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