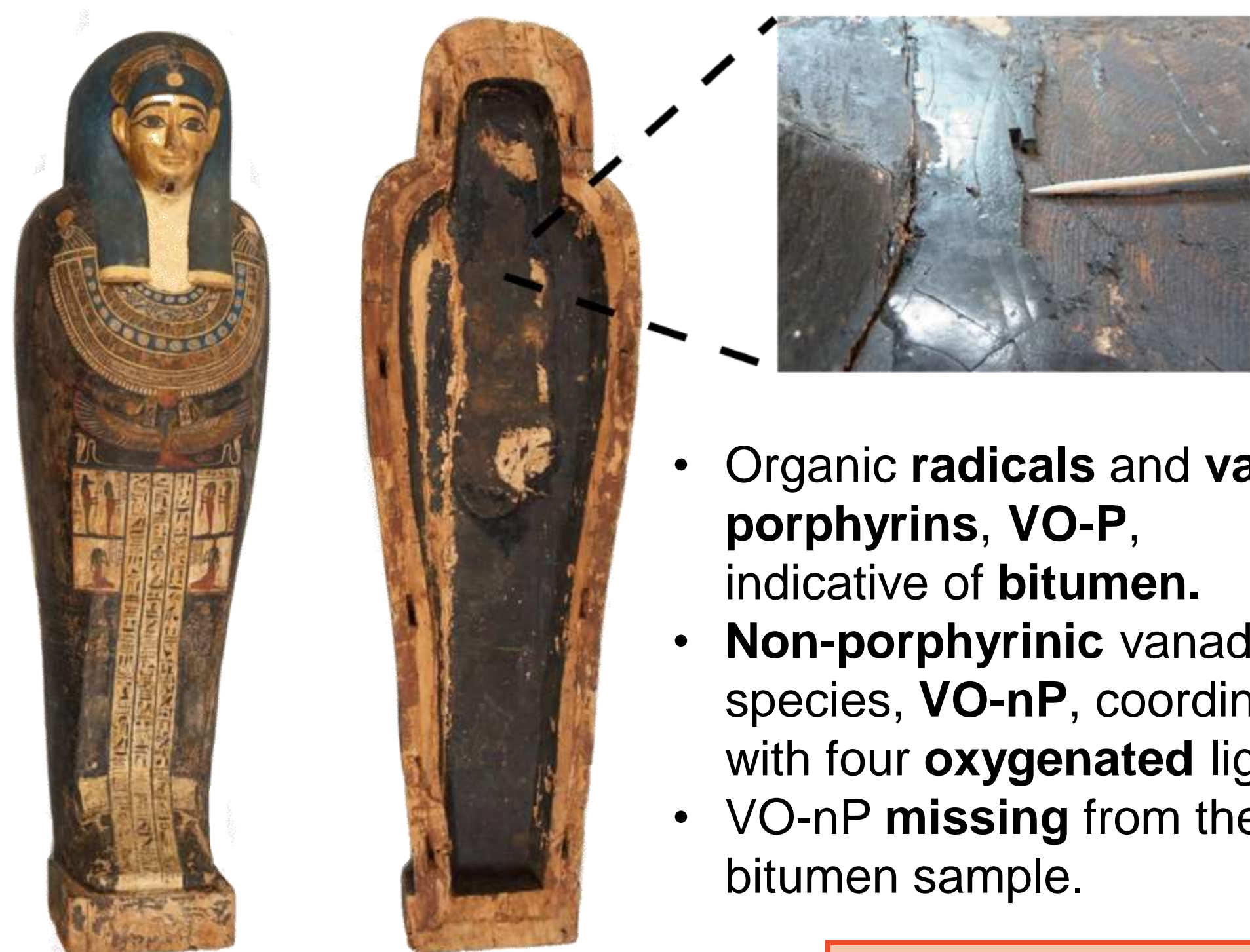


General chemical structure of vanadyl porphyrins (VO-P).

