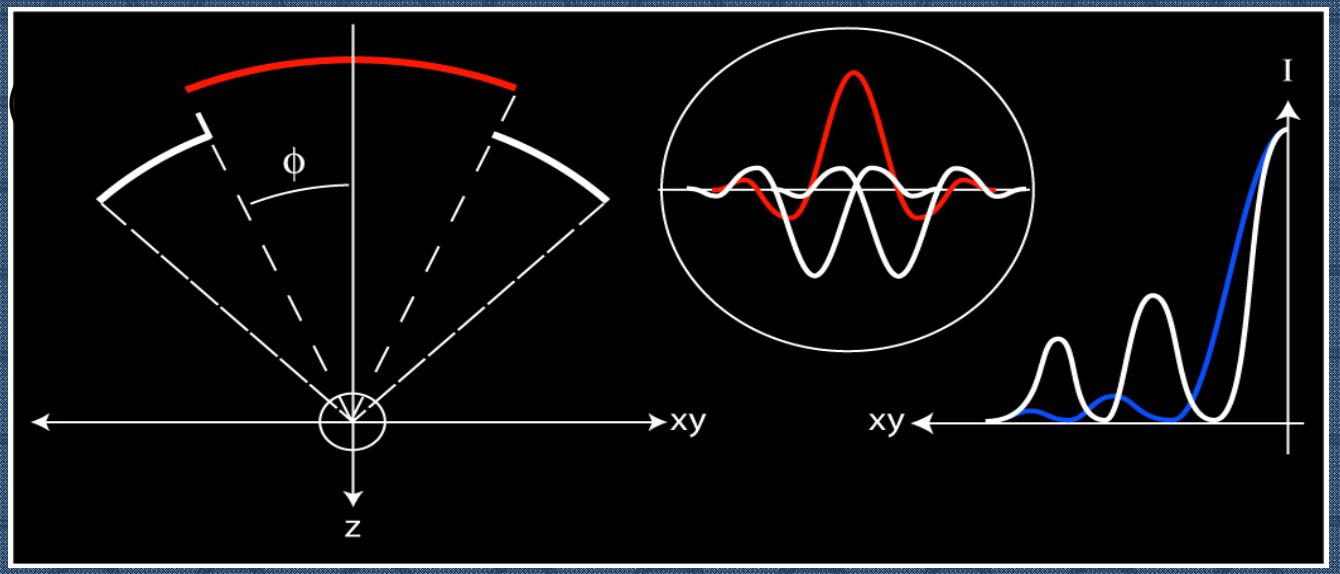
Nano-Material Identification using Fluorescence Lifetime Imaging Microscopy



