Electronic Supplementary Material (ESI) for Nanoscale.
This journal is © The Royal Society of Chemistry 2016

# Supplementary Information

## Carboxylated Nanodiamonds Inhibit γ-Irradiation Damage of Human Red Blood Cells

K. Santacruz-Gomez*[a,b] E. Silva-Campa[c], R. Melendrez-Amavizca[c], F. Teran Arce[b,d,g], V. Mata-Haro[e], P. B. Landon[b,d], C. Zhang[f], M. Pedroza-Montero[c] and R. Lal*[b,d]

[a]Departamento de Física. Universidad de Sonora. Blvd. Luis Encinas y Rosales s/n. C.P. 83000. Hermosillo, Sonora, México
[b]Department of Mechanical and Aerospace Engineering, University of California, San Diego, 9500 Gilman Drive, La Jolla, USA.
[c]Departamento de Investigación en Física. Universidad de Sonora. Hermosillo, Sonora, México
[d]Department of Bioengineering, University of California San Diego, La Jolla, CA.
[e]Centro de Investigación en Alimentación y Desarrollo, AC. Carretera a la Victoria Km 0.6. Hermosillo, Sonora, México.
[f]Department of Nanoengineering, University of California, San Diego.
[g]Currently at Division of Translational and Regenerative Medicine, Department of Medicine, University of Arizona, Tucson, AZ, USA

