IVMC 91

Technical Digest

The Fourth International Vacuum Microelectronics Conference

August 22-24, 1991
Nagahama, Japan

FOURTH INTERNATIONAL
VACUUM
MICROELECTRONICS
CONFERENCE

Editors

S. Namba, Y. Nannichi, T. Utsumi

Organizing Committee of the Fourth International Vacuum Microelectronics Conference

ISBN 4-980813-45-X

IVMC 91

Technical Digest

The Fourth International Vacuum Microelectronics Conference

August 22-24, 1991
Nagahama, Japan

Editors

S. Namba, Y. Nannichi, T. Utsumi

Sponsored by

Organizing Committee of
the Fourth International Vacuum Microelectronics Conference

In cooperation with

The Japan Society of Applied Physics (JSAP)
The Tokyo Section of the IEEE (IEEE Tokyo)
The Electron Devices Society of the IEEE (IEEE EDS)

The American Vacuum Society (AVS)
The Chemical Society of Japan (CSJ)
The Electrochemical Society of Japan (ECSJ)
The Institute of Television Engineers of Japan (ITEJ)
The Institute of Electrical Engineers of Japan (IEEJ)
The Institute of Electronics, Information, and Communication Engineers (IEICJ)
The Japan Society of Precision Engineering (JSPE)
The Surface Science Society of Japan (SSSJ)
The Vacuum Society of Japan (VSJ)

Published by

Program Committee of
the Fourth International Vacuum Microelectronics Conference
Chairman : Y. Nannichi, Vice-Chairman : T. Utsumi

ISBN : 4-980813-45-X

c / o Osaka Office
Business Center for Academic Societies Japan (BCASJ)
10th Tabuchi Building
6-3 Matsugae-cho,
Kita-ku, Osaka
530 Japan
Phone : +81-6-356-6041
Facsimile : +81-6-356-6190

PREFACE

On behalf of the local committee, we welcome all of you to the Fourth International Vacuum Microelectronics Conference (IVMC 91) to be held in Nagahama, Japan from the 22nd to the 24th, August 1991.

This digest contains extended abstracts to be presented at IVMC 91. A total of well over one hundred papers were submitted and among them 84 papers were accepted for presentation. This includes 9 invited talks, 38 oral presentations and 37 poster presentations. The last minute news, which we expect will keep arriving until the day of registration, are not included. The fact that the numbers of submitted papers have significantly increased over all previous conferences have shown the definite trend of rapidly growing interest and effort in this fascinating new field of technology all over the world. If the conference enchances our feeling that we are all comrades in making Vacuum Microelectronics a reality to open up a new frontier of science and technology and that we will be able to achieve our goals in a long run, then this conference is a great success.

We wish to express our sincere thanks to all attendees to the conference, especially to contributers who have done a tremendous job to present their works of excellence and to all attendees who are to do a superb job by participating in lively discussions during the conference.

We also wish to express our warm gratitude to the local organizing committee members for spending considerable time and effort for organizing the conference and the dedicated staff of the Secretariat of the Business Center for Academic Societies in Japan for arranging the conference.

We also wish to express our sincere gratitude to Dr. H. F. Gray of Naval Research Laboratories who assisted tremedously our local committee to organize the conference and accepted to become a guest editor of the special issue of Vacuum Microelectronics in the Journal of Vacuum Science and Technology (B) to publish the full papers of this conference.

Finally this conference could never have been realized at this level without generous financial support from the public as well as private organizations in Japan whose names are listed on page v.

We hope that all of you enjoy your stay in Nagahama and its vicinity famous for its natural beauty and its unique history in one of the most dramatic periods of Japan.