Ryan Beams

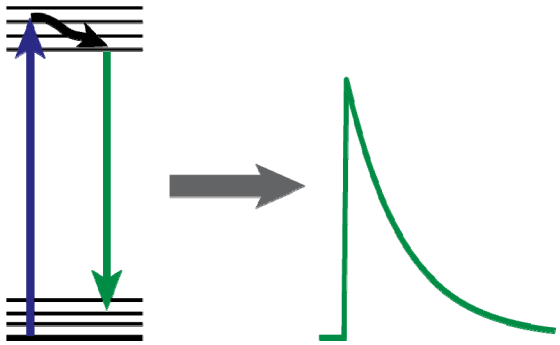
DIDSR, FDA, Silver Spring, MD

Oct 10, 2018

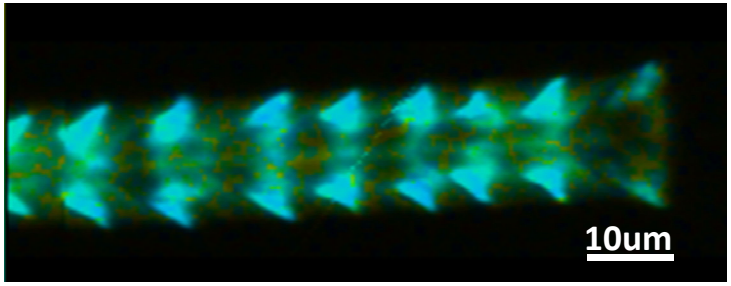
QEEN II Oct 9-10, 2018

Motivation for Fluorescence Lifetime Imaging

Fluorescence Lifetime



High Resolution Imaging

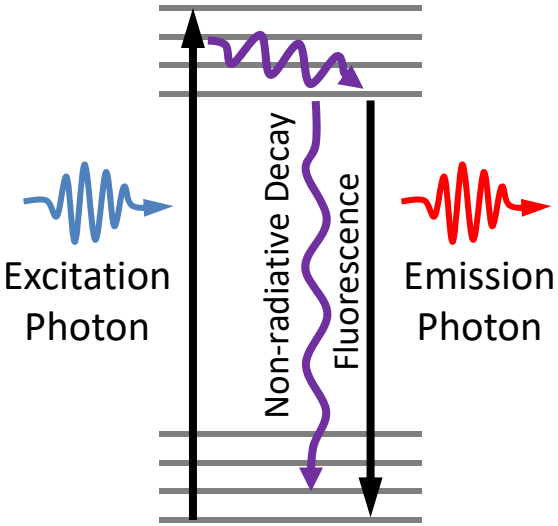


Advantages of Fluorescence Lifetime Imaging Microscopy (FLIM):

- Excited state dynamics information
- Generally non-destructive and non-contact
- Sub-micron lateral resolution
- Works in ambient conditions
- Robust: Not dependent on concentration, excitation power, or photo-bleaching
- Sensitive to the local chemical and environmental changes: pH, degrees of freedom, refractive index.

Local Environment and Quantum Yield

Local environment influences the quantum yield of an emitter

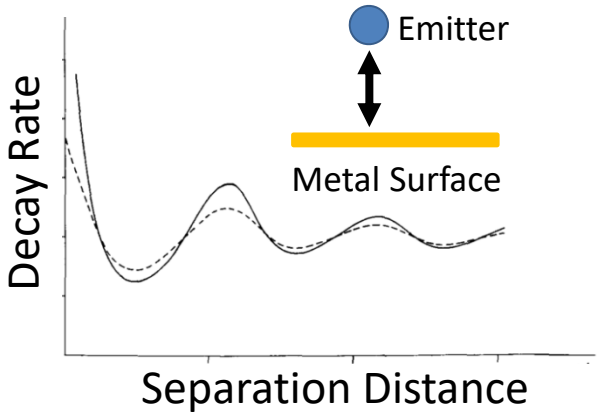


$$I_{em} \propto \sigma * q * I_{ex}$$

$$q = \frac{\gamma_r}{\gamma_{nr} + \gamma_r} = \gamma_r * \tau$$

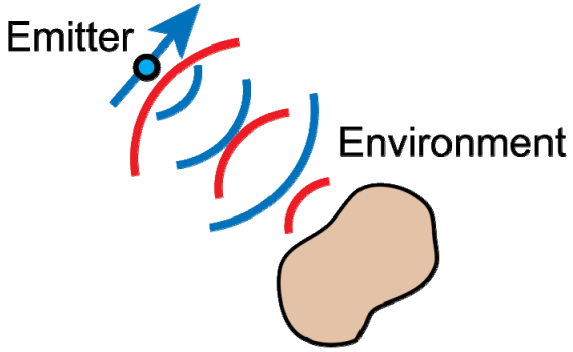
q: quantum yield τ: lifetime

γ_r: radiative rate γ_{nr}: non-radiative rate



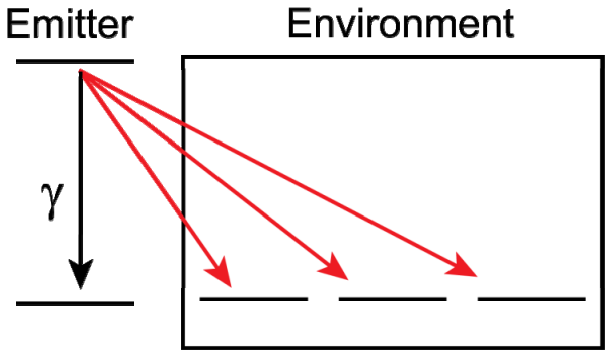
Drexhage, J. of Lumin. (1970)

