Absolute measurement of low energy electron-induced strand-break damage in films of plasmid DNA and plasmid DNA/Dap^{2+} complexes

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Synopsis A simple model of electron transmission in thin film targets permits absolute measurement of cross section for electron-induced damage in such films of DNA and DNA complexed with 1-3 diaminopropane.

Cross sections (CSs) for the interaction of low-energy electrons (LEE) with DNA are essential parameters for the accurate modeling of radiation-induced damage in biological systems. Electron irradiation of dry nanometer-scale macromolecular solid films has previously been used to measure CSs and other quantitative parameters for LEE interactions including formation of transient negative ions and molecular dissociation. Since such films have thicknesses comparable with electron thermalization distances, energy deposition varies throughout the film and is in certain cases subject to severe film charging, that can further hamper accurate and absolute measurement [1]. We have developed a simple mathematical model, termed the "molecular survival" model [1], which employs a CS for a particular damage process together with an attenuation length related to the total CS, to describe how a measured CS might vary with experimental conditions. Using this model, we measure and compare absolute CS for the formation of DNA strand breaks (SBs) by electron irradiation at 10eV, in films of lyophilized plasmid DNA and DNA complexed with doubly-charged, 1-3 diaminopropane (Dap^{2+}). The addition of Dap^{2+} ions to DNA has recently been shown to permit the growth of plasmid DNA films of precisely controlled uniform thickness on highly ordered pyrolitic graphite substrates [2]. The Dap^{2+} ions additionally serve as surrogates for the presence of proteins such as histones, which bind to DNA in cell nuclei. Since such films are also soluble, they represent an interesting alternative target for electron irradiation studies.

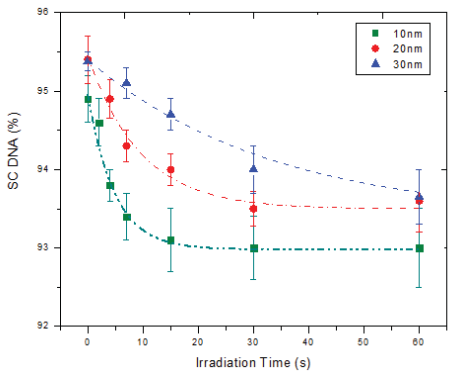


Figure 1. Exposure response curve for lyophilized plasmid DNA films prepared at three different thicknesses of 10, 20 and 30 nm irradiated with 10 eV electrons. The dash-point lines are guides for eye.

The absolute CSs measured for SB damage (i.e., loss of super-coiled DNA) at 10 eV electrons, for pure, dry DNA and DNA/Dap^{2+} complexes are (3.8 ± 1.2)x10^{-14} cm^2 and (4.8 ±0.4)x10^{-14} cm^2 respectively, suggesting similar electron-DNA interactions operate in these two targets. The molecular survival model additionally permits the present results to be compared with earlier experimentally derived *effective* CSs obtained on target films of differing thickness and preparation.

References

[1] Rezaee M *et al* 2012 *Phys. Rev. E* **86**, 031913
[2] Boulanouar O *et al* 2011 *J. Phys. Chem.* C **115**, 21

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