August 1991

Susumu Namba
Chairman
Organizing
Committee
IVMC 91

Yasuo Nannichi
Chairman
Program Committee
IVMC 91

Takao Utsumi
Vice-Chairman
Program Committee
IVMC 91

THE FOURTH INTERNATIONAL VACUUM MICROELECTRONICS CONFERENCE

ORGANIZING COMMITTEE

Chairman: Susumu Namba, Osaka Univ., Japan

Vice-Chairman: Yasuo Nannichi, Univ. of Tsukuba, Japan

Members: Junzo Ishikawa, Kyoto Univ., Japan
Kouichi Murakami, Univ. of Tsukuba, Japan
Mikio Takai, Osaka Univ., Japan
Hiroshi Tsuji, Kyoto Univ., Japan
Takao Utsumi, CANON, Japan

INTERNATIONAL STEERING COMMITTEE

Members: Paul H. Cutler, The Pennsylvania State Univ., USA
Jacques Duchene, LETI-CENG, FRANCE
Henry F. Gray, Naval Research Lab., USA
Yuri V. Gulyaev, Inst. of Radio Eng. and Elect., USSR
Johanes Mitterauer, Tech. Univ. Wien, AUSTRIA
Susumu Namba, Osaka Univ., Japan
Yasuo Nannichi, Univ. of Tsukuba, Japan
W. A. Phillips, GEC Hirst Res. Center, UK
Heinz Schindler, Siemens AG, Germany
Charles A. Spindt, SRI International, USA
Takao Utsumi, CANON, Japan
Gerard van Veen, Philips, The Netherlands

FINANCIAL COMMITTEE

Chairman: Susumu Namba, Osaka Univ., Japan

Vice-Chairman: Takao Utsumi, CANON, Japan

Member: Mikio Takai, Osaka Univ., Japan

PROGRAM COMMITTEE

Chairman: Yasuo Nannichi, Univ. of Tsukuba, Japan

Vice-Chairman: Takao Utsumi, CANON, Japan

Members: David W. Branston, Siemens AG, Germany
Heinz H. Busta, Amoco, USA
T. H. P. Chang, IBM J. J. Watson Res. Center, USA
Paul H. Cutler, The Pennsylvania State Univ., USA
Luo Enze, Xidian Univ., China
Henry F. Gray, Naval Research Lab., USA
Junji Itoh, Electrotechnical Lab., Japan
Takao Kageyama, NEC, Japan
Akira Kaneko, Matsushita Res. Inst. Tokyo, Japan
Vladimir C. Litovchenko, National Academy of Science, USSR
Robert B. Marcus, Bell Communication Res. USA
Robert Meyer, LETI-CENG, FRANCE
Johannes Mitterauer, Tech. Univ. Wien, AUSTRIA
Chuhei Oshima, Waseda Univ., Japan
Nikolai I. Sinitsyn, Inst. of Radio Eng. and Elect., USSR
Charles A. Spindt, SRI International, USA
Mikio Takai, Osaka Univ., Japan
Hiroshi Tsuji, Kyoto Univ., Japan
Masaru Tsukada, Univ. of Tokyo, Japan
Gerard van Veen, Philips, The Netherlands
J. K. Wigmore, Univ. of Lancaster, UK
Shigehiko Yamamoto, Hitachi, Japan
Kuniyoshi Yokoo, Tohoku Univ., Japan

SECRETARIAT

Secretary General: Junzo Ishikawa, Kyoto Univ., Japan

(in alphabetical order)

SPONSORSHIP

International Communications Foundation
Shimadzu Science Foundation
Nagahama City

Canon Inc.
Fujitsu Laboratories Limited
Futaba Corporation
IBM Japan, Ltd.
Ise Electric Corporation
Innotech Corporation
Hitachi, LTD.
Matsushita Electric Industrial Co., Ltd.
Matsushita Research Institute Tokyo Inc.
Mitsubishi Electric Corporation
NEC Corporation
New Japan Radio Co., Ltd.
Nippon Telegraph and Telephone Corporation
Oki Electric Industry Co., Ltd.
Seiko Epson Corporation
Seiko Instruments Inc.
Sharp Corporation
Sony Corporation
Sumitomo Electric Industries, Ltd.
Toshiba Corporation
Yokogawa Electric Corporation

CONTENTS

☆☆ Keynote Speech
☆ Invited Talk

Session V : Microwave Generation and Amplification

Chairpersons : Yu. Gulyaev (Acad. Sci. Moscow, U. S. S. R.)
K. Yokoo (Tohoku Univ., Japan)