Purcell Effect



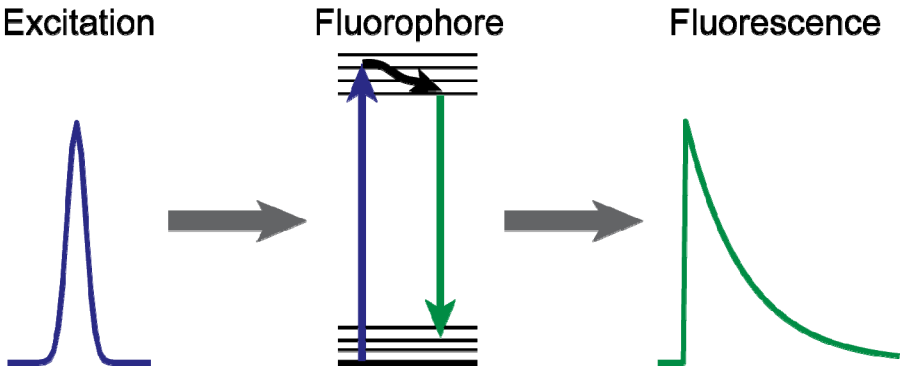
$\Delta\phi = \phi_{emit} - \phi_{scatt}$

Fermi's Golden Rule



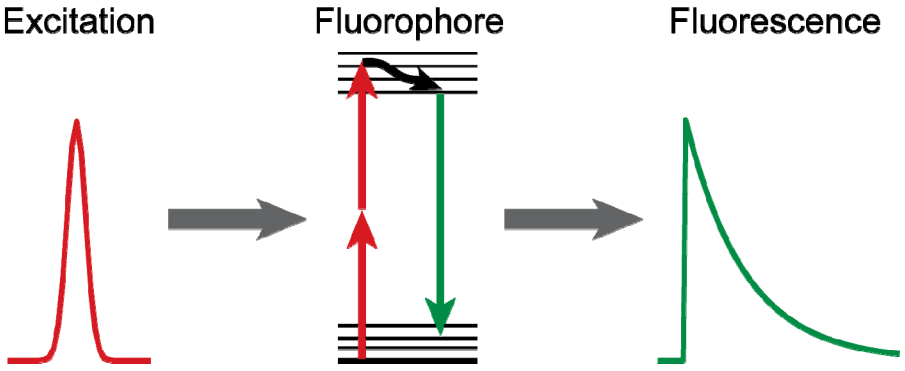
Linear vs Two-Photon Fluorescence

Linear Fluorescence Lifetime



$$I(t) = \eta_{1P}\, I_0\ e^{-t/\tau}$$

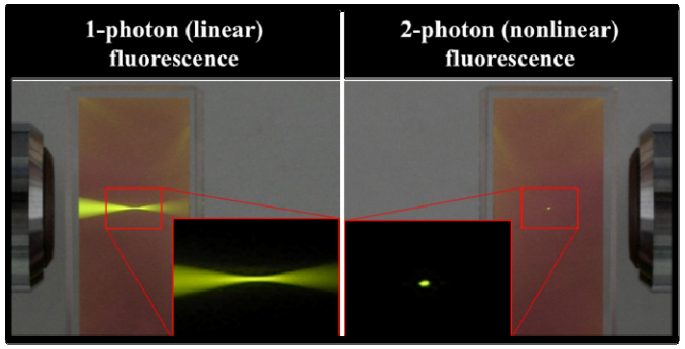
Two-Photon Fluorescence Lifetime



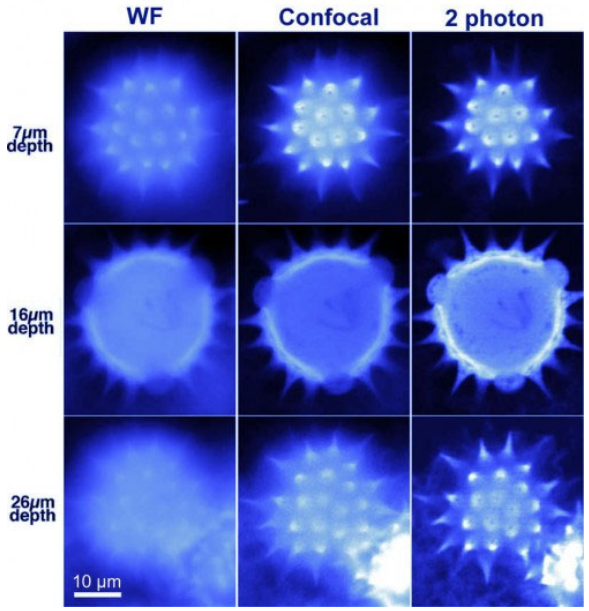
$$I(t) = \eta_{2P}\, I_0^2\ e^{-t/\tau}$$