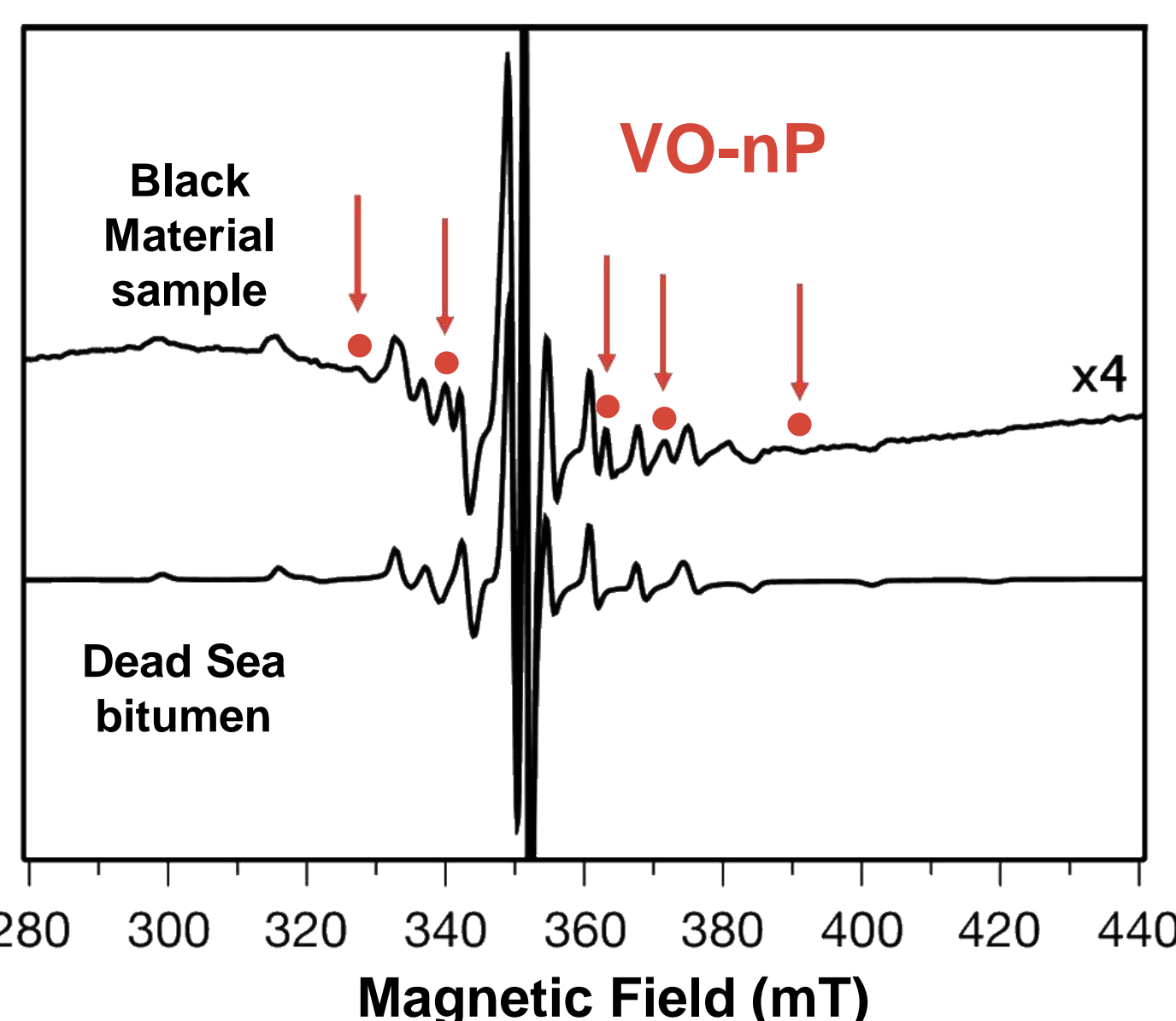
Our Objectives

- Black Materials samples**
Emphasis on high-resolution mass spectrometry for a broader range of organic and organometallic compounds.
- The experimental recreation of ancient recipes**
"Mock-ups" to identify molecular markers indicative of the manufacturing process (raw material sources, proportions of components, production conditions).