Session VI : Fabrication

Chairpersons : J. Mitterauer (Tech. Univ. Wien, Austria)
M. Takai (Osaka Univ., Japan)

Session VII : Properties and Characterization

Chairpersons : J. K. Wigmore (Univ. of Lancaster, U.K.)
H. Adachi (Muroran Inst. of Tech., Japan)

Session VIII : Cold Emitters

Chairpersons : P. H. Cutler (Pennsylvania State Univ., U. S. A.)
S. Yamamoto (Hitachi, Japan)

Session IX : Novel Applications

Chairpersons : D. W. Branston (Siemens AG, Germany)
M. Okunuki (Canon, Japan)

Session X : Poster Session

Closing Session

Opening Session

Opening Address

Keynote Speeches

COHERENCE PROPERTIES OF A FIELD EMISSION ELECTRON BEAM AND ITS APPLICATIONS

Akira TONOMURA

Advanced Research Lab., Hitachi, Ltd.
Electron Wavefront Project, JRDC
Hatoyama, Saitama 350-03, Japan

1. INTRODUCTION

An electron beam field emitted from a pointed tip has a higher brightness (current density per solid angle) and a narrower energy spread than a thermal emission beam.[1] In 1968, these features were effectively employed for forming a fine probe and improving the resolution limit of scanning electron microscopes by Crewe.[2] This beam was also used in 1978 for a "coherent" electron beam.[3] Using this beam, the total number of electron interference fringes recordable on film increased from 300 to more than 3,000 with an exposure time of 30 seconds, and the fringes become directly observable on the fluorescent screen.

As a result of this improvement, electron holography became practical in that its reconstructed images are comparable in resolution to electron micrographs. New application fields for electron holography are now being opened up. For example, flux lines penetrating a superconductor can be seen in the form of magnetic lines of force in interference micrographs.[4] Their dynamics can also be observed.[5]

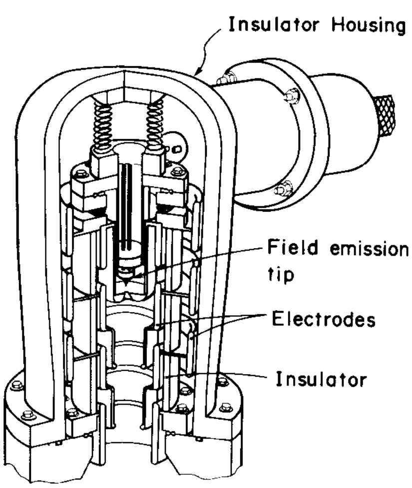

Fig. 1. Field emission electron gun.

2. ELECTRON GUN

An example of our field emission electron gun is schematically shown in Fig. 1. Electrons are emitted from a tungsten tip 1,000 Å in radius, and accelerated up to 125 kV through three-stage accelerating electrodes. Electrons are focused through condenser lenses to form a fine probe a few hundreds of Å in diameter, and illuminate a specimen.

The illumination angle can be made as small as 5×10^{-8} radians, allowing the spatial coherence length in the specimen plane to be as large as 80 μm. The spatial coherence length is the maximum diameter of the circular region within which the electron wavefront can be defined. Interference can occur within this region.

The time coherence length of an electron beam is given by λ $(2E/\Delta E)$. Here, λ is the electron wavelength, E is the kinetic electron energy, and ΔE is the energy spread. When E=100 keV and ΔE=0.3 eV, the time coherence length is around 2 μm. Interference occurs when the path difference between two beams is smaller than this length. This value seems extremely small when compared with that of a laser beam, but this is not the case. The number of wavelengths contained in this length is as large as 700,000. Usually electron interference experiments are not restricted by the time coherence length. There have been, however, two experiments in which this occurred.[6,7]

3. ELECTRON HOLOGRAPHY

Electron holography[8] is a two-step imaging method using electron and light waves (see Fig. 2). An electron wave illuminates an object and is then scattered. A reference wave that has been tilted by a prism is then projected onto the scattered wave to form an interference pattern, which is recorded on film. This film, called a hologram, is subsequently illuminated by a collimated laser beam. The exact image is then reproduced three-dimensionally.

