Cell damage by energy saving light bulbs

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ABSTRACT

The growing concern regarding green house gas emissions during power generation has increased awareness regarding energy conservation. Next to transportation, lighting is one of the major sources of energy consumption. Compact fluoresce light bulbs (CFL) can provide the same amount of lumens as incandescent light bulbs, using one quarter of the energy. As a result they are rapidly gaining in popularity and are being used to replace the incandescent bulbs in all types of lighting.

Keywords: cell damage, reactive oxygen species, incandescent light bulbs, compact fluorescent light bulbs.

INTRODUCTION

The bulbs work on the principal of excitation of Hg vapors and production of the Hg emission lines that then are used to excite the phosphor that emits light in the visible range. In addition to emission, the phosphor also serves as an absorber of the UV radiation. Data sheets found on line from differ manufactures show the emissions spectra of 'typical" bulbs, which are adjusted for differ colors in the visible range, without any emission in the UV range.

In the past two years some disturbing reports have surfaced, mostly in European Union literature which indicate that exposure to these bulbs are responsible for exacerbating certain skin conditions in humans [1, 2]. A recent study [3] performed a general survey of the emissions from commercially available bulbs and found significant amounts of UVA, B and C were produced.

Therefore, we studied UV emissions in CFL, and the effects of CFL exposure on dermal fibroblasts and on DNA. We tested ten bulbs, with different power outputs and found on average significant amounts of UV produced (Table 1). The light bulbs were placed in a typical disclaim and the emissions were tested at a distance of 3 inches and the typical distance that the lamp would be from exposed skin 14 inches. These values can be compared to solar UV emissions and correspond to exposure for several hours.

Table 1. UV-light emissions by CFL

	3 inches			14 inches		
	UVA µW/ cm^2	UVB µW/ cm^2	UVC µW/ cm^2	UVA µW/ cm^2	UVB µW/ cm^2	UVC µW/ cm^2
GE 26 Watt	252	0	0.5	21.8	0	0.072
Satco 26 Watt	310	7.1	2.28	23.4	1	0.31
Satco 23 Watt	47.8	0.7	0.33	4.8	0.1	0.056
Satco 5 Watt	17.24	0.3	0.069	1.6	0.1	0.01
Satco 11 Watt	55.3	0.1	0.17	5.9	0	0.03
GE 40 Watt	24.8	0.1	0.74	2.36	0.01	0.02
GE 26 Watt	30.8	0	0.085	3.6	0	0.007
GE 60 Watt	84.3	0	0.18	6.5	0	0.02
GE 13 Watt	107.8	0.3	0.4	10.1	0	0.05

Since most people in the US also wear different types of skin care products, containing TiO_2 for pigment of SPF protection, we also tested dermal fibroblasts which were incubated with rutile and anatase TiO_2 nanoparticles. We found that unlike rutile, anatase enhances the damage.

Further experiments are in progress to study the extend of DNA damage, ROS production, and recovery.

The major source of the UV appears to be physical defects in the bulbs where the phosphorus has chipped or failed from the glass surface. In contrast to the linear florescent bulbs, these bulbs contain narrow glass tubes where large stresses on the phosphor is introduced in the curves. Optical examination of the bulbs reveals bald areas in specimens regardless of manufacture.

MATERIALS AND METHODS

Cell culture: Primary human dermal fibroblasts and preadipocytes (CF-29, National Institute on Aging (NIA) Bank) were plated at cell density 150000 cells per 75 cm^2 Petri dish. Dulbecco's Modified Eagle's Medium (DMEM) was used with 1% of *penicillin*-streptomycin (PS) and 10% of fetal bovine serum (FBS) (all purchased from Sigma). 15 ml of medium containing TiO_2 (0.2 µg/ml rutile or anatase) was added to each Petri dish 24 hours after plating. The samples were incubated with TiO_2 for 24 hours and exposed to compact fluorescent light bulb (CFL). Samples at chosen time points (up to 4 days) were counted or fixed, stained and imaged. All incubations were performed at 37^{o}C and 5% CO_2.

Cell counting: To determine the cell number during the growth curve experiments cells were plated at an initial density of 150000 cells per 75cm^2 Petri dish and counted using hemacytometer at the specific time point 2 and 4 days. Each grid square of the hemacytometer slide represents a volume of 10^{-7} m^3, and cells were counted in 10 squares in 1µl of the cell suspension. Each condition had triplicates and all experiments were conducted three times. Cell suspensions were mixed for uniform distribution and were diluted enough so that the cells did not aggregate.

