

5-20-2016

Possible Radiation-Induced Damage to the Molecular Structure of Wooden Artifacts Due to Micro-Computed Tomography, Handheld X-Ray Fluorescence, and X-Ray Photoelectron Spectroscopic Techniques

Madalena Kozachuk
mkozach@uwo.ca

Alexandra Suda

Lisa Ellis

Mary Walzak

Mark Biesinger

See next page for additional authors

Follow this and additional works at: <https://ir.lib.uwo.ca/biologypub>

 Part of the [Biology Commons](#)

Citation of this paper:

Kozachuk, Madalena; Suda, Alexandra; Ellis, Lisa; Walzak, Mary; Biesinger, Mark; Macfie, Sheila; Hudson, Robert; Nelson, Andrew; Martin, Ronald; and Heginbotham, Arlen, "Possible Radiation-Induced Damage to the Molecular Structure of Wooden Artifacts Due to Micro-Computed Tomography, Handheld X-Ray Fluorescence, and X-Ray Photoelectron Spectroscopic Techniques" (2016).

Biology Publications. 40.

<https://ir.lib.uwo.ca/biologypub/40>

Authors

Madalena Kozachuk, Alexandra Suda, Lisa Ellis, Mary Walzak, Mark Biesinger, Sheila Macfie, Robert Hudson, Andrew Nelson, Ronald Martin, and Arlen Heginbotham

SHORT REPORT

Possible Radiation-Induced Damage to the Molecular Structure of Wooden Artifacts Due to Micro-Computed Tomography, Handheld X-Ray Fluorescence, and X-Ray Photoelectron Spectroscopic Techniques

Madalena Kozachuk*, Alexandra Suda†, Lisa Ellis†, Mary Walzak‡, Mark Biesinger‡, Sheila Macfie*, Robert Hudson*, Andrew Nelson*, Ronald Martin* and Arlen Heginbotham§

This study was undertaken to ascertain whether radiation produced by X-ray photoelectron spectroscopy (XPS), micro-computed tomography (μ CT) and/or portable handheld X-ray fluorescence (XRF) equipment might damage wood artifacts during analysis. Changes at the molecular level were monitored by Fourier transform infrared (FTIR) analysis. No significant changes in FTIR spectra were observed as a result of μ CT or handheld XRF analysis. No substantial changes in the collected FTIR spectra were observed when XPS analytical times on the order of minutes were used. However, XPS analysis collected over tens of hours did produce significant changes in the FTIR spectra.

Keywords: X-ray Analysis; FTIR; Wooden Artifacts; Damage

Introduction

Prayer beads are sixteenth century devotional objects constructed of dense wood whose shapes are variable but generally consist of two segments attached by a hinge with the outer surface decorated in complex patterns and an interior showing elaborate, biblical scenes (**Figure 1**). The largest beads are approximately 6 cm in diameter with a depth of approximately 3 cm. The construction techniques used for these important cultural heritage artifacts have been investigated using synchrotron-based X-ray tomography (Reischig et al., 2009) and, more recently, micro-X-ray computed tomography (μ CT) was carried out at Sustainable Archaeology, The University of Western Ontario (London, Ontario) on a collection of prayer beads from the Thomson Collection at the Art Gallery of Ontario (Ellis et al., 2012). While X-ray analysis of cultural heritage objects is now widely used (Janssens et al., 2000; Bergmann, 2007; Dik et al., 2008; Janssens et al., 2010; Garside and O'Connor, 2007; Mantler and Klinkovits, 2004), surprisingly little work has been undertaken on possible radiation damage to artifacts during analysis

(Bergmann et al., 2012; Richards et al., 2012; Grubb, 1974; Hoffmeyer and Hanna, 1989). Furthermore, Bergmann et al. (2012, 365) specifically state that “X-ray techniques are generally non-destructive at sufficiently low doses. However, X-rays may cause some damage . . . [and] therefore, damage studies must be performed in some cases in order to optimize analysis to the smallest necessary dose”.

Barker et al. (1999) and Pandey et al. (1999) have used Fourier transform infrared spectroscopy (FTIR) to identify differences between the lignin and cellulose content of hardwoods and softwoods providing detailed information regarding the molecular structure of wood. In addition, FTIR has been used to examine damage to wood and wood products as a result of fungal attack and ionizing radiation, as well as visible and UV light, the latter usually for long exposures. Accordingly, FTIR was used in the research reported here to ascertain whether or not radiation exposure during analysis using X-ray photoelectron spectroscopy (XPS), X-ray tomography and/or handheld X-ray fluorescence (XRF) equipment resulted in changes to the wood at the molecular level.

