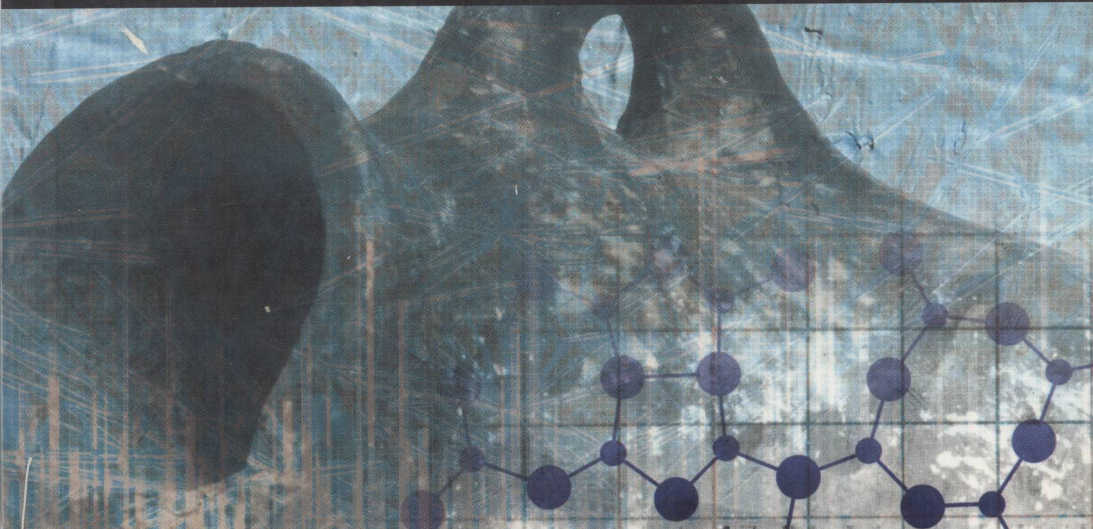
ANALYTICAL TECHNIQUES IN

MATERIALS CONSERVATION

BARBARA STUART



WILEY

Analytical Techniques in Materials Conservation

Barbara H. Stuart
Department of Chemistry,
Materials and Forensic Sciences
University of Technology, Sydney,
Australia

BICENTENNIAL 1807 WILEY 2007

John Wiley & Sons, Ltd

Telephone (+44) 1243 779777

Email (for orders and customer service enquiries): cs-books@wiley.co.uk
Visit our Home Page on www.wileyeurope.com or www.wiley.com

Other Wiley Editorial Offices

John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030, USA

Jossey-Bass, 989 Market Street, San Francisco, CA 94103-1741, USA

Wiley-VCH Verlag GmbH, Boschstr. 12, D-69469 Weinheim, Germany

John Wiley & Sons Australia Ltd, 42 McDougall Street, Milton, Queensland 4064, Australia

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01, Jin Xing Distripark, Singapore 129809

John Wiley & Sons Canada Ltd, 6045 Freemont Blvd, Mississauga, Ontario, L5R 4J3, Canada

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Library of Congress Cataloging-in-Publication Data:

Stuart, Barbara (Barbara H.)
Analytical techniques in materials conservation / Barbara Stuart.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-470-01280-2 (cloth : alk. paper) – ISBN 978-0-470-01281-9 (pbk. : alk. paper)
1. Materials – Deterioration. 2. Preservation of materials. I. Title.
TA418.74.S78 2007
702.8′8 – dc22

2006100401

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 978-0-470-01280-2 (HB) 978-0-470-01281-9 (PB)

Typeset in 10.5/13pt Sabon by Laserwords Private Limited, Chennai, India.
Printed and bound in Great Britain by TJ International Ltd, Padstow, Cornwall
This book is printed on acid-free paper responsibly manufactured from sustainable forestry in which at least two trees are planted for each one used for paper production.

Analytical Techniques in Materials Conservation

Abbreviations

AAS	atomic absorption spectroscopy
ABS	acrylonitrile-butadiene-styrene
AES	atomic emission spectroscopy/Auger electron spectroscopy
AFM	atomic force microscopy
AMS	accelerator mass spectrometer
ANN	artificial neural network
ATR	attenuated total reflectance
CAT	computerised axial tomography
CE	capillary electrophoresis
CEMS	conversion electron Mössbauer spectroscopy
CGE	capillary gel electrophoresis
CI	chemical ionisation
CP	cross polarisation
CZE	capillary zone electrophoresis
DAC	diamond anvil cell
DAD	diode array detection
DETA	dielectric thermal analysis
DMA	dynamic mechanical analysis
DMTA	dynamic mechanical thermal analysis
DSC	differential scanning calorimetry
DTA	differential thermal analysis
DTG	derivative thermogram
DTGS	deuterium triglycine sulfate
DTMS	direct temperature mass spectrometry
EDS	energy dispersive spectroscopy
EDTA	ethylenediaminetetraacetic acid
EDXRF	energy dispersive X-ray fluorescence
EELS	electron energy loss spectroscopy
EGA	evolved gas analysis
EI	electron impact
EMPA	electron microprobe analysis
ESEM	environmental scanning electron microscopy
ESI	electrospray ionisation