EPR Analysis of Black Material Sample^[1]



- Organic radicals and **vanadyl porphyrins, VO-P**, indicative of **bitumen**.
- **Non-porphyrinic** vanadyl species, **VO-nP**, coordinated with four **oxygenated** ligands.
- **VO-nP missing** from the pure bitumen sample.



EPR spectra comparison of black material sample and Dead Sea bitumen reference sample.

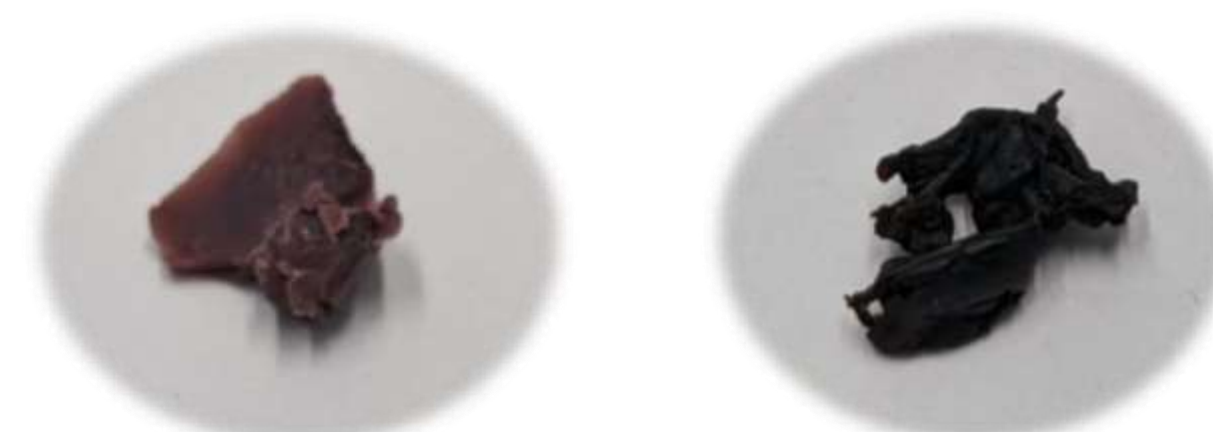
Hypothesis: VO-nP derive as by-products of fabrication process or VO-P degradation.

Mock-ups

Model systems of pure **vanadyl octaethylporphine (VOOEP)** powder mixed to a final concentration of 1 or 0.1% with:

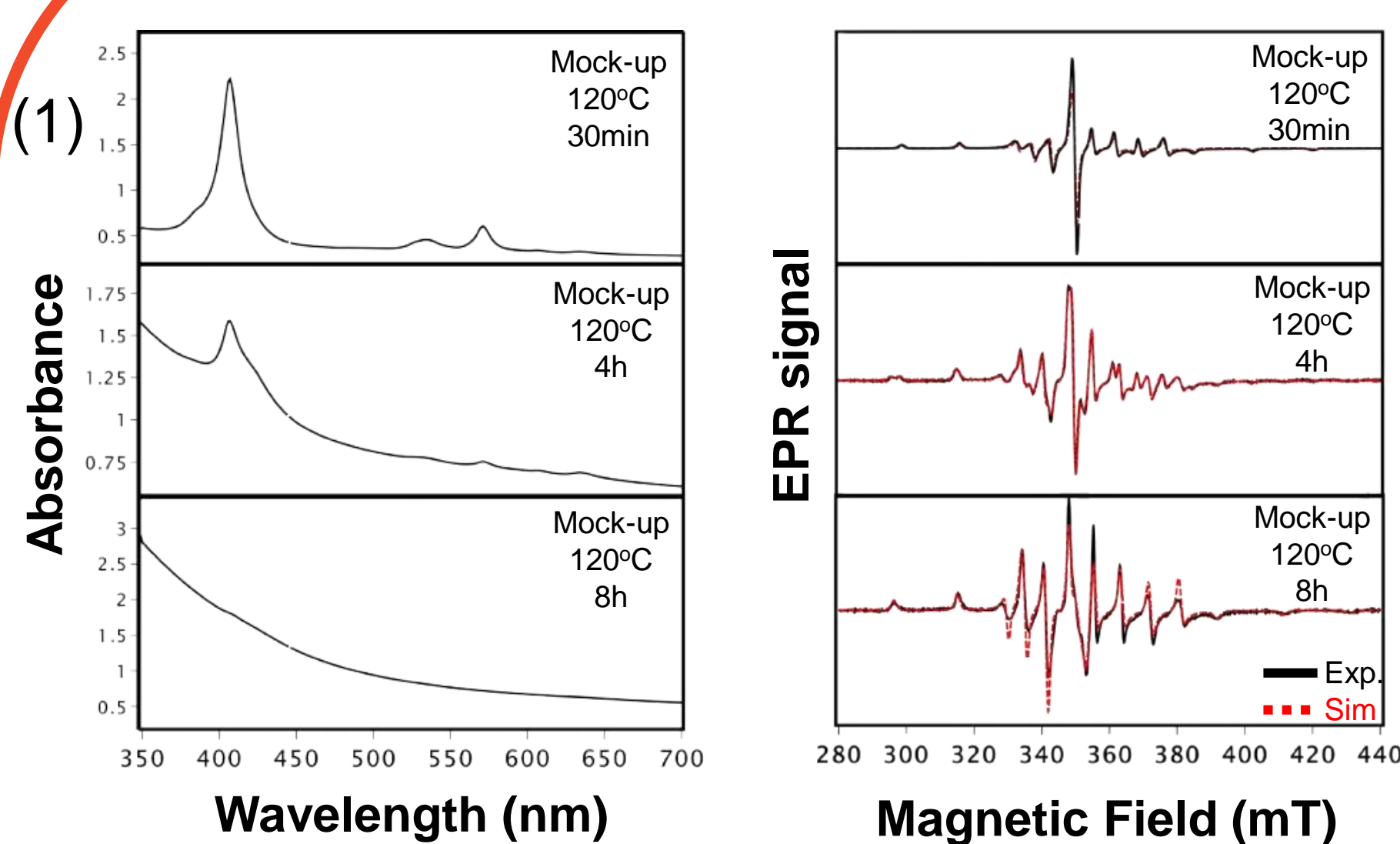
- Beeswax
- Mastic resin
- Rosin
- Stearin
- Stearic acid

and heated at 120°C at varying durations.