Advantages of Two-Photon Fluorescence

- Less scattering (i.e. deeper penetration)
- Only excite fluorescence in focus (free confocality)
- Less photo-damage

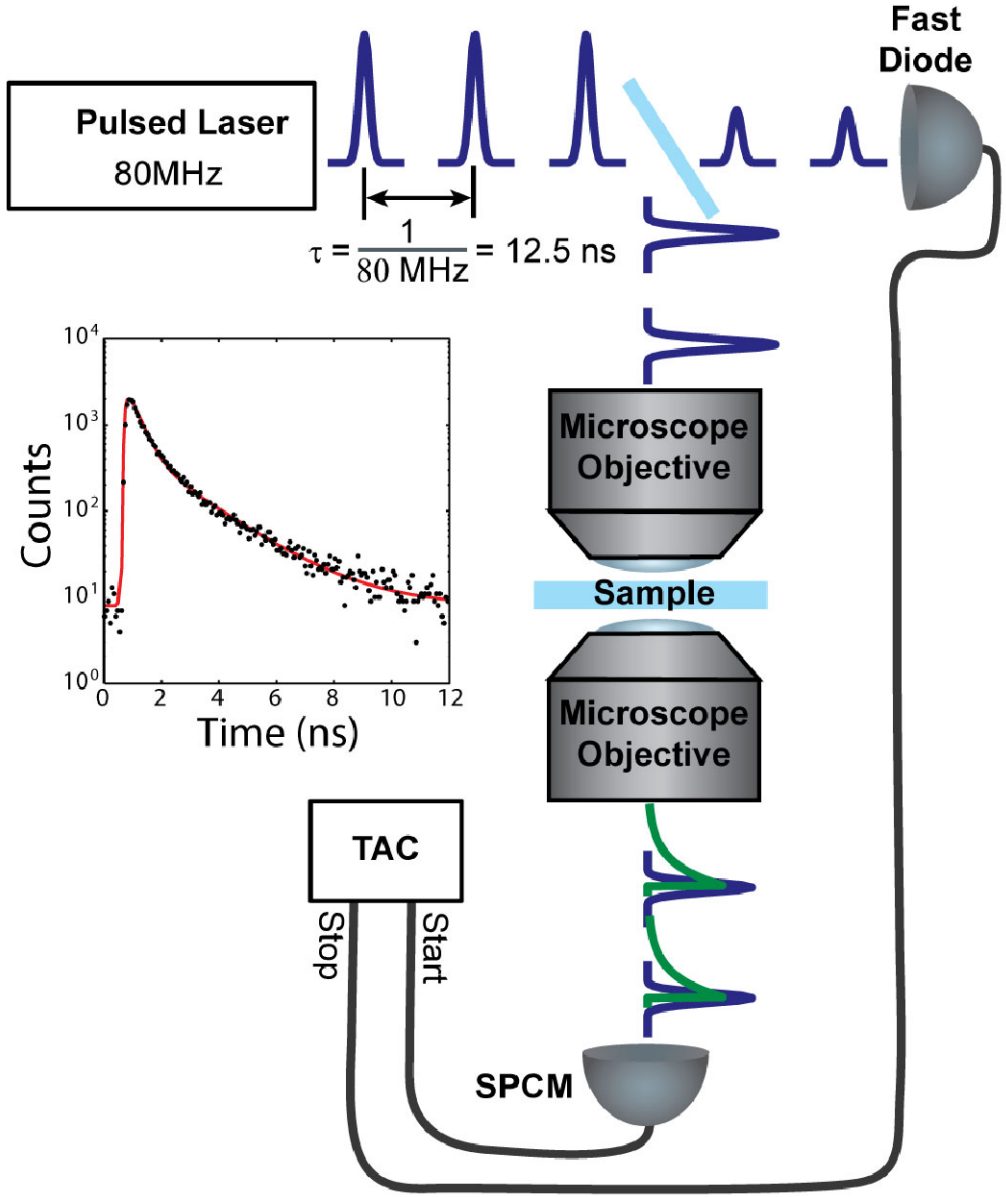