The research was conducted in two distinct parts. In the first portion, FTIR was used to monitor changes in the surface chemistry of wood samples as a result of routine analysis using X-ray tomography and handheld XRF. These X-ray techniques were chosen because they are widely used in the examination of cultural heritage artifacts and the exposure times selected are representative of those used in conservation studies. In the second

* The University of Western Ontario, CA
mkozachu@uwo.ca

† The Art Gallery of Ontario, CA

‡ Surface Science Western, CA

§ The Paul Getty Museum, US

Corresponding author: Madalena Kozachuk

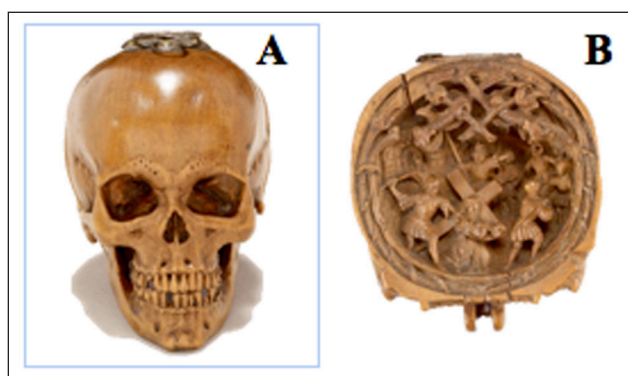


Figure 1: A boxwood prayer bead from the Thomson Collection at the Art Gallery of Ontario: **(A)** exterior when closed **(B)** interior carvings of base hemisphere.

portion, FTIR was used to monitor the effect of large X-ray doses imposed via XPS to wood samples, in order to deliberately induce changes to the wood chemistry such as the loss of functional groups (i.e. ethers and alcohols), which would lead to water loss and crosslinking, ultimately leading to darkening/charring of the surface and changes in mechanical strength. This approach provides a concrete comparison of a purposefully altered sample, indicative of long-term damage, to the samples analyzed by typical X-ray sources in conservation studies. This was done to help establish safe time limits and energy levels for X-ray exposure. Consequently, the presented results are relevant to contemporary researchers.

Methods and Materials

Wood sample

A piece of San Domingo Boxwood, approximately $8 \times 2.5 \times 2.5$ cm, was supplied by the Art Gallery of Ontario. This sample was identified by Arlen Heginbotham of The J. Paul Getty Museum as *Phyllostylon rhamnoides*. While the Thomson Collection prayer beads are made from a different species of boxwood (believed to be European Boxwood, *Buxus sempervirens*) this sample has similar density and workability, both traits ideal for carving, and was used to serve as a surrogate for the wood used in the construction of the artifacts. In addition, the results obtained might be expected to apply to any dense wood hard enough to allow for fine carving. Individual subsamples for each subsequent treatment were cut from this piece using a steel chisel or a surgical blade as appropriate to the size requirement of the analytical method(s) of choice.

X-ray photoelectron spectroscopy

A subsample of wood for analysis by X-ray photoelectron spectroscopy (XPS) was cut from the parent sample using a sterile stainless steel scalpel to obtain a piece of approximately $10 \times 5 \times 2$ mm. The sample was then mounted on a carbon stud prior to analysis. XPS analysis was carried out at Surface Science Western, University of Western Ontario, using a Kratos AXIS Ultra XPS and a monochromatic Al K_{α} X-ray source with a current of 15 mA and an energy of 14 kV (210 W) producing an X-ray analytical area of 300×700 μm at $1.5 - 2 \times 10^{-9}$ torr base vacuum. The sample was subjected to two analysis times: one of

44 hours throughout which photoelectron spectra were collected every 25 minutes and a second of 13 hours with spectra collected every four minutes. High-resolution carbon $1s$ spectra were obtained in order to monitor changes in the chemistry of organic species. The longer radiation exposure and resulting high X-ray dose was used to identify functional groups sensitive to X-ray exposure, while the shorter analysis, having only 4 minutes between spectra, could be used as an indicator of early changes in the sample.

Micro-computed tomography

A subsample of wood measuring approximately $2.5 \times 2.5 \times 1$ cm, removed from the parent sample using a stainless steel scalpel, was subjected to micro-computed tomography (μCT) at Sustainable Archaeology using a Nikon Metrology XT-225 industrial μCT scanner with a 3 μm spot size from a tungsten reflecting target. The instrument voltage was 105 kVp at a current of 48 μA , with a 500 μs exposure and 2 frames averaged per projection. The total scan time was 53 minutes.