In holography, two images are always reconstructed. They are exactly the same except that their amplitudes are complex conjugates of each other——that is, their phase values are reversed in sign. The conjugate image is a nuisance in image observations, but it plays an important role in high-precision phase measurements. Holography imaging is unique in that it requires no lenses and uses only the most fundamental wave properties of interference and diffraction. Therefore, imaging is possible even between completely different waves. A large wavelength difference is not a problem, since interference and diffraction always take place in wavelength units.

Once electron wavefronts are reproduced as light wavefronts, versatile optical techniques can be supplemented by electron optics. One example is a holographic interference microscope. In this case, an interference micrograph, or contour map of the wavefront, can be obtained simply by combining an optical interferometer in the optical reconstruction stage. This is done by overlapping an optical plane wave with the reconstructed image. If a conjugate image instead of a plane wave overlaps this wavefront, the phase difference becomes twice as large, as if the phase distribution were amplified two times. By repeating this technique, a phase shift even as small as 1/100 of a wavelength can be detected.

Phase-amplified interference electron microscopy provides information about a specimen's thickness distribution in atomic dimensions[9] and microscopic distribution of the electric[10] and magnetic[11] fields.

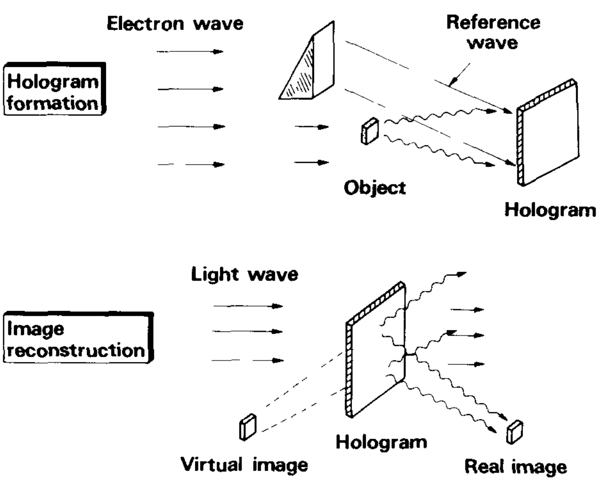

Fig. 2. Principle behind electron holography.

4. APPLICATIONS

a) Specimen thickness measurements: An interference micrograph amplified 24 times of a cleaved molybdenite thin film is shown in Fig. 3. The phase distribution is displayed here as a deviation from regular fringes, i. e., an interferogram. Steps A, B, and C in the micrograph correspond to one, three, and five layers of atomic surface steps. The thickness change at step A is 6.2 Å (one-half of the c-axis spacing), and produces a phase shift of $2\pi/50$. This experiment shows that a phase shift can be detected with an accuracy of the order of $2\pi/100$.

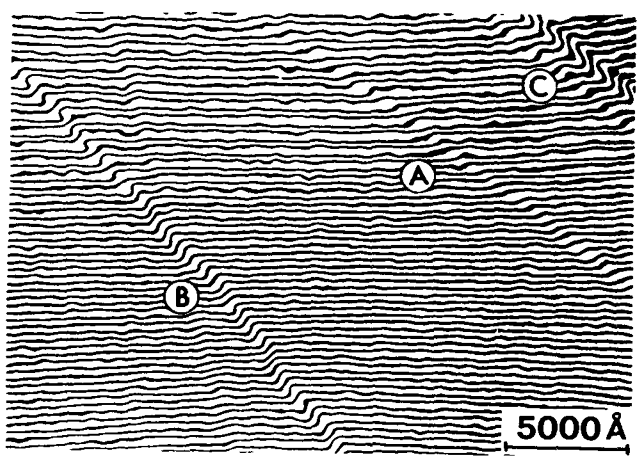

Fig. 3. Interferogram of molybdenite thin film (phase amplification: x 24).