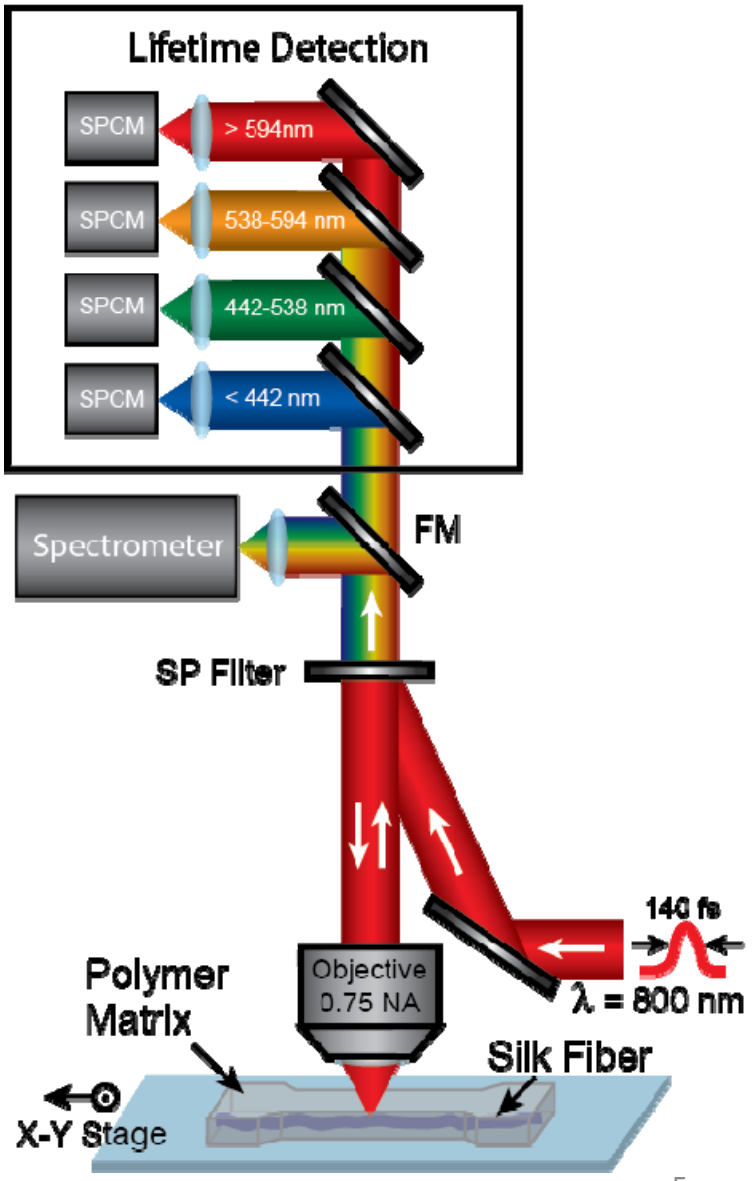
Courtesy of Tana Villafaña



http://candle.am/microscopy

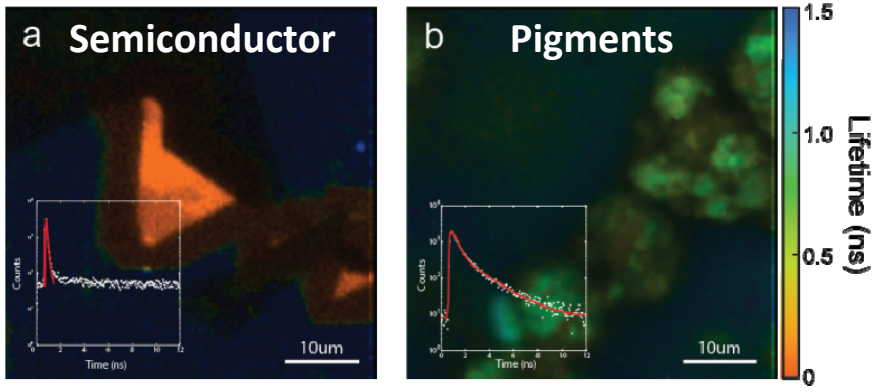
Two Photon Fluorescence Lifetime Imaging



