RUTHERFORD Bulletin 6

3 - 17 April 1978

Dr A F Gibson elected FRS

On Thursday 16 March 1978, the Royal Society announced the election of 40 Fellows; amongst the list of names was Dr A F Gibson, Head of the Laser Division at the Rutherford Laboratory.

The citation read......*"For contributions to physics of semi-conductors and for applying them to development of laser detectors and modulators, especially in making possible detection of infrared laser pulses and in achieving stabilization of CO_2 lasers"*.

After leaving Birmingham University, Alan Gibson joined the Royal Signals and Radar Establishment, Malvern (then known as TRE) in 1944, working on radar displays, infrared detectors, transistors and other aspects of solid state physics being particularly concerned with the optical properties of solids. By 1961 he had attained the grade of Deputy Chief Scientific Officer by individual merit.

He left Malvern to become the first Professor of Physics at the newly created University of Essex in 1963, a year before it first began to take students.

At Essex, the new Professor of Physics built up a group to initiate research in the virtually untrodden field of laser physics. When work began on CO_2 lasers, he recognised the possibility of a completely new form of detector for measuring the intensity of radiation from this form of laser, with nonasecond time resolution. The principle used was that of photon drag in which the passage of light through germanium reacting on the electrons, creates a measurable potential across the germanium.

This detector revolutionised the measurement of gain switched and mode locked CO_2 laser pulses, a method internationally recognised and now the basis of commercially available high speed laser light detectors. During the investigations, a new method of operation of transverse discharges applicable to high pressure gas lasers was developed which made use of Professor Gibson's wide knowledge of semi-conductor physics. This involved the control of arcing in high-voltage transverse discharges through the use of germanium discharge electrodes to stabilise the discharge current.

By the time Professor Gibson left Essex he had written over 70 research papers in the field of solid state physics. In 1974 he published, with co-author R J Elliott, Wykeham Professor of Physics, University of Oxford, a book entitled "An Introduction to Solid State Physics and its Applications" which has become recognised as a standard text book on the subject: it was reprinted in 1976.

Alan Gibson was appointed Head of the newly formed Laser Division at the Rutherford Laboratory in 1976 and took up the post on 1 January 1977. We offer our congratulations to him on his election to the oldest scientific society in England (formed in 1660) and probably the most prestigious of all learned bodies in the world of science.

Also elected: Professor P H Burke who holds a joint appointment as Head of the Theory and Computational Science Group at Daresbury and Professor of Mathematical Physics and Head of Department of Applied Mathematics and Theoretical Physics, Queens University Belfast; Professor A Iggo, Edinburgh University, Member of the Biological Sciences Committee, Science Board, SRC; Professor B L Shaw, Leeds University, Member of the Chemistry Committee, Science Board, SRC.

Electron Beam Lithography at Rutherford

The editor wishes to thank EBLF Project Leader Ron Lawes for the following article and for advice and suggestions on the introductory article, "Microelectronics at Rutherford", published in the last issue of the Bulletin. As 'suggestions' included reading material which ran into some 140 pages of articles and books, the Editor welcomes the promise of a device which would precis the relevant information in a short time. No - not a microsecond - just long enough for a cup of coffee!

Solid state device physics is an important area of research being supported by the Engineering Board of the Science Research Council.

Facilities for device fabrication costing a total of £1.33M are now being set up at the Universities of Edinburgh, Sheffield, Southampton and Surrey and the Rutherford Laboratory so that university scientists and engineers will have access to the latest equipment and techniques.

The Universities of Edinburgh and Southampton will concentrate on the fabrication of silicon integrated

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OVERSEAS VISITS

Mr E W G Wallis and Mr B T Payne, to DESY Hamburg, 3-4 April, for TASSO Collaboration Meeting and technical discussions.

Mr D G House and Mr C D Osland, to Berne, Switzerland, 3-7 April, to attend SHARE European Association Spring Technical meeting.

Mr M D Jeffs and Mr J Hoskins, to CERN, 3-7 April, for installation and commissioning of EMC NWPC readout system electronics.