Handheld X-ray fluorescence spectroscopy

Two subsamples, approximately $1 \times 1 \times 0.5$ cm, used for analysis with the handheld XRF instrument, were removed from the parent sample using a stainless steel chisel in the University of Western Ontario physics machine shop. The analytical instrument used was a Bruker TRACER-IV (Shugar & Mass, 2012) that produced an oval beam 0.5 cm at its widest point when projected on the sample surface. Two pieces of boxwood were examined using a 40 keV X-ray at an anode current of 13 μA . Two locations on one piece were exposed for 60 seconds and 3 locations were exposed for 120 seconds on the other. In all cases, locations were selected such that there was no overlap between sites. The exposure times were taken to be typical of those used in routine field analysis.

Fourier transform infrared spectroscopy

All FTIR spectra were obtained using a surface reflectance, Bruker IFS 55 (SR-FTIR) spectrometer at Surface Science Western. The instrument was equipped with an IRScope microscope with an attenuated total reflection (ATR) objective equipped with a germanium crystal. The ATR objective probes an elliptical area approximately 80×100 μm having an estimated collection depth of 1–2 μm and a resolution of 4 cm^{-1} . There were 100 background scans collected from the air and these were used to generate an average background spectrum, which was subtracted from subsequent runs. A total of 10 FTIR spectra were obtained from the sample that was analyzed by micro-CT and a total of 9 and 7 spectra were obtained from the samples exposed under XRF for 60 or 120 seconds, respectively.

A reference spectrum was prepared in the following way using an unexposed subsample of the boxwood. FTIR spectra were obtained at 30 sites chosen at random from the sample surface with a rotation of 90° after 15 spectra were collected to compensate for the heterogeneity of the surface. A three-point baseline correction was performed on each spectrum using straight lines drawn between

wavenumbers 3680, 1850 and 825 cm^{-1} . These 30 spectra were then averaged to produce a reference spectrum for all subsequent analyses. The functional groups used to identify possible damage to the wood by comparison with the reference spectrum were selected as they were characteristic of lignin and cellulose components found in each spectrum (Barker & Owen, 1999; Pandey, 1999; Garside & Wyeth, 2003; Ferraz et al., 2000) (**Table 1**). Additionally, they are representative of the structural units that were visibly charred during the XPS analysis. Alkyl C – OH and C – O – C from cellulose, whose absorbance is observed at 1033 cm^{-1} , was chosen to monitor any X-ray induced chemical variation. The absorbance at 3347 cm^{-1} is associated with the O – H vibrational mode in water and is sensitive to relative humidity and the ultrahigh vacuum in the XPS instrument. This absorbance is not included in any further analysis. All absorbance positions are compared using absolute peak height.

Statistical analysis

Since all analytical samples were derived from the same piece of boxwood, it was impossible to get independent, biological replicates making detailed statistical analysis inappropriate. Nonetheless, multiple measurements were taken from each sample to reflect variable changes to boxwood molecular structures in response to the various X-ray treatments. The following analyses were carried out to obtain an unbiased assessment of whether or not the molecular structure differed between X-ray treated samples and the reference sample. For the μCT data, a Mann-Whitney U test was applied as the data did not meet the assumptions of a parametric t-test; the data were not normally distributed and the variances were not homogeneous. A one-way ANOVA was run on the handheld XRF data to compare the treatments of beam-analyzed samples at 60 and 120 seconds with the reference samples. Both normality and homogeneity of variance were confirmed prior to running the ANOVA. All the above statistical analysis was carried out using SigmaPlot version 11.1. The absorbance at 1033 cm^{-1} , seen in the FTIR spectra following the XPS analyses, was compared to that of the reference sample with a Student's t-test using Excel 2007.

FTIR Absorbance Location (cm^{-1})	Vibration	Structural Unit
3347	O–H	Cellulose, Lignin, Absorbed H_2O
1596	Aromatic skeletal C–C	Lignin
1508	Aromatic in-plane C–C	Lignin
1369	C–H	Cellulose
1033	Alkyl C–OH	Cellulose

Table 1: FTIR absorbance: assigned vibrations and corresponding structural units (Barker & Owen, 1999; Pandey, 1999; Garside & Wyeth, 2003; Ferraz et al., 2000; Collier et al., 1992).