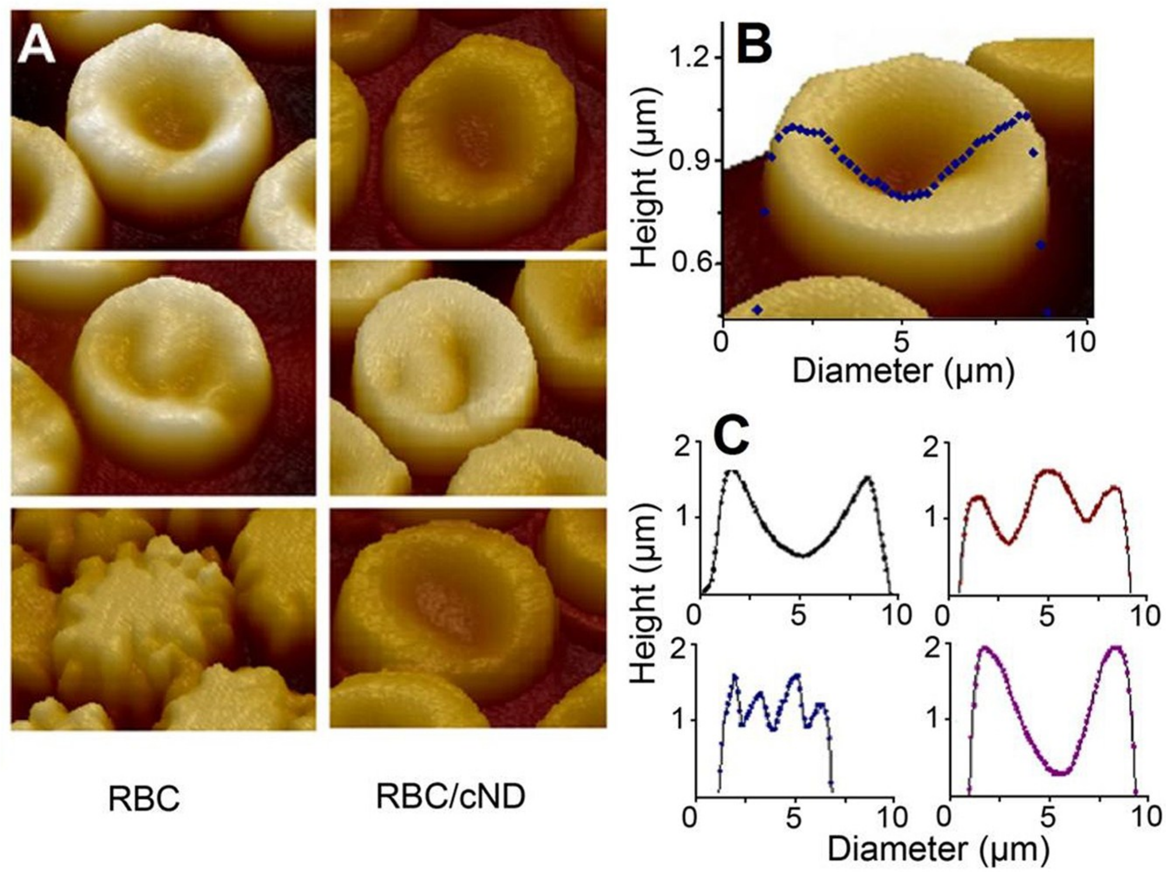


**Figure S1.** (A) AFM images of human RBCs subtypes with and without cNDs after 60 Gy of γ- irradiation: normal RBC (right and left, top), codocytes (right and left columns, middle panel), echinocyte (left column, bottom panel) and stomatocyte (right column, bottom panel). (B) Measurements of central pallor (diameter and depth) based on the topographic profile obtained by AFM in a normal RBC. (C) Topographic profile of single normal RBCs (top panel), codocytes (right and middle panel), echinocyte (left column, bottom panel) and stomatocyte (right column, bottom panel) after γ-irradiation.

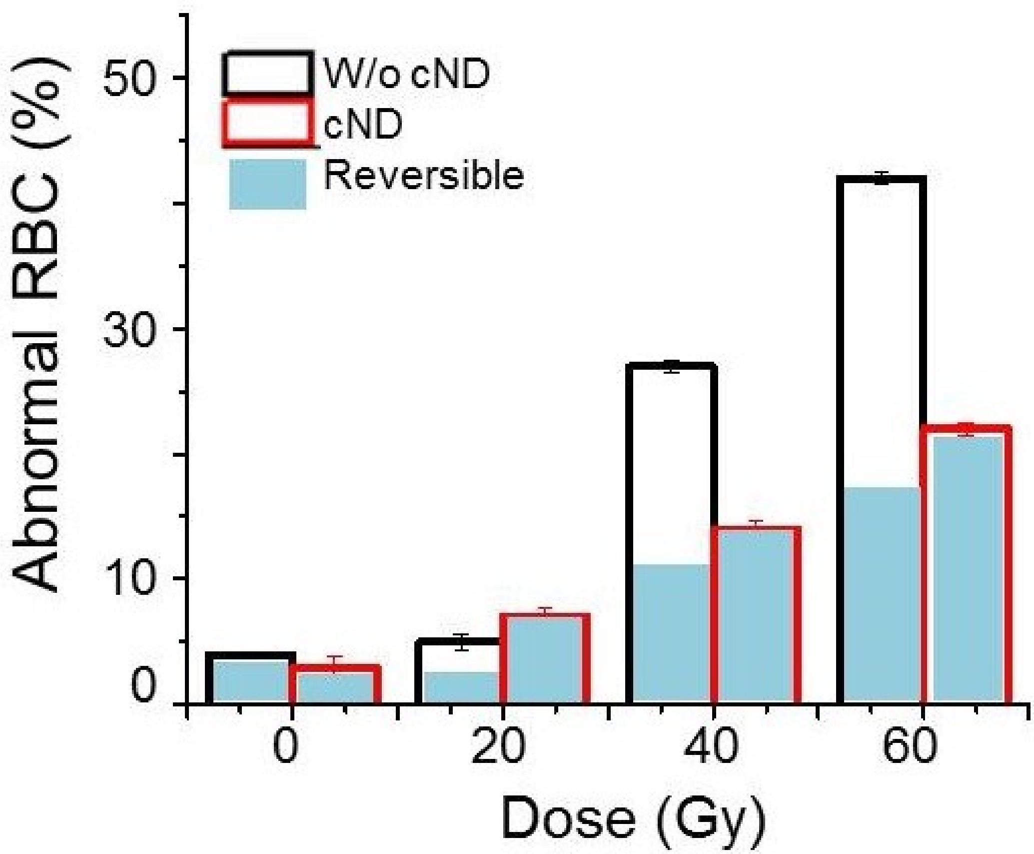


**Figure S2.** Percentage of abnormal RBC subtypes after γ-irradiation dose of 0, 20, 40 and 60 Gy in presence (black outlined histogram) and absence (red outline histogram) of cND. The blue filled histograms represent the percentage of reversible cells subtype. The effect of the γ-irradiation on RBCs deformation is more significant in absence of cND, including a high percentage of irreversible deformation.