Dr J Carr, to CERN, 3-14 April, to work on EMC experiment.

Mr H Hadley, to ESTEC Noordwijk, Holland, 4-5 April, to attend meetings concerned with equipment for use in Spacelab flights.

Mr N H Cunliffe and Mr R Roberts, to CERN, 4-5 April, to attend EMC polarised target meeting.

Mr D Moore and Mr P Horton, to CERN, 4-7 April, for installation of EMC equipment.

Dr M W Johnson, to ILL Grenoble, 5-12 April, to carry out approved experiment.

Dr C J Carlile, to ILL Grenoble, 8-18 April, to carry out approved experiments.

Mr W M Evans and Mr G T J Arnison, to the USA, 8-30 April for discussions at LBL, SLAC, FNAL and BNL.

Dr A G Michette, to the USA, 9 April-5 May, to attend conferences at Pardue and Washington and give seminars at various laboratories.

Mr L Phillips, to CERN, 9-13 April, for installation of EMC chambers.

Mr J A Fox, to CERN, 10-12 April, for discussions with Energy Enquiry group.

Mr T G Coleman and Mr W J Tallis, to CERN, 10-12 April, for discussions on RCBC.

Mr W Glasgow and Mr L L S Coulter, to CERN, 10-14 and 12-14 April respectively for Betatron Source acquisition.

Dr D J Nicholas and Dr R G Evans, to the USA, 12-30 April to attend Tucson conference and visit various laboratories.

Dr G L Greene, to ILL Grenoble, 12-21 April, for discussions and experimental work.

Dr G C Stirling, to France, 13-20 April, to give invited talk on SNS at SIN and to ILL for discussions.

To CERN, Mr B Diplock and Mr D Evans, 17-18 April, Dr R W Newport, Mr W Turner, Mr B Edwards and Mr A Thorpe 17-19 April, to attend various meetings on RCBC.

WEEKLY NATIONAL SAVINGS

Certificates may be collected from the Cash Office, Building R20.

Weekly paid members of staff who wish to join the scheme or those wishing to alter their savings, should collect a form from the Cash Office.

FILM BADGE NOTICE

Period 4 commenced Monday, 27 March. Colour Strip - ORANGE for βγ films and neutron packs.

Please check that you are wearing the correct films and that all old ones are returned.

Six monthly dosimeter change for people with surnames commencing M, N, O and P.

PERIODICAL SAFETY TEST OF PORTABLE ELECTRICAL EQUIPMENT

The test carried out during Feb./March has now been completed. The current marker is RED and is marked "DO NOT USE AFTER JULY 1978".

Portable electrical equipment marked otherwise should be considered unsafe and must not be used. All such items should be returned if possible to Electrical Services Section, Building R18, alternatively ring A Hipwell, Ext 573.

MISSING EQUIPMENT

The following item of equipment has been reported missing from Building R25:

Hewlett-Packard Integrating Voltmeter, Type D12401B, Ser. No. 444/01518.

Anyone with information on the present whereabouts of this instrument is asked to contact Mr G Tuck, R25, Ext 6634/304.

SALES TO EMPLOYEES

Sales of scrap metal/plastics as set out in RLN 12/73 will be made on 14 and 28 April.

HAT TRICK FOR PETER CRASKE

The 1977/78 Rutherford Laboratory Chess Tournament ended with victory going to Peter Craske. He won all of his games finishing with a total of 9 points, thus giving him his third successive win in three years. Not surprisingly Peter comments that it was "a good tournament"

Peter Hemmings, producing his usual high standard, finished with 8 points only losing one match, and that against the champion. Good efforts from Roy Culliford, third with 6½ points and Rob Hambleton, fourth with 5 points.

BULLETIN NOTICE

Readers will like to know that the present editor of the Bulletin will be retiring on 10 May. This change will to some extent affect the style and content of future Bulletins. Readers will be kept informed of the changes in due course.

G Stapleton

RUTHERFORD LABORATORY BULLETIN *Published by the Scientific Administration Group*

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circuits, the University of Sheffield on special semi-conductor materials and the University of Surrey on a technique known as ion-implantation.