ESR	electron spin resonance
FAB	fast atom bombardment
FD	field desorption
FI	field ionisation
FID	free induction decay
FORS	fibre optics reflectance spectroscopy
FPA	focal plane array
FTIR	Fourier transform infrared
GC	gas chromatography
GC-IR	gas chromatography – infrared
GC-MS	gas chromatography – mass spectrometry
GFAAS	graphite furnace atomic absorption spectroscopy
GPC	gel permeation chromatography
HDPE	high density polyethylene
HMDS	hexamethyldisilazane
HPLC	high performance liquid chromatography
IBA	ion beam analysis
IC	ion chromatography
ICP	inductively coupled plasma
IRMS	isotope ratio mass spectrometry
LA	laser ablation
LD	laser desorption
LDA	linear discriminant analysis
LDPE	low density polyethylene
LIBS	laser induced breakdown spectroscopy
MALDI	matrix assisted laser desorption/ionisation
MAS	magic angle spinning
MCT	mercury cadmium telluride
MRI	magnetic resonance imaging
MS	mass spectrometry
MTBS	N-methyl-N-tert-butyldimethylsilyl
NAA	neutron activation analysis
NMR	nuclear magnetic resonance
NRA	nuclear reaction analysis
OES	optical emission spectroscopy
OM	optical microscopy
OSL	optically stimulated luminescence
PAN	polyacrylonitrile
PAS	photoacoustic spectroscopy
PC	polycarbonate
PCA	principal component analysis

PDMS	poly(dimethyl siloxane)
PE	polyethylene
PEO	poly(ethylene oxide)
PET	poly(ethylene terephthalate)
PIGE	proton induced gamma emission
PIXE	proton induced X-ray emission
PL	photoluminescence
PLM	polarised light microscopy
PMMA	poly(methyl methacrylate)
PP	polypropylene
PS	polystyrene
PSL	photostimulated luminescence
PTFE	polytetrafluoroethylene
PU	polyurethane
PVA	poly(vinyl acetate)
PVAl	poly(vinyl alcohol)
PVC	poly(vinyl chloride)
Py-MS	pyrolysis mass spectrometry
RBS	Rutherford backscattering spectrometry
RI	refractive index
RP	reversed phase
RRS	resonance Raman spectroscopy
SAXS	small angle X-ray scattering
SEC	size exclusion chromatography
SERS	surface enhanced Raman spectroscopy
SFC	supercritical fluid chromatography
SG	specific gravity
SIMS	secondary ion mass spectrometry
SPME	solid phase microextraction
SSIMS	static secondary ion mass spectrometry
STEM	scanning transmission electron microscopy
STM	scanning tunneling microscopy
TEM	transmission electron microscopy
TGA	thermogravimetric analysis
TMAH	tetramethylammonium hydroxide
THM	thermally assisted hydrolysis methylation
TIC	total ion current
TLC	thin layer chromatography
TMA	thermal mechanical analysis
TMS	tetramethylsilane
TOF	time-of-flight

UV	ultraviolet
WAXS	wide angle X-ray scattering
WDXRF	wavelength dispersive X-ray fluorescence
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
XRF	X-ray fluorescence

Preface

The use of scientific techniques in materials conservation has notably expanded in recent decades. There is much interest in identifying the materials used in culturally important objects. Of great importance is a clear understanding of the state and mechanisms of degradation of objects susceptible to deterioration with time and exposure to environmental factors. An understanding of the state of materials at a molecular level can provide valuable information for conservators, enabling them to decide on a conservation procedure.

There is an extensive range of analytical techniques used by scientists that may be applied to heritage materials. The application of modern analytical techniques to conservation issues continues to expand with the ability to analyse smaller and smaller quantities of sample. The development of non-destructive remote sampling methods and portable instruments will further allow for precious objects to be examined safely.

The aim of this book is to provide those with an interest in material conservation with an overview of the analytical techniques that are potentially available to them. When making the initial decision to investigate an object, it can be difficult to decide on the best analytical approach. Chapters 2 to 10 provide a straightforward background to each of the common analytical techniques. An explanation of how an instrument actually works is provided without excessive technical detail that can be overwhelming for the first-time user. The nature and size of a sample required for analysis is also an important consideration in conservation and this information is provided for each technique. Additionally, for each technique, examples of the application of the method to specific types of heritage materials are provided, with the relevant literature references provided. Clearly, a review of all the studies that have been carried out using each technique is not feasible given the extensive use of particular techniques, but suitable examples are provided in each case. An introductory chapter also provides an overview of the different types of materials that may be encountered in conservation work. An understanding of the structures of such materials aids in the interpretation of the data obtained from analytical techniques.

Naturally, conservators working in a museum environment will not necessarily have access to a laboratory equipped with all the techniques described! However, many analytical techniques are becoming more compact and less expensive to purchase with time, making it possible that a museum laboratory can have access to a suitable instrument for their interests. Additionally, for more specialised techniques involving more substantial and expensive equipment, collaboration with university and research organisations may be required. However, as will be gathered from a study of the literature provided in this book, there has been a great history of collaboration between such institutions.

I hope that this book provides a useful source of information for those with an interest in materials conservation. While it should prove an aid to those already working in this field, the book is also aimed at those entering the field who would like to know more about the analysis of heritage materials. I have not assumed an in-depth knowledge of chemistry, materials science or analytical chemistry in preparing this book, so those without a strong background in these fields will be able to cope with the scientific concepts.

I would like to thank all the conservators, curators and researchers with whom I have communicated during the preparation of this book. There is much fascinating conservation work being carried out around the world. I hope this book will help make a contribution.

Barbara H. Stuart
University of Technology, Sydney,
Australia

Trade Mark Acknowledgements

Bakelite – Bakelite AG; Dacron – DuPont; Kevlar – DuPont; Lycra – DuPont; Nomex – DuPont; Perspex – Lucite International; Parylene – Union Carbide; Teflon – DuPont; Terylene – ICI.

Contents