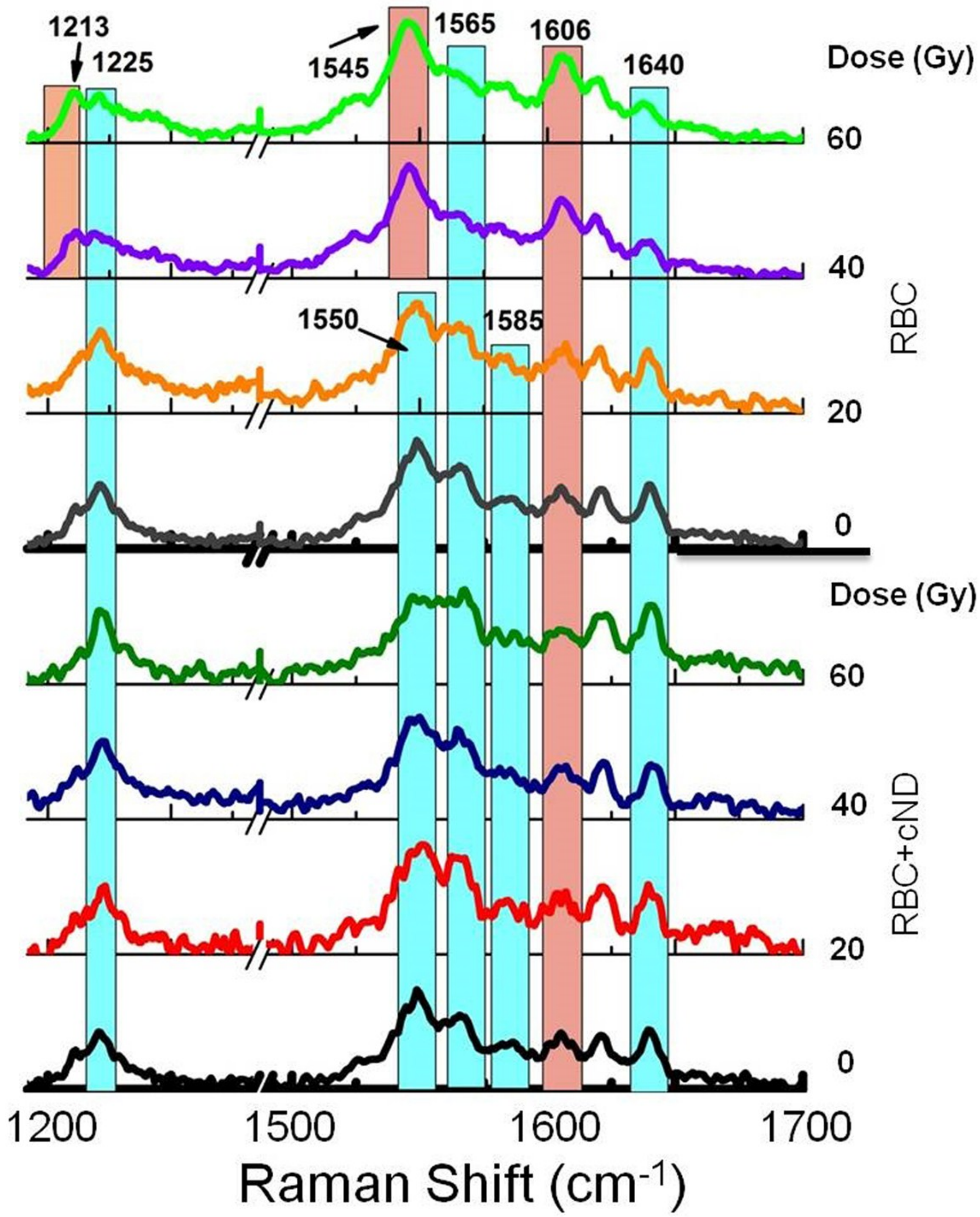


**Figure S3.** RBCs were found to gradually deoxygenate at increasing γ-radiation doses. RBCs incubated with cNDs exhibited more oxygenated Raman peaks than RBCs in non cNDs-treated samples. The number marks the position of the major oxygenated (blue boxes) and deoxygenated (red boxes) peaks. Raman spectra were obtained with a 632 nm laser. Each Raman spectra represent 30 singles cells averaged.