Cell Staining for Confocal Microscopy: Cell area and overall morphology as a function of time and concentration was monitored using a Leica confocal microscope. For these experiments, cells were fixed with 3.7% formaldehyde for 15 minutes following exposure to CFL for 2 and 4 days. Alexa Fluor 488–Phalloidin was used for actin fiber staining and Propidium Iodide for nuclei staining. In addition, a set of images was obtained using an Hg lamp with the excitation filter of 450-490 nm and the emission filter of long pass (LP) at 515 nm.

Cell exposure to CFL: Cells were exposed in the CO_2 independent media (Sigma) for 2 hours to CFL 24 hours after exposure to TiO_2 nanoparticles at the 1 inch distance. After the CFL exposure media was replaced with fresh regular cell growth media.

ROS determination: For reactive oxygen species determination 5-(and-6)-chloromethyl-2', 7'-dichlorodihydrofluorescein diacetate, acetyl ester (CM-H_2DCFDA) was used (Invitrogen Cat # C6827). In the typical experiment 50000 cells were placed in each well of 96-well cell culture dish in the 50ml of media, after that 100 ml of working solution of CM-H_2DCFDA was added to each well and incubated at 37 C for 20 minutes. After that 100 ml of 25 mM NaN_3 solution was added to each well and placed to the incubator for 2 hours. Fluorescence was determined at ELISA fluorescence reader at 490 nm excitation and 580 nm emission.

RESULTS AND DISCUSSION

In table 1 we list the intesnsity of UVlight emitted by different CFL available commercially. The CFL were purchased from different vendors and tested at random. From the table we can see that the amount of UV emitted varied greatly between different bulbs and different manufactures. Examination of the bulbs, especially the ones with the largest emissions, showed large cracks in the phosphor coating, especially around turns in the tubes, which probably accounted for the emissions.

In the Figure 1 we show MTT data for dermal fibroblasts exposed to CFL and incandescent light bulb.

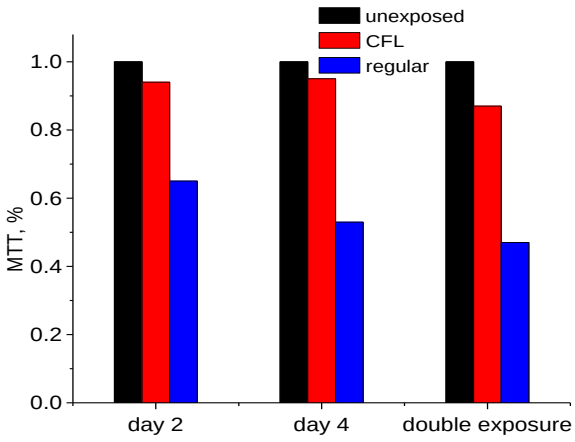

Figure 1. MTT results for cells exposed to incandescent light bulbs and CFL.

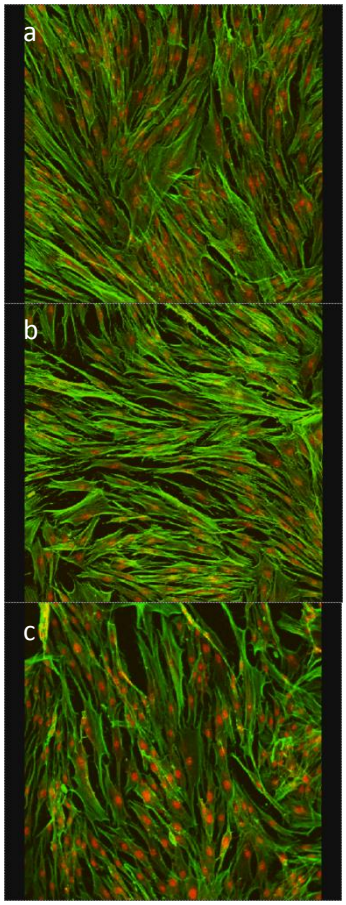

Figure 2. a. control cells, b – cells exposed to incandescent light bulb, c – cells exposed to CFL for 2 hours.

From the figure we can see that there is no significant difference cell count or MTT between cells exposed to the incandescent bulb and the unexposed control sample.

On the other hand, only 50% of the cells in the sample exposed to CFL have survived two, and did not continue to multiply even four days after exposure.