Results and Discussion

The photoelectron yields associated with selected organic functional groups as a function of time for both 13 and 44-hour XPS exposures are shown in **Figure 2**. These spectra were not normalized since they were run specifically to establish the scale of measurable damage that would occur after long exposure to the X-rays. Neither treatment caused any change in photoelectron yield during at least the first 10 minutes of analysis (this is clearly visible in the spectra obtained during the 13-hour XPS exposure when results were collected every 4 minutes). Longer exposure times induced an increase in photoelectrons characteristic of C-C and C-H functionality with a co-incident decrease in C – O – C and C – O – H consistent with the charring that was visible on the sample surface. C = O and O – C = O show much less variability with time suggesting that these groups are more stable under X-ray exposure.

After the 44-hour exposure to XPS X-rays, the FTIR analysis (**Figure 3**) showed changes near 1033 cm^{-1} associated with alkyl O – H and C – O – C bonds. A Student's t-test confirmed a change at 1033 cm^{-1} in the FTIR spectrum as a result of the X-ray exposure.

The FTIR data from the μCT exposed wood were examined via a Mann-Whitney U test (**Figure 4A**) and the FTIR data from the handheld XRF exposed wood were examined using a one-way ANOVA (**Figure 4B**). The analysis performed on the μCT data revealed no difference between the scanned surface and the reference sample. Furthermore, the FTIR spectra of the wood surfaces exposed to the handheld XRF for 60 or 120 seconds did not differ from each other or from the reference sample.

Statistical analyses were done simply to obtain an unbiased assessment of whether or not the molecular structure differed between X-ray treated samples and the reference sample. These statistics were collected from the same parent block and therefore can only provide us with the effect of X-rays on this single piece of San Domingo boxwood. However, the changes induced in this wood sample should serve to caution conservators to limit the time of exposure to X-ray sources when studying dense, wooden artifacts, such as prayer beads. However, short exposure during analysis using the XPS, μCT or XRF equipment used here did not produce any significant changes to the structure of the wood after analysis times typical of routine investigations.

The XPS treatment was deliberately undertaken to expose the wood surface to a highly localized, X-ray dose. There was some visible charring and the resulting FTIR spectrum differed from that of the reference sample; specifically, a marked change occurred at approximately 1033 cm^{-1} as a result of XPS analysis. This absorbance corresponds to alkyl O – H and C – O – C ether linkages. Extensive damage will lead to loss of water and carbonate ions. Prior to this, changes such as carbon chain free radical induced cross-linking, leading to changes in mechanical strength, might be anticipated (Colom et al., 2003; Bouchard et al., 2006). The photoelectron spectrum from the 44-hour analysis (**Figure 2A**) showed an increase in the C – C and C – H peaks consistent with the observed charring along with an attendant decrease in the electron yield for the O – H and C – O – C. The 13-hour analysis (**Figure 2B**)