| Reaction | Products |
|---|---|
| Hydroxyl | |
| $OH + O_2^-$ | $O_2 + OH^-$ |
| $OH + HO_2^-$ | $HO_2 + OH^-$ |
| $OH + H_2O_2$ | $HO^2$ |
| $OH + HO_2$ | $O_2$ |
| $OH + e^-aq$ | $OH^-$ |
| $OH\cdot + OH\cdot$ | $H_2O_2$ |
| Aqueous electron | |
| $e^-aq + H_2O$ | $OH + OH^-$ |
| $e^-aq + H$ | $H2 + OH^-$ |
| $e^-aq + H_3O^+$ | $H\cdot + H_2O$ |
| $e^-aq + HO_2$ | $HO_2^-$ |
| e–aq + $O_2$ | $O_2^-$ |
| e–aq + $O_2^-$ | $OH^- + HO_2^-$ |
| $e^-aq + H^+$ | $H\cdot$ |
| Hydroperoxyl | |
| $HO_2 + HO_2$ | $H_2O_2 + O_2$ |
| $HO_2 + O_2^-$ | $O_2 + HO_2^-$ |
| $H + H_2O_2$ | $OH$ |
| Hydrogen | |
| $H^+ + O_2$ | $HO_2\cdot$ |
| Hydronium Ion | |
| $H_3O^+ + O_2^-$ | $HO_2$ |
| $H_3O^+ + HO_2^-$ | $H_2O_2$ |
| Neutralization | |
| $H_3O^+ + OH^-$ | $H_2O$ |
| $OH + H$ | $H_2O$ |
| $H^+ + OH\cdot$ | $H_2O$ |
| $H^+ + OH^+$ | $H_2O$ |
| $OH + H_2$ | $H_2O$ |
| $H + H$ | $H_2$ |
| $H^+ + H\cdot$ | $H_2$ |

**Figure S4.** Chemical reactions for free radicals generated during water radiolysis. The radiolysis of water leads to free radical molecules such as hydroxyl, aqueous electron, hydroperoxyl and hydronium ion. These free radicals can react between them forming much more free radicals and ROS. Some of these species may be neutralized among them, and others propagate through the cytoplasm causing oxidative damage.

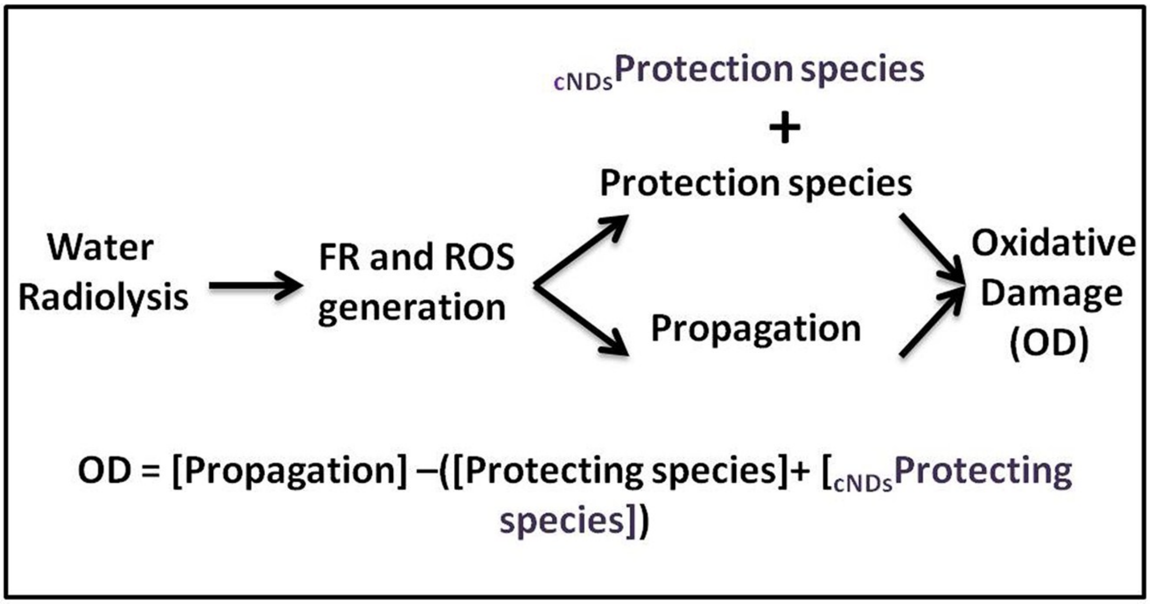


**Figure S5.** The exposure of cells to γ-irradiation results in the chemical dissociation of the cytoplasmic water molecule (water radiolysis) into H+ and OH- free radicals (FR). These FR are highly reactive and they recombine to produce reactive oxygen species (ROS) such as superoxide (HO2) and peroxide (H2O2). Some of these ROS neutralizes each other, but other can propagate leading to oxidative damage (OD). Thus, the OD depends of the concentration of ROS. When RBCs are incubated with cNDs, the same FR and ROS chain reaction occurs. However, in the presence of cNDs, the neutralization of ROS or protection of species becomes enhanced with potential minimization of the OD. Lower concentrations of ROS leading to cellular minimized oxidative damage after γ–radiation in cNDs RBCs compared with non cNDs-treated RBCs