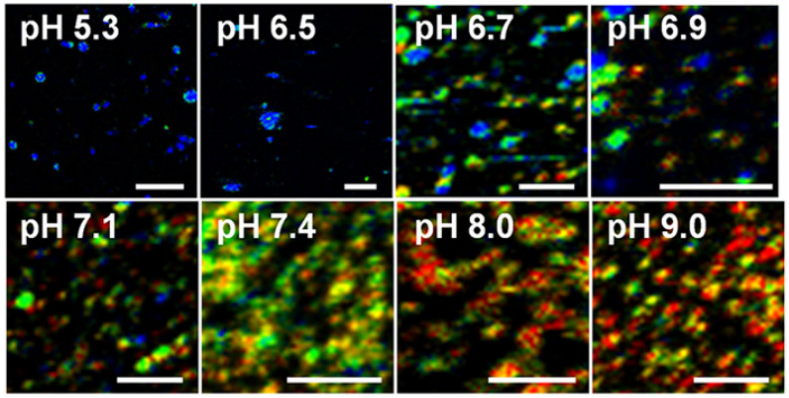


Applications of Fluorescence Lifetime

Intrinsic Lifetime

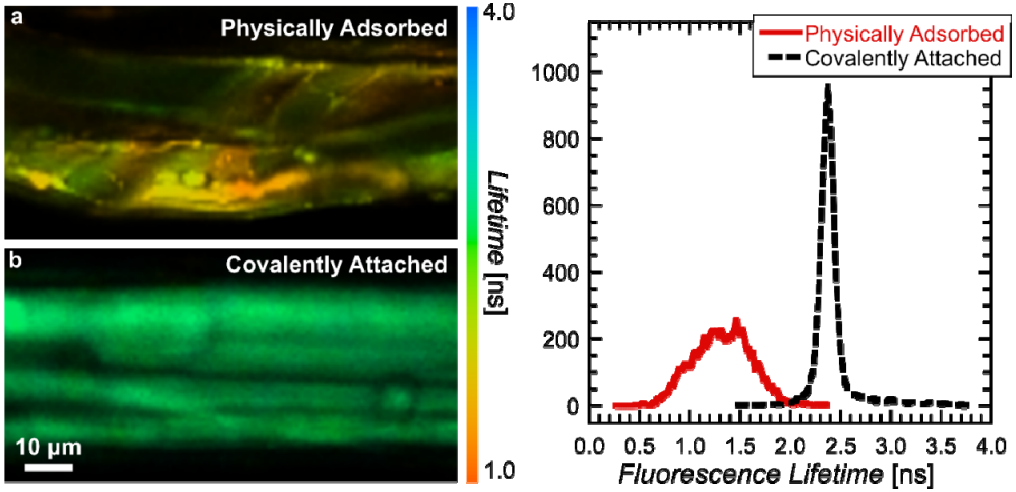


Lifetime Detection of pH

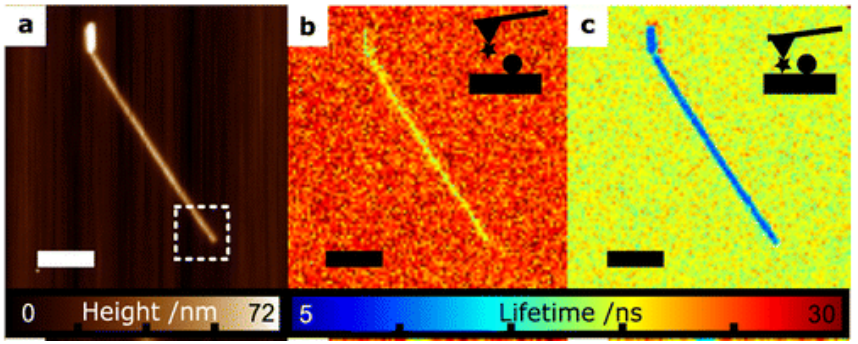


Orte, *et al.* ACS Nano (2013)

Chemical Bonds



Local Density of States Imaging

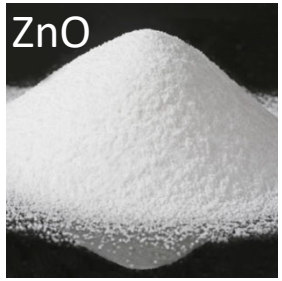


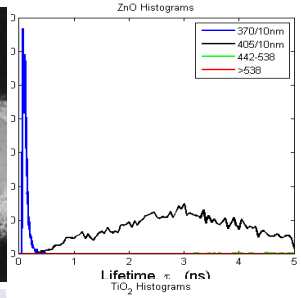
Schell, *et al.* Nano Letters (2014)

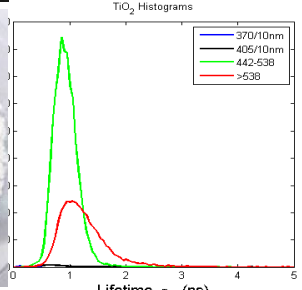
Woodcock, Beams, *et al.* Adv. Mat. Inter. (2017)

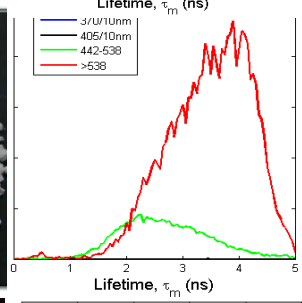
Identifying Nano-Materials

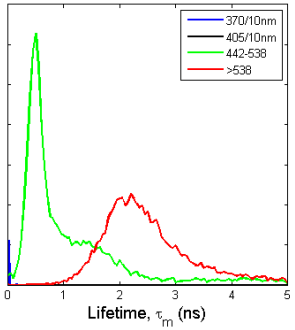
White Pigments and Fillers



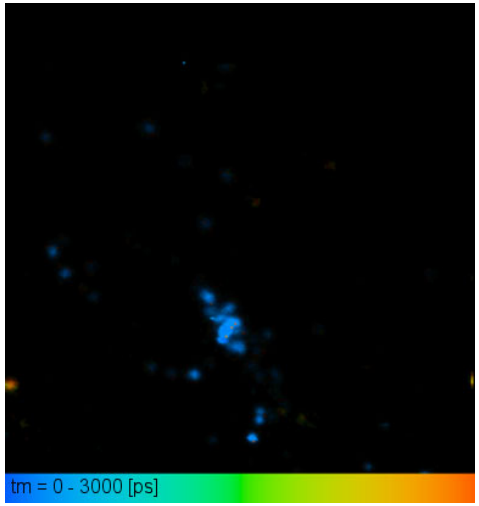




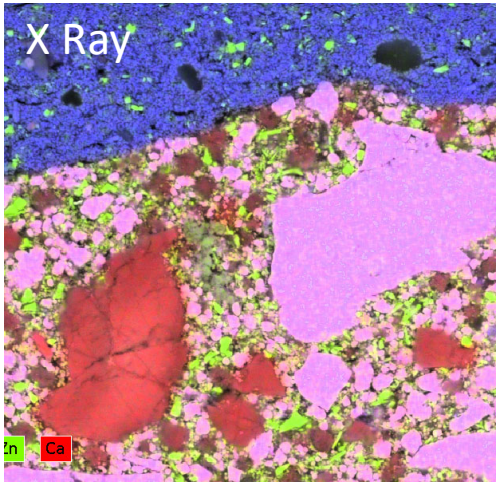


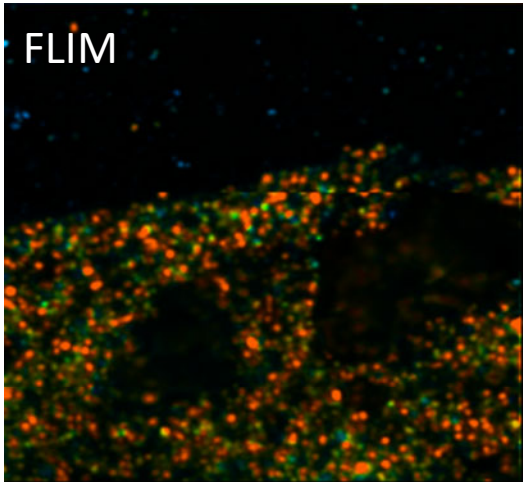


Ag Nano-Particles



Metal Oxide Particles





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Ryan.Beams@fda.hhs.gov

NIST

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