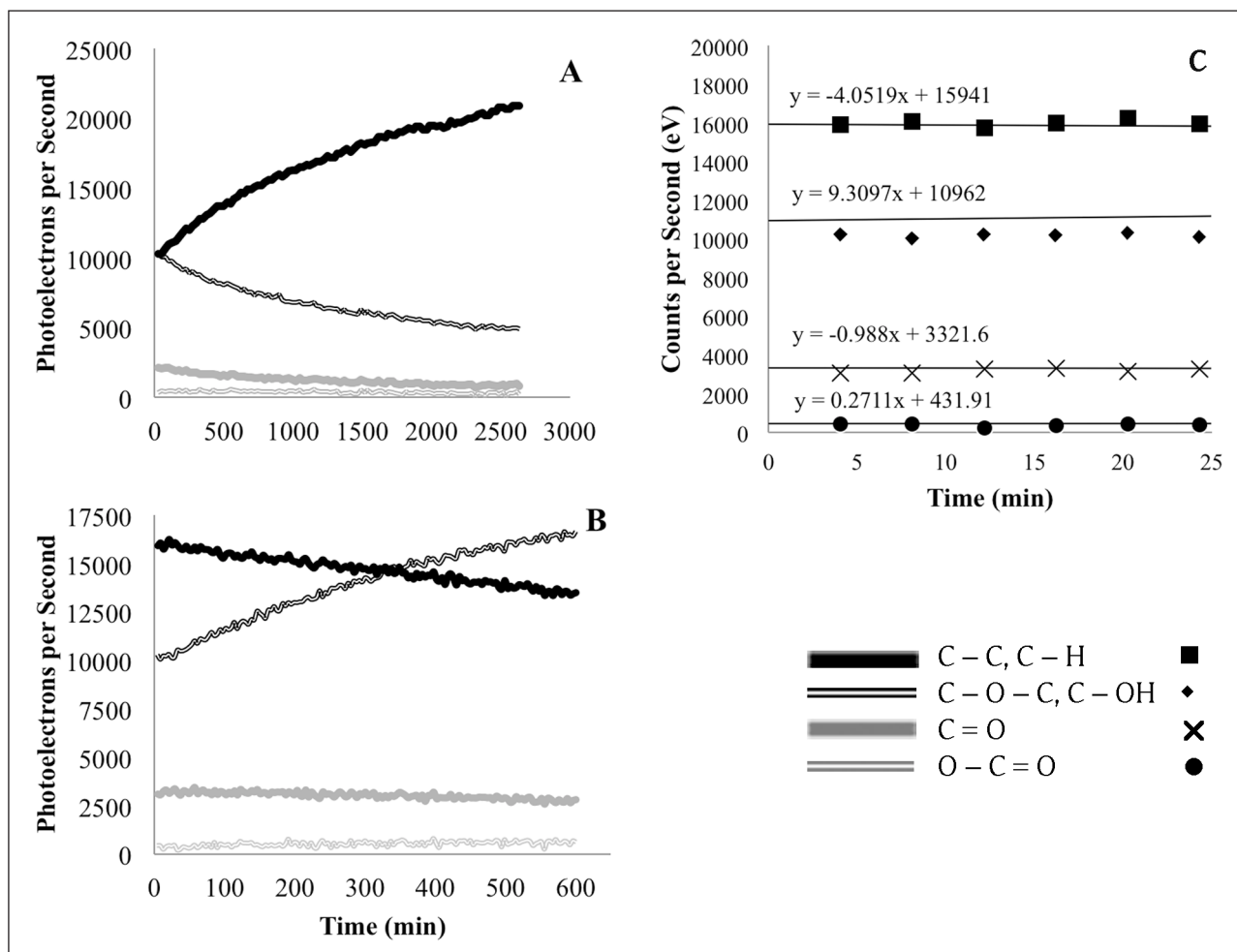


Figure 2: X-ray photoelectron spectra of high-resolution carbon 1s (A) 44-hour experiment with data collected every 25 minutes (B) 13-hour experiment with data collected every 4 minutes (C) first 25 minutes of the 13-hour experiment.

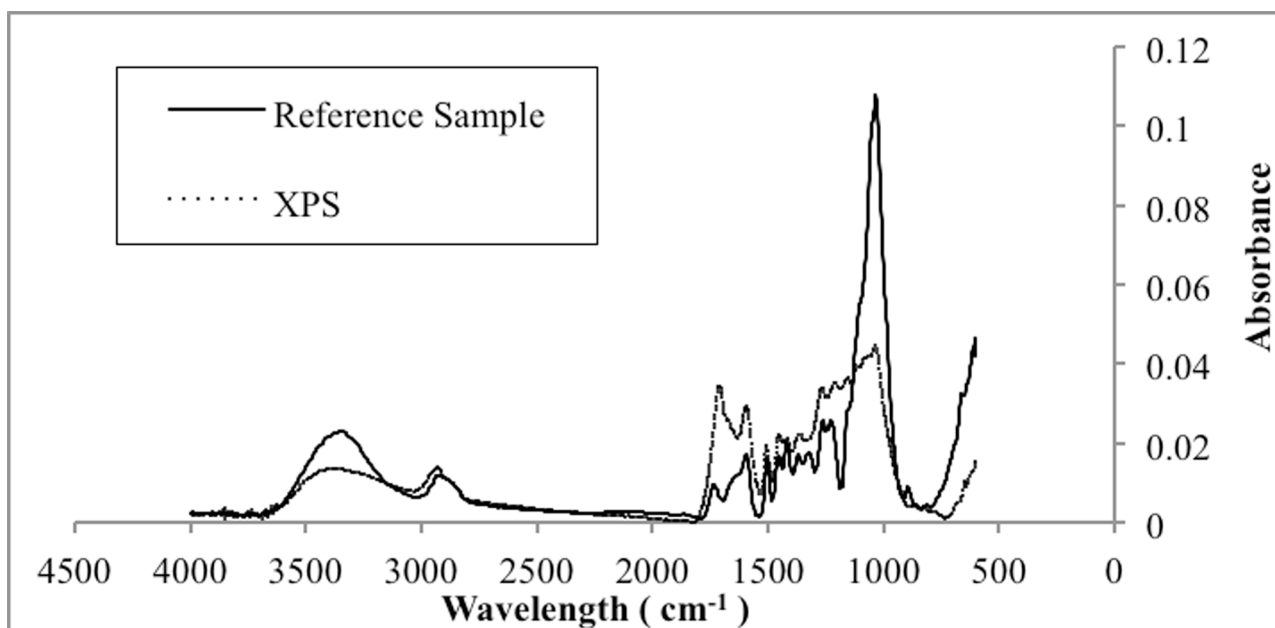


Figure 3: FTIR spectrum before and after 44-hour exposure to XPS.

