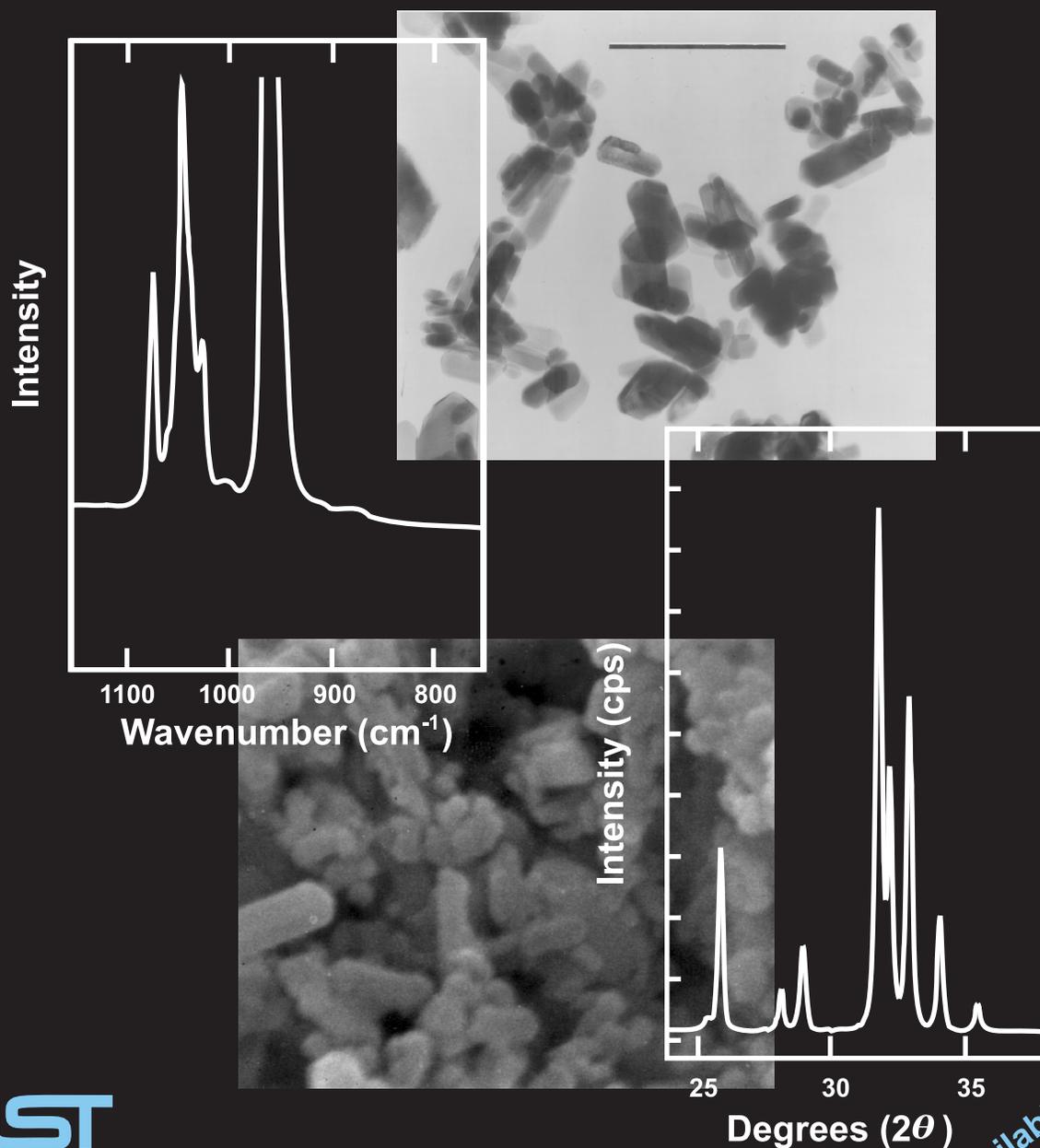


Journal of Research

of the

National Institute of Standards and Technology

November - December 2004, Vol. 109, No. 6 ISSN 1044-677X



NIST

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Available Online
<http://www.nist.gov/jres>

The National Institute of Standards and Technology was established in 1988 by Congress to “assist industry in the development of technology ... needed to improve product quality, to modernize manufacturing processes, to ensure product reliability ... and to facilitate rapid commercialization ... of products based on new scientific discoveries.”

NIST, originally founded as the National Bureau of Standards in 1901, works to strengthen U.S. industry’s competitiveness; advance science and engineering; and improve public health, safety, and the environment. One of the agency’s basic functions is to develop, maintain, and retain custody of the national standards of measurement, and provide the means and methods for comparing standards used in science, engineering, manufacturing, commerce, industry, and education with the standards adopted or recognized by the Federal Government.

As an agency of the U.S. Commerce Department’s Technology Administration, NIST conducts basic and applied research in the physical sciences and engineering, and develops measurement techniques, test methods, standards, and related services. The Institute does generic and precompetitive work on new and advanced technologies. NIST’s research facilities are located at Gaithersburg, MD 20899, and at Boulder, CO 80303. Major technical operating units and their principal activities are listed below. For more information visit the NIST Website at <http://www.nist.gov>, or contact the Publications and Program Inquiries Desk, 301-975-3058.

