

## Lanthanide ions for suppressing photodegradation of biological cells under deep-ultraviolet light exposure

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Application of deep-ultraviolet (DUV) light for analytical imaging has been recently pursued since DUV light can provide different sample information from visible light [1,2]. However, photodegradation of specimens under DUV exposure [3] limits the applications of DUV-based analytical imaging [1,2]. Here we report that the trivalent ions of three lanthanide elements,  $\text{Tb}^{3+}$ ,  $\text{Eu}^{3+}$ , and  $\text{Tm}^{3+}$ , can suppress photodegradation of biological cells under DUV exposure [4]. The cells treated with these lanthanide ions were less damaged than the cells without lanthanide ions treatment under DUV ( $\lambda = 257\text{nm}$ ) exposure. Figure 1 represents the effects of lanthanide ions on the morphology of the fixed cells under DUV exposure. With  $\text{Tb}^{3+}$ , the cells remained in place after DUV exposure, while without  $\text{Tb}^{3+}$ , the irradiated area of the cells disappeared. Figure 2 represents the effects of lanthanide ions on DUV-absorptive molecules in the fixed cells under DUV exposure. DUV ( $\lambda = 257\text{nm}$ ) Raman intensity images reconstructed by a resonance band assigned to nucleobases show that a larger signal-to-noise ratio image was measured for the cells treated with  $\text{Tb}^{3+}$ , meaning that the  $\text{Tb}^{3+}$  treatment maintained a larger number of nucleobases in cells through DUV Raman measurement than no  $\text{Tb}^{3+}$  treatment.  $\text{Eu}^{3+}$  and  $\text{Tm}^{3+}$  showed the similar level of the protective effects both on the morphology and the nucleobases in the cells under DUV exposure. The protective effects of the lanthanide ions also enabled repetitive DUV measurement of a cell as it increased the resistance to repeated DUV exposures of the cells. The ability of the lanthanide ions to suppress the photodegradation of biological cells can unlock the limitations of DUV-based analytical techniques especially for quantitative, trace, and repetitive measurements.

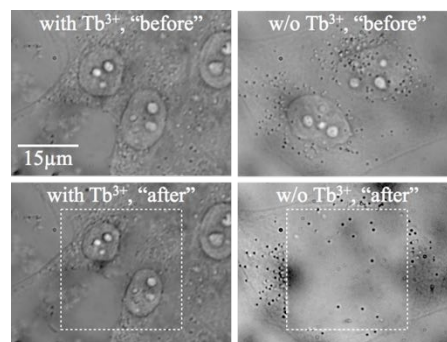


Fig. 1. Bright-field images of the cells with and without  $\text{Tb}^{3+}$  before and after DUV exposure.

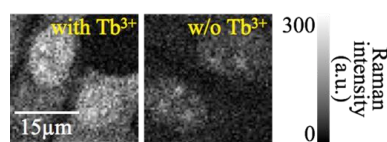


Fig. 2. DUV Raman images of the cells treated with and without  $\text{Tb}^{3+}$ .

### References

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