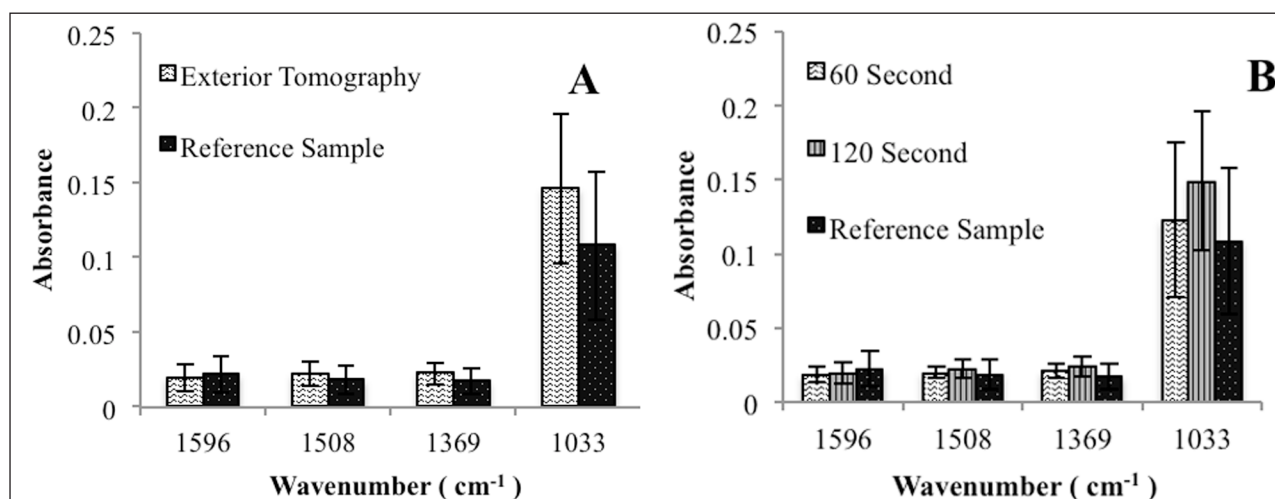


Figure 4: FTIR peak absorbance values for boxwood: (A) μ CT scanned sample compared to reference (B) sample exposed to handheld XRF for 60 or 120 seconds compared to reference. For each data set, no differences in absorbance at any measured wavenumber were detected (μ CT: $U \leq 66.0$, $P > 0.140$; XRF: $F \leq 1.436$, $P > 0.159$).

showed a similar result while the better time resolution indicates that no significant change occurred to the sample during, at least, the first 20 minutes of the exposure. It is important to note that X-rays do not interact strongly with elements with low atomic numbers. However, beam energy, current, and exposure time need to be carefully considered prior to artifact analysis to ensure that no surface damage occurs as a result of scientific examination.

The principal value of this result is that it shows that FTIR and XPS are effective techniques for investigating X-ray induced changes in the structure of wood. However, the latter technique, requiring an ultrahigh vacuum, may cause significant dehydration of the wood's surface.

Conclusions

Given the caveats attendant on our statistical analysis, the results show that, under the specific conditions used in this experiment, which sought to replicate typical analytical protocols, there is no apparent damage to wood as a result of μ CT or handheld XRF treatments. No change occurred in the XPS spectra for exposure times of less than 10 minutes.

The deliberate attempt to damage the sample using prolonged XPS analysis showed that the alkyl C – O – H and C – O – C bonds are sensitive to X-rays, thus revealing that limiting the exposure time of the sample is one of the precautions necessary to avoid damage when using any form of ionizing radiation – especially with valuable cultural heritage artifacts.