The Rutherford Laboratory will construct and operate a Facility for the construction of precision masks based upon electron beam lithography and will also coordinate the work of the five centres in order to provide a comprehensive service.

As the subject of electron beam lithography is of considerable interest to industry, the Laboratory is participating in a national programme involving Ferranti, GEC, Plessey and the Cambridge Instrument Company. The programme is sponsored by the Department of Industry. The details of the Electron Beam Lithographic Facility (EBLF) were formulated during 1977 and in October of that year the Laboratory was authorized to proceed with construction; EBLF is expected to be operational early in 1979.

Semiconductor Device Manufacture

The essential steps in manufacturing semi-conductor or integrated circuit devices were outlined in the article "Microelectronics at Rutherford" in the previous Bulletin and in an excellent series of articles in the September 1977 edition of Scientific American.

It is sufficient here to note that an integrated circuit consists of a complex three dimensional structure fabricated from many layers of materials selectively defined in a basic substrate material, which is usually but not exclusively silicon. The detailed geometry of each layer must be produced in a suitable masking material, usually silicon dioxide grown on the surface of the substrate and various metallic elements diffused (or ion-implanted) into the selected exposed areas of the substrate. Typically a substrate may have several hundred identical circuits known as "chips" fabricated in it. Each chip can be as complicated as a complete microprocessor computer and contain in excess of 100,000 components such as transistors, resisters and capacitors.

The two-dimensional geometrical imformation necessary to define the patterns at each layer is iniitially held in the form of a chromium image on a glass plate before being transferred onto the substrate in the form of silicon dioxide.

The plates are known as photomasks or masks and the process of defining the geometrical patterns, either in the silicon substrate during device fabrication or in the generation of the original chrome-on-glass mask itself is known as lithography.

Mask Generation

The manufacture of masks is a demanding technology; it has been subject to a high degree of automation at all stages of the manufacturing process and relies heavily on computer-aided-design (CAD) techniques. The reason for this is illustrated in Fig 1 which shows a small section of one mask. It may take 100,000-1,000,000 computer words to describe a complete mask plate!

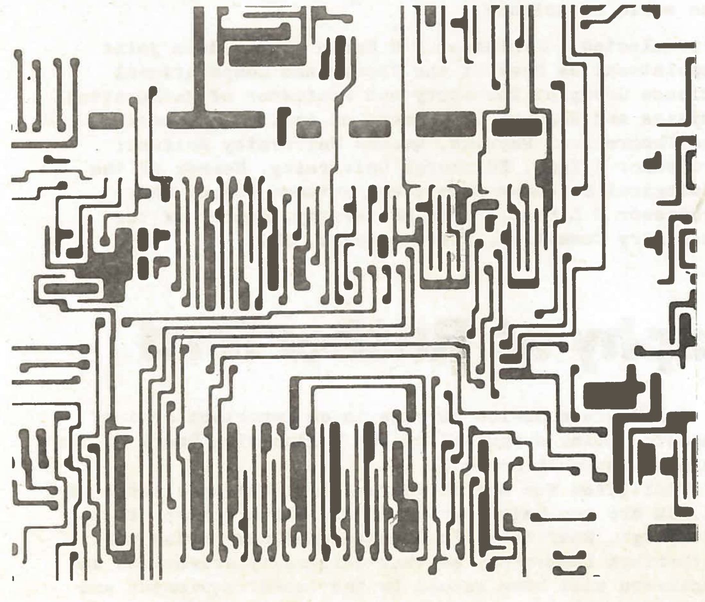

Fig 1: *Small section of a single mask plate showing typical geometry.*

The basic steps in mask manufacture start with the definition of the required pattern using some form of interactive graphical terminal connected to the CAD program resident in a computer. When the design is satisfactory the resultant CAD data set is used to computer control a machine known as a pattern generator.

This machine writes the pattern onto a sensitive material known as a resist, which has been previously spread onto the surface of a glass plate completely covered with chromium. Removal of the plate from the pattern generator and development of the resist leaves hardened resist material on the surface of the chromium in the form of the required pattern (the form may be positive or negative depending upon the type of resist used).