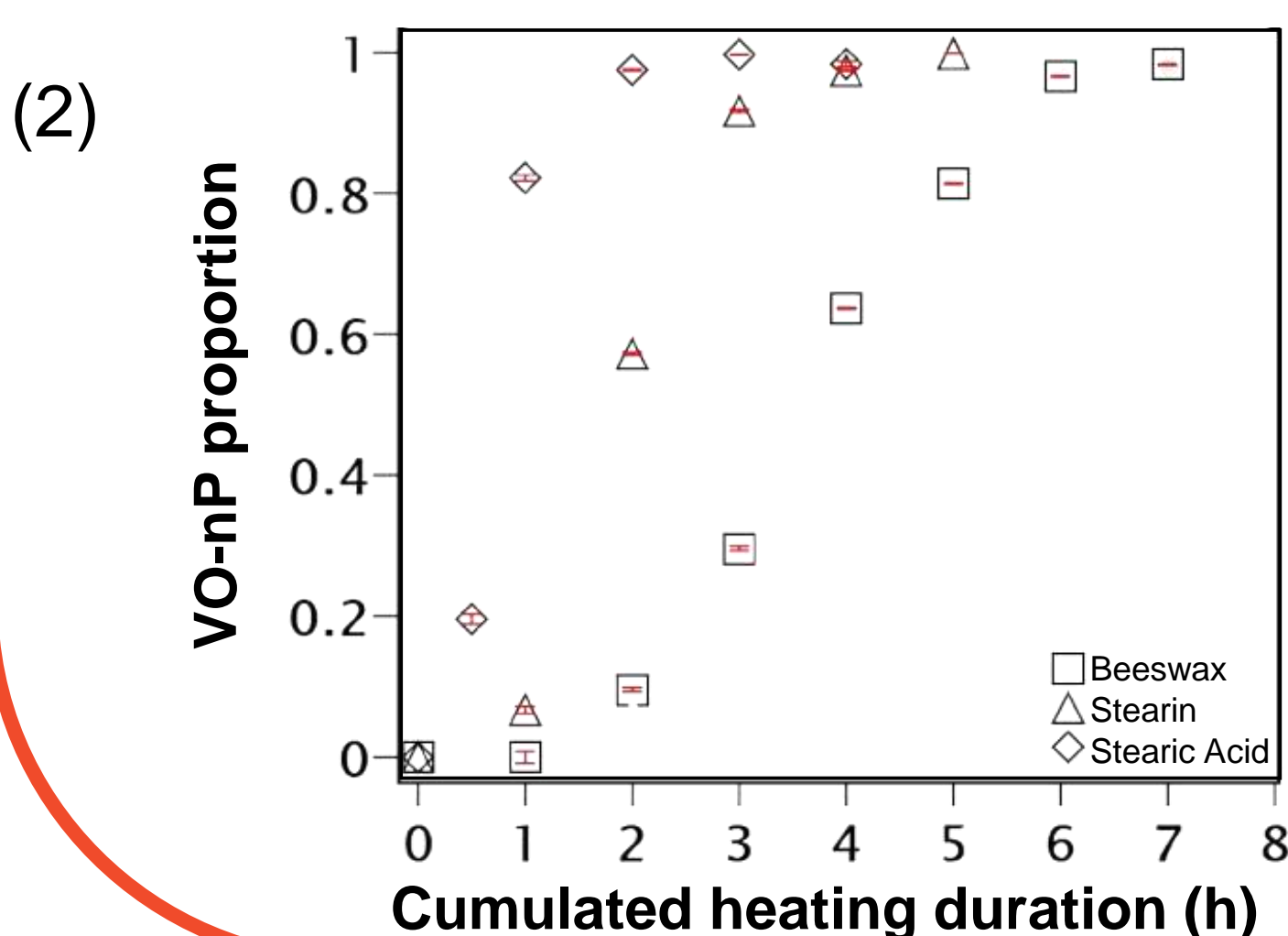


Aliquot of VOOEP 1% in beeswax, heated for 30 min (left) and 8h (right)