Competing Interests

[[COMPETING INTEREST STATEMENT TO BE PROVIDED]]

References

- Barker, B and Owen, N L** 1999 Identifying softwoods and hardwoods by infrared spectroscopy, *J. Chem. Educ.*, 76(12): 1706–1709. DOI: <http://dx.doi.org/10.1021/ed076p1706>
- Bergmann, U** 2007 Archimedes brought to light. *Phys World*, 20(11): 39–42. DOI: <http://dx.doi.org/10.1088/2058-7058/20/11/39>
- Bergmann, U, Manning, P L and Wogelius, R A** 2012 Chemical mapping of paleontological and archaeological artifacts with synchrotron X-rays. *Annu. Rev. Anal. Chem.*, 5: 361–389. DOI: <http://dx.doi.org/10.1146/annurev-anchem-062011-143019>
- Bouchard, J, Methot, M and Jordon, B** 2006 The effects of ionizing radiation on the cellulose of woodfree paper. *Cellulose*, 13(5): 601–610. DOI: <http://dx.doi.org/10.1007/s10570-005-9033-0>
- Collier, W E, Schultz, T P and Kalasinsky, V F** 1992 Infrared study of lignin: Reexamination of aryl-alkyl ether C-O stretching peak assignments. *Holzforschung*, 46(6): 523–528. DOI: <http://dx.doi.org/10.1515/hfsg>
- Colom, X, Carrillo, F, Nogues, F and Garriga P** 2003 Structural analysis of photodegraded wood by means of FTIR spectroscopy. *Polym. Degrad. Stabil.*, 80(3): 543–549. DOI: [http://dx.doi.org/10.1016/S0141-3910\(03\)00051-X](http://dx.doi.org/10.1016/S0141-3910(03)00051-X)
- Dik, J, Janssens, K, van der Snickt, G, van der Loeff, L, Rickers, K and Cotte, M** 2008 Visualization of a lost painting by Vincent van Gogh using synchrotron radiation-based x-ray fluorescence elemental mapping. *Anal. Chem.*, 80(16): 6436–6442. DOI: <http://dx.doi.org/10.1021/ac800965g>
- Ellis, L, Martin, R, Moffatt, Z, Morris, E, Nelson, A and Newman, R** 2012 Prayer beads in the Thomson collection at the Art Gallery of Ontario: materials and construction, proceedings from prayer nuts, private devotion and early modern art collecting. *Abegg-Stiftung, Riggisberg, Switzerland, International Colloquium*, pp. 20–21.
- Ferraz, A, Rodriguez, J, Freer, J and Baeza, J** 2000 Estimating the chemical composition of biodegraded pine and eucalyptus wood by DRIFT spectroscopy and multivariate analysis, *Bioresour Technol.*, 74(3): 201–212. DOI: [http://dx.doi.org/10.1016/S0960-8524\(00\)00024-9](http://dx.doi.org/10.1016/S0960-8524(00)00024-9)