Office of the Director

- National Quality Program
- International and Academic Affairs

Technology Services

- Standards Services
- Technology Partnerships
- Measurement Services
- Information Services
- Weights and Measures

Advanced Technology Program

- Economic Assessment
- Information Technology and Applications
- Chemistry and Life Sciences
- Electronics and Photonics Technology

Manufacturing Extension Partnership Program

- Regional Programs
- National Programs
- Program Development

Electronics and Electrical Engineering Laboratory

- Microelectronics
- Law Enforcement Standards
- Electricity
- Semiconductor Electronics
- Radio-Frequency Technology¹
- Electromagnetic Technology¹
- Optoelectronics¹
- Magnetic Technology¹

Materials Science and Engineering Laboratory

- Intelligent Processing of Materials
- Ceramics
- Materials Reliability¹
- Polymers
- Metallurgy
- NIST Center for Neutron Research

Chemical Science and Technology Laboratory

- Biotechnology
- Process Measurements
- Surface and Microanalysis Science
- Physical and Chemical Properties²
- Analytical Chemistry

Physics Laboratory

- Electron and Optical Physics
- Atomic Physics
- Optical Technology
- Ionizing Radiation
- Time and Frequency¹
- Quantum Physics¹

Manufacturing Engineering Laboratory

- Precision Engineering
- Manufacturing Metrology
- Intelligent Systems
- Fabrication Technology
- Manufacturing Systems Integration

Building and Fire Research Laboratory

- Applied Economics
- Materials and Construction Research
- Building Environment
- Fire Research

Information Technology Laboratory

- Mathematical and Computational Sciences²
- Advanced Network Technologies
- Computer Security
- Information Access
- Convergent Information Systems
- Information Services and Computing
- Software Diagnostics and Conformance Testing
- Statistical Engineering

¹At Boulder, CO 80303

²Some elements at Boulder, CO

Journal of Research of the **National Institute of Standards and Technology**

Volume 109

Number 6

November-December 2004

Board of Editors

Theodore V. Vorburger
Chief Editor

Available online
<http://www.nist.gov/jres>

Robert L. Watters, Jr., Technology Services
James K. Olthoff, Electronics and Electrical Engineering Laboratory
Craig M. Shakarji, Manufacturing Engineering Laboratory
Cynthia J. Zeissler, Chemical Science and Technology Laboratory
Joseph P. Rice, Physics Laboratory
Clare M. Allocca, Materials Science and Engineering Laboratory
Nicos S. Martys, Building and Fire Research Laboratory
Alan H. Goldfine, Information Technology Laboratory
Walter S. Liggett, Jr., Information Technology Laboratory
Clifton M. Carey, Paffenbarger Research Center
Barry N. Taylor, Chief Editor Emeritus

Julian M. Ives
Managing Editor, and Technical Production Editor

Ilse E. Putman, Karen J. Wick
Electronic Composition



U.S. Department of Commerce—**Donald L. Evans**, Secretary
Technology Administration—**Phillip J. Bond**, Under Secretary of Commerce for Technology
National Institute of Standards and Technology—**Hratch G. Semerjian**, Acting Director

Cover: Parts of the Raman spectrum and x-ray diffraction pattern of the NIST calcium hydroxyapatite Standard Reference Material (HA-SRM), and transmission and scanning micrographs of the HA-SRM crystals with cylindrical shape and submicrometer size. For details see paper on p. 553. Cover art arranged by C. Carey.

The *Journal of Research of the National Institute of Standards and Technology*, the flagship periodic publication of the national metrology institute of the United States, features advances in metrology and related fields of physical science, engineering, applied mathematics, statistics, biotechnology, and information technology that reflect the scientific and technical programs of the Institute. The *Journal* publishes papers on instrumentation for making accurate measurements, mathematical models of physical phenomena, including computational models, critical data, calibration techniques, well-characterized reference materials, and quality assurance programs that report the results of current NIST work in these areas. Occasionally, a Special Issue of the *Journal* is devoted to papers on a single topic. Also appearing on occasion are review articles and reports on conferences and workshops sponsored in whole or in part by NIST.

ISSN 1044-677X

Coden: JRITEF

Library of Congress Catalog Card No.: 89-656121

United States Government Printing Office, Washington: 2004

Contents

Available online
<http://www.nist.gov/jres>

Articles

A Small-Volume Apparatus for the Measurement of Phase Equilibria	Stephanie L. Outcalt and Byung-Chul Lee	525
SRM 2460/2461 Standard Bullets and Casings Project	J. Song, E. Whitemton, D. Kelley, R. Clary, L. Ma, S. Ballou, and M. Ols	533
Properties of Nanostructured Hydroxyapatite Prepared by a Spray Drying Technique	Laurence C. Chow, Limin Sun, and Bernard Hockey	543
Preparation and Comprehensive Characterization of a Calcium Hydroxyapatite Reference Material	Milenko Markovic, Bruce O. Fowler, and Ming S. Tung	553
Ambiguities in Powder Indexing: Conjunction of a Ternary and Binary Lattice Metric Singularity in the Cubic System	Alan D. Mighell	569

Indexes to Volume 109

Subject Index to Volume 109	581
Author Index to Volume 109	585