UV-vis and EPR



VO-nP species result from the VOP/organic matrix interaction

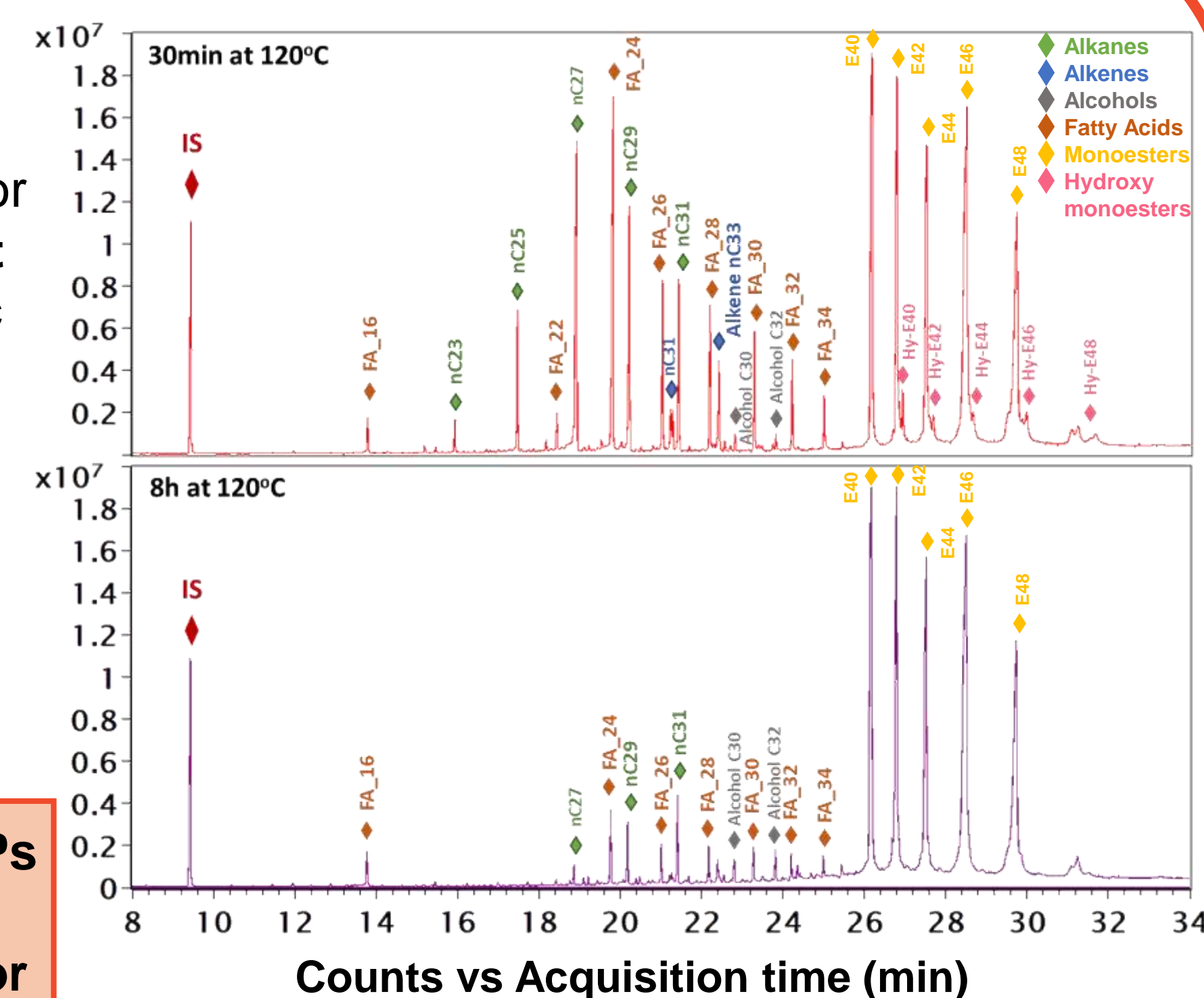


- (1) UV-vis absorption (left) and EPR (right) spectra evolution of 1% VOOEP in beeswax. Experimental spectra in black and simulated spectra in red.
- (2) VO-nP proportions as a function of cumulated heating duration for the mock-ups of beeswax, stearin, and stearic acid.

GC - Single Quadrupole MS

- Only the beeswax mock-up heated for 8h had a **different chromatographic profile**.
- **Lower molecular weight fatty acids and alkanes decreased in intensity.**

Hypothesis: VOPs are promoting polymerization or cross link reaction



TIC comparison of 1% VOOEP in beeswax aliquots taken at 30min (above) and 8h (below) of heating.

Perspectives

Complimentary analytical techniques

- FT-ICR-MS
- MALDI-TOF-MS
- Pulsed EPR

Preparation of improved mock-ups

- Test different ratios of organic materials according to **recipes** in literature.
- **Bitumen** mock-ups.