- Garside, P** and **O'Connor, S** 2007 Assessing the risks of radiographing culturally significant textiles. *e-PS*, 4: 1–7.
- Garside, P** and **Wyeth, P** 2003 Identification of cellulosic fibres by FTIR spectroscopy: thread and single fibre analysis by attenuated total reflectance. *Stud. Conserv.*, 48(4): 269–275. DOI: <http://dx.doi.org/10.1179/sic.2003.48.4.269>
- Grubb, D T** 1974 Radiation damage and electron microscopy of organic polymers. *J. Mater. Sci.*, 9(10): 1715–1736. DOI: <http://dx.doi.org/10.1007/BF00540772>
- Hoffmeyer, P** and **Hanna, R B** 1989 Electron beam damage during testing of wood in the SEM, *Wood Sci. Technol.*, 23(3): 211–214. DOI: <http://dx.doi.org/10.1007/BF00367734>
- Holloway, P H, Madey, T E, Campbell, C T, Rye, R R** and **Houston, J F** 1979 Electron spectroscopy of condensed multilayers: line shape changes due to electron beam damage and excitation mode. *Surf. Sci.*, 88(1): 121–138. DOI: [http://dx.doi.org/10.1016/0039-6028\(79\)90571-5](http://dx.doi.org/10.1016/0039-6028(79)90571-5)
- Janssens, K, Dik, J, Cotte, M** and **Susinni, J** 2010 Photon-based techniques for nondestructive subsurface analysis of painted cultural heritage artifacts. *Acc. Chem. Res.*, 43(6): 814–825. DOI: <http://dx.doi.org/10.1021/ar900248e>
- Janssens, K, Vittiglio, G, Deraedt, I, Aerts, A, Vekemans, B, Vîneze, L, Wei, F, Deryek, I, Schalm, O, Adams, F, Rindby, A, Knöchel, A, Simionovici, A** and **Snigerrev, A** 2000 Use of microscopic XRF for non-destructive analysis in art and archaeometry. *X-ray Spectrom.*, 29(1): 73–91. DOI: [http://dx.doi.org/10.1002/\(SICI\)1097-4539\(200001/02\)29:1<73::AID-XRS416>3.0.CO;2-M](http://dx.doi.org/10.1002/(SICI)1097-4539(200001/02)29:1<73::AID-XRS416>3.0.CO;2-M)
- Mantler, M** and **Klikovits, J** 2004 Analysis of art objects and other delicate samples: is XRF really nondestructive? *Powder Diffr.*, 19(1): 16–19. DOI: <http://dx.doi.org/10.1154/1.1649962>
- Moore, A K** and **Owen, N L** 2001 Infrared spectroscopic studies of solid wood. *Appl. Spectrosc. Rev.*, 36(1): 65–86. DOI: <http://dx.doi.org/10.1081/ASR-100103090>
- Pandey, K K** 1999 A study of chemical structure of soft and hardwood and wood polymers by FTIR spectroscopy. *J. Appl. Polym. Sci.*, 71(12): 1969–1975. DOI: [http://dx.doi.org/10.1002/\(SICI\)1097-4628\(19990321\)71:12<1969::AID-APP6>3.0.CO;2-D](http://dx.doi.org/10.1002/(SICI)1097-4628(19990321)71:12<1969::AID-APP6>3.0.CO;2-D)
- Pandey, K K** and **Pitman, A J** 2003 FTIR studies of the changes in wood chemistry following decay by brown-rot and white-rot fungi. *Int. Biodeter. Biodegr.*, 52(3): 151–160. DOI: [http://dx.doi.org/10.1016/S0964-8305\(03\)00052-0](http://dx.doi.org/10.1016/S0964-8305(03)00052-0)
- Pantano, C G** and **Madey, T E** 1981 Electron beam damage in auger electron spectroscopy, *Appl. Surf. Sci.*, 7(1–2): 115–141. DOI: [http://dx.doi.org/10.1016/0378-5963\(81\)90065-9](http://dx.doi.org/10.1016/0378-5963(81)90065-9)
- Reischig, P, Blass, J, Botha, C, Bravin, A, Porra, L, Nemoz, C, Wallert, A** and **Dik, J** 2009 A note on medieval microfabrication: the visualization of a prayer nut by synchrotron-based computer x-ray tomography. *J. Synchrotron Radiat.*, 16(2): 310–313. DOI: <http://dx.doi.org/10.1107/S0909049508043082>
- Richards, G D, Jabbour, R S, Horton, C F, Ibarra, C L** and **MacDowell, A A** 2012 Colour changes in modern and fossil teeth induced by synchrotron microtomography, *Am. J. Phys. Anthropol.*, 149(2): 172–180. DOI: <http://dx.doi.org/10.1002/ajpa.22103>
- Shugar, A A** and **Mass, J M** (eds.) 2012 *Handheld XRF for art and archaeology*, Leuvan University Press: Belgium.

How to cite this article: Kozachuk, M, Suda, A, Ellis, L, Walzak, M, Biesinger, M, Macfie, S, Hudson, R, Nelson, A, Martin, R and Heginbotham, A 2016 Possible Radiation-Induced Damage to the Molecular Structure of Wooden Artifacts Due to Micro-Computed Tomography, Handheld X-Ray Fluorescence, and X-Ray Photoelectron Spectroscopic Techniques. *Journal of Conservation and Museum Studies*, X(X): X, pp. 1–6, DOI: <http://dx.doi.org/10.5334/jcms.126>

Published: XX XXXXXXXX 201X

Copyright: © 2016 The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. See <http://creativecommons.org/licenses/by/4.0/>.

Journal of Conservation and Museum Studies is a peer-reviewed open access journal published by Ubiquity Press.

OPEN ACCESS 

Typesetting queries

1. The journal has a policy to include a competing interest statement in all published articles, to ensure transparency. Please could you provide a competing interest statement, or confirm that all authors of this article have no competing interests. Further information is available here: www.jcms-journal.com/information/competingInterestGuidelines.
2. The following item has been included within the reference list, but is not cited within the text. For un-cited reference, please advise where it should be cited in the text, or confirm that it can be removed from the reference list.
 - a. Ref no. 14. "Holloway, P H, Madey, T E, Campbell, C T, Rye, R R and Houston, J F 1979"
 - b. Ref no. 18. "Moore, A K and Owen, N L 2001"
 - c. Ref no. 20. "Pandey, K K and Pitman, A J 2003"
 - d. Ref no. 21. "Pantano, C G and Madey, T E 1981"