**Electrochemical Modification of Polymer Chains: Synthesis of Crosslinked Poly(vinylpyrrolidone) Nanogels**

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**Highlights**

* Electro-Fenton is a facile, low cost, environmentally-friendly route to crosslink PVP
* Semi-dilute PVP, 0.5-1.0 mmol dm-3 Fe2+, low *j* and short *t*: *R*h < 10 nm (intramolecular crosslinking)
* Longer *t* and higher PVP and Fe2+ contents: *M*w increases (intermolecular crosslinking)

**1. Introduction**

In recent years, increasing attention has been paid to the development of nanogels as nanocarriers for biomedical and bioengineering applications [1], being very useful in key tasks such as anti-cancer treatments [2]. Methods like gamma-ray irradiation or pulse radiolysis, which are based on the generation of free radicals that favour the formation of active centers on the polymer, have been previously investigated to promote the inter and/or intramolecular recombination that causes crosslinking. In a recent investigation, we have reported a certainly promising, innovative and simple electrochemical methodology to generate hydroxyl radicals that trigger the formation of chemically crosslinked nanogels [3]. Poly(vinylpirrolidone) (PVP) is a polymer with high versatility since non-charged PVP shows a high hydrophilicity and biocompatibility, absence of toxicity and adequacy to form interpolymer complexes [4]. In the present work, we have focused the attention on the homogeneous electrogeneration of hydroxyl radicals by electro-Fenton (EF) process in order to modify poly(vinylpyrrolidone) (PVP) in aqueous solutions [3,5].

**2. Methods**

PVP k-60 (*M*r = 1.60×105 g mol-1, *M*w = 3.95×105 g mol-1, 45 wt.% solution) was purchased from Aldrich and used as received. Oxygen (99.999% purity) and nitrogen (99.998% purity) were supplied by Air Liquide. All other chemicals used were from Sigma-Aldrich or Fluka and used as received. Before each experiment, fresh PVP aqueous solutions were prepared using double-distilled water and stirred overnight, filtered with 0.22 μm nylon filters under vacuum. An undivided thermostated glass cell equipped with a water jacket was used for the electrosynthesis of nanogels. The cell contained 50 cm3 of PVP solution at a given concentration with 0.05 M Na2SO4 in the presence of FeSO4 as catalyst at pH 2.8 under continuous stirring. A carbon-polytetrafluorethylene (PTFE) air-diffusion electrode was used as the cathode to electrogenerate H2O2, whereas a Ti/IrO2–Ta2O5 (DSA®) plate was used as anode. The geometric surface area of all electrodes in contact with PVP solution was 3 cm2. The cathode was fed with pressurized O2 for H2O2 generation. An Amel 2053 potentiostat/galvanostat was employed to operate at constant current.

**3. Results and discussion**

The main operation parameters such as polymer concentration, reaction time, catalyst (Fe2+) concentration and charge passed (*Q*) were investigated. The dimensions of the nanogel formed, in terms of hydrodynamic radius (*R*h) and weight-average molecular weight (*M*w), have been evaluated via dynamic and static light scattering and gel permeation chromatography (GPC) analyses. In all cases, an important reduction of the size of PVP particles was achieved, along with narrower GPC peaks. Chain scission and intra-molecular recombination events were promoted at lower PVP concentration (< 0.50 wt.%) and for the low electrolysis times, leading to a reduction of *R*h from 28 to 8-9 nm at catalyst concentration of 0.5-1.0 mM, while intermolecular crosslinking also concurred at longer times. Beside the electrolysis time, catalyst concentration and current density, *j*, are two other tunable parameters that can shift the balance between chain scission and crosslinking reactions. FT-IR analyses confirmed the functionalization of PVP nanogels, which become suitable for further conjugation reactions with biologically relevant molecules.

**4. Conclusions**

We found that EF can be adopted to crosslink PVP thus offering a cheap, eco-friendly, simple and fast alternative to current technologies. The adoption of proper balance of operation conditions is crucial for tuning up the main features of the resulting PVP nanogel in terms of particle size, mass and functionalization, which are modulated by the rate of generation of •OH obtained from in situ electrogenerated H2O2.

**References**

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