The plate is then subjected to an etching process, which attacks only the exposed chromium leaving the hardened resist untouched. Subsequent removal of the hardness resist leaves a glass mask plate with a chromium pattern suitable for use in the device fabrication process.

Electron Beam Lithography

For many years the semi-conductor industry has used optical techniques for lithography in order to fabricate commercially available integrated circuits. Geometrical features involving lines or gaps in the range 4-5 microns are routinely manufactured and the techniques employed are capable of producing circuits with details as small as 2 microns.

However, in the last few years there has been considerable world wide scientific and commercial interest in the use of electron beams for lithography, particularly for pattern generators.

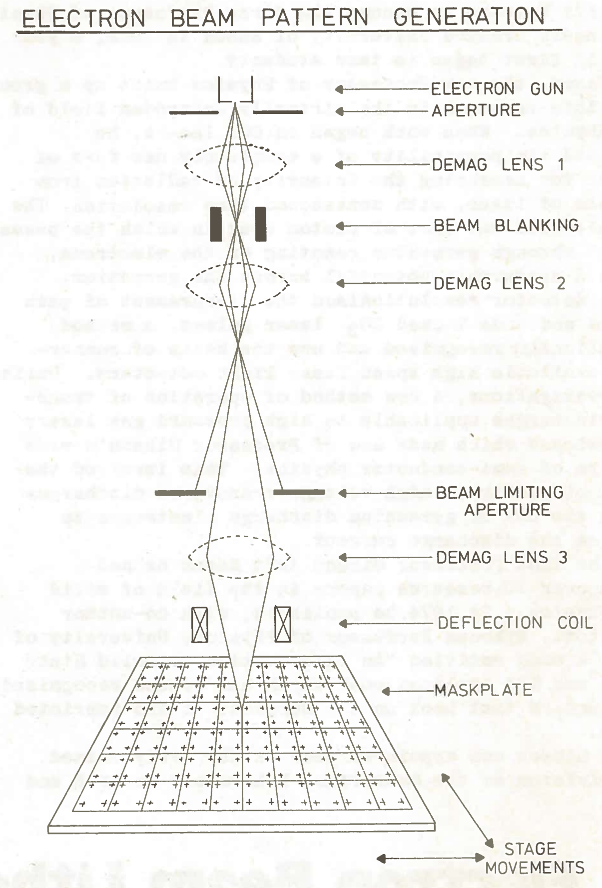

Fig 2: *Basic components of an electron beam pattern generator showing simple electron optics column and X-Y stage.*

An electron beam pattern generator consists of two basic parts as illustrated in Fig 2 above. These are:

(i) An electron optics column capable of focussing a beam of electrons down to a diameter of 0.05-1 micron. The spot may be deflected over a field approximately 1 mm x 1 mm at stepping rates in the order of 1 MHz to an accuracy of 1:10,000.

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(ii) An X-Y computer controlled stage, driven by stepping motors and using laser interferometers to digitize position to ± 0.026 microns. The stage system enables large mask plates up to 4" x 4" to be fabricated from a number of electron beam fields carefully aligned to each other.

The complete system inculding power supplies, controls, digital logic etc is packaged together as a system under the control of a suitable mini-computer. The sequence of stage movements, beam deflection and beam unblanking is left to the readers imagination.

Electron beam lithography (EBL) offers several advantages over the conventional computer controlled optical pattern generator. These are principally:

(i) EBL is faster than mechanical pattern generators.

(ii) EBL has the ability to define much finer features than is possible with optical lithography. Diffraction effects and the difficulties of making practical optical systems limits optical lithography to features in excess of 1 micron. EBL suffers from no effective diffraction limitations and lines as fine as 0.08 micron line widths have been fabricated under experimental conditions. However, in practical lithography the scattering of electrons in the resist material limits resolution of images to about 0.1 micron.

(iii) EBL has the potential to write directly onto the substrate, thus eliminating the need for mask plates.