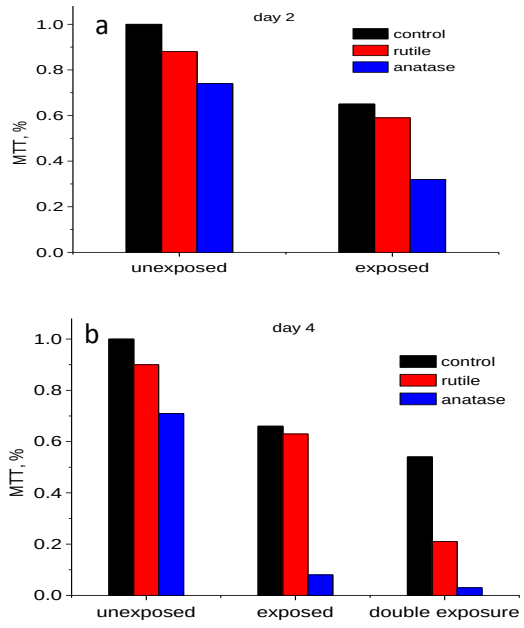

Figure 3. MTT results for cells exposed to CFL. a - 2 days after exposure, b - 4 days after exposure. Confocal microscopy (Figure 2) also confirms damage for the cells exposed to CFL. As we can see, unlike control and cells exposed to regular light bulb, these cells, start to detach from the surface and do not have a normally stretched actin fibers that support entire cell structure.

Pan et al [4] have reported that there is significant uptake when dermal fibroblasts are exposed to of titanium dioxide nanoparticles. Since these particles are commonly present in personal care products, as well as dental formulations, we also tested the effect of irradiation when the cells were also exposed to TiO2 nanoparticles. Their results are shown in figure 3, where we find that their sensitivity of UV light is heightened. The cells where TiO_2 was not present in the media, have a decrease of 37% two days after irradiation, and an additional 14% for those that were irradiated again on the second day.

For those not irradiated on the second day, we observe an increase in cells number, indicting recovery is observed on day 4. The cells exposed to rutile particles have a slightly larger decrease than the control by day 2, and larger decrease after the second irradiation by day 4.

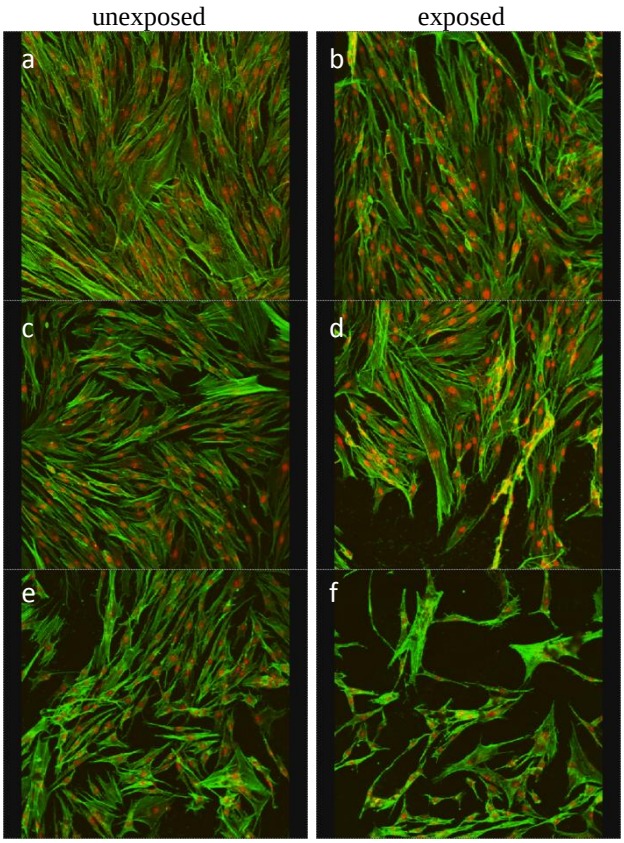

Figure 4. Confocal images of cells 4 days after exposure to CFL. a and b –control, c and d –rutile, e and f – anatase.

NSTI-Nanotech 2010, www.nsti.org, ISBN 978-1-4398-3415-2 Vol. 3, 2010

Those exposed to anatase have a drastically lower cell number even after the first irradiation and are completely eliminated by the fourth day.

These results confirm that harmful levels of UV irradiation can be emitted by CFL, and furthermore, exposure to TiO2 nanoparticles can increase the sensitivity of cells to UV irradiation.

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