032. SYNTHESIS AND MODIFICATION OF FUNCTIONAL POLYMER NANOGELS USING PULSED-ELECTRON BEAM IONIZING IRRADIATION

Ileana Pazos[1], Jung-Chul An[1], Natascia Grimald[1,2], Patricia Yoko Takinami[1,3], Dianne Poster[4], Clelia Dispenza[2], Nelida del Mastro[3], Wyatt Vreeland[4], Mohamad Al-Sheikhly[1,*]

[1] *University of Maryland College Park, Maryland, USA*
[2] *Università di Palermo, Palermo, Italy*
[3] *Nuclear and Energy Research Institute -Ipen/CNEN/SP - Brazil*
[4] *National Institute of Standards and Technology, Gaithersburg, Maryland, USA*
* *mohamad@umd.edu*

Nanogels made of bio-compatible hydrophilic polymers can be used in various medical applications such as targeted nano-medicine delivery and imaging agents. Intravenously introduced nanogel-drug conjugates may accumulate in tumors through the enhanced permeability and retention effect. We present our latest results on the synthesis and kinetic analysis of two nanogel systems (1) poly(vinyl pyrrolidone) (PVP) and (2) gelatin/polyethylene (GEL/PEG) using ionizing irradiation (γ-ray, electron beam).

The characteristics of nanogels depend on the radiation synthesis parameters (e.g., total dose, pulse repetition rate, etc.) as well as physical parameters (e.g., solution concentration, irradiation temperature, etc.). Specifically, one may tune the parameters to promote the crosslinking reaction within the same polymer chain (intra-crosslinking) and to suppress the crosslinking between two different chains (inter-crosslinking). At higher temperatures (> 60 °C), there is a disruption of polymer-water hydrogen-bonds resulting in a collapsed form. Smaller nanogels can be produced with high repetition rates of the pulsed electron beam irradiation while low dose rate pulses favor inter-molecular crosslinking.

The nanogels were analyzed using asymmetric flow field-flow fractionation coupled to multi-angle static light scattering and dynamic light scattering detectors. The measured hydrodynamic radius (R_h) of the PVP hydrogels were concentration dependent with a range from 15 to 80 nm with a polydispersity index of 0.2– 0.3 and molecular weight of 0.4–13 MDa. On the other hand, the R_h of the GEL/PEG mixed nanogels decrease from 350 to 20 nm as a function of dose. Additionally, atomic force microscopy images confirm the synthetic approach results in globular shapes. X-ray photoelectron spectroscopy (XPS) measurements confirm that the chemical structure of these nanomaterials closely resemble that of the un-irradiated polymers. Moreover, XPS also provides data on the level of oxidation and enables confirmation of chemical grafting.

In addition, pulse radiolysis elucidates the mechanism that leads to nanogels generation. The second order reaction rate constants (k_2) of PVP radical recombination are determined to be ca. 1.1–2.8 E9 L mol^{-1} s^{-1} (PVP-H, $\varepsilon_{390\,nm} = 510 \pm 30$ L mol^{-1} cm^{-1}). The activation energy (E_a) of this reaction is calculated from the Arrhenius plot of PVP radical decay rate constants at the series of temperatures and show 1.0 kcal mol^{-1} below 60 °C and 6.8 kcal mol^{-1} above 60 °C. These two measured E_a constants can be explained by the different rate-determining mechanism of PVP radical recombination reaction at two temperature regions. Below 60 °C, the low E_a reflects the diffusion controlled polymer radical reaction in a good solvent. But at higher temperatures, above 60 °C, polymer chains are segregated from the aqueous solution by micro-phase separation and collapse.