The elimination of the masking steps in the device fabrication process removes a source of errors and enhances the yield of good circuits (ie lowers the cost!). The future production of very complex circuits (eg ⩾ a million components per chip), a process known as Very Large Scale Integration (VLSI), will be dependent upon direct writing techniques.

As the details on a mask can only be reproduced onto the substrate by further optical lithography, (although experimental techniques exist using X-rays and even synchrotron radiation), direct writing by electron beams is essential for the definition of features less than about 1 micron.

(iv) EBL pattern generator offers increased flexibility and shorter turn around, particularly for small design changes. Thus, the university researcher can expect mask sets within days-weeks rather than weeks-months.

The Rutherford Facility

The main items of equipment in the Facility will be:

(i) An electron beam pattern generator complete with a PDP-11/34 control computer to be manufactured by the Cambridge Instrument Company.

(ii) An ion-beam etching machine which uses ion-beam bombardment to define features in the order of 0.1 microns (chemical etching produces poorly resolved features below about 2 micron).

(iii) A scanning electron microscope for inspection of features at high resolution.

(iv) An r.f. sputter-coating machine capable of depositing thin metallic and non-metallic films.

(v) Ancillary apparatus housed in laminar flow cabinets. Apparatus includes a resist spinner for covering plates with a thin film of resist, an automatic electron beam resist developer, plasma ashing equipment to remove the developed resist after the pattern etching process has been completed and a special vacuum contact printer designed for applications suited to optical reproduction.

The complete Facility will be housed in a special clean room of 300 m^2 with the apparatus in Class 100 ⩽ 100 dust particles/cubic foot of air) conditions of cleanliness. This room is currently under construction by the Central Works Unit in approximately half of the area in R1-East Wing recently vacated by the central IBM computer.

The CAD facilities will be provided via a graphics terminal situated in the EBL Facility and connected directly to the PRIME 400 computer housed in the Interactive Computing Facility in R27. The CAD program GAELIC, developed originally by the University of Edinburgh, will be used to design test patterns and masks during the commissioning of the Facility and for some production work during operational running.

INTERNAL EVENTS

NIMROD LECTURE SERIES Monday 3 April at 1130 Lecture Theatre	A Review of the Theory and Phenomenology of Lepton Pair Production. *R C Hwa/RL*	
FILM SHOW Thursday 6 April at 1240 Lecture Theatre	"Battle of the Bats", a 35 min colour film of the 34th World Table Tennis Championships, 1977 held at Birmingham with commentary by Tony Gubba(BBC). Mainly featured are the mens singles semifinals and final with the top players from Japan, China, Europe etc.	
USERS MEETING Monday 10 April Lecture Theatre	The programme, following coffee at 1100, is as follows: 1130 Financial Estimates for 1978/79 and the FYFL for 1979/80-1983/84 1200 The SNS Facility 1345 Use of the SNS Facility for Particle Physics: Neutrino Physics : Hadronic Physics 1515 Results and Future Plans at the SPS	 *J C Polkinghorne* *G Manning* *T Jones* *D V Bugg* *I Butterworth*
TRADE EXHIBITION Monday 10 April 1000-1600 Foyer of Bldg R1	Vacuum Generators are showing a range of Ultra High Vacuum components and systems including the new Model SPB4 low cost UHV Pump set incorporating the new Horizontal series CCT liquid nitrogen trap; the series HPT Multidirectional Manipulator; samples of UHV stainless steel fabrications, and a selection of recently introduced measuring instruments, valves and UHV feed throughs. Marketing Director Tim Pearce will be in attendance.	
PROPOSAL TALK Tuesday 11 April at 1130 Lecture Theatre	Proposal No 24: A Proposal for a 4π Solid State Detector for the SPS used as a Proton-Antiproton Collider at a Centre of Mass Energy of 540 GeV. Talk to be given by Dr J D Dowell/Birmingham University.	
HEP SEMINAR Wednesday 12 April at 1100 R61 Conference Room	Quark Hyperfine Interactions in Baryons. *N Isgar/Oxford and Toronto*	
NIMROD LECTURE SERIES Monday 17 April at 1130 Lecture Theatre	Phenomenology of Light Z°'s *R J N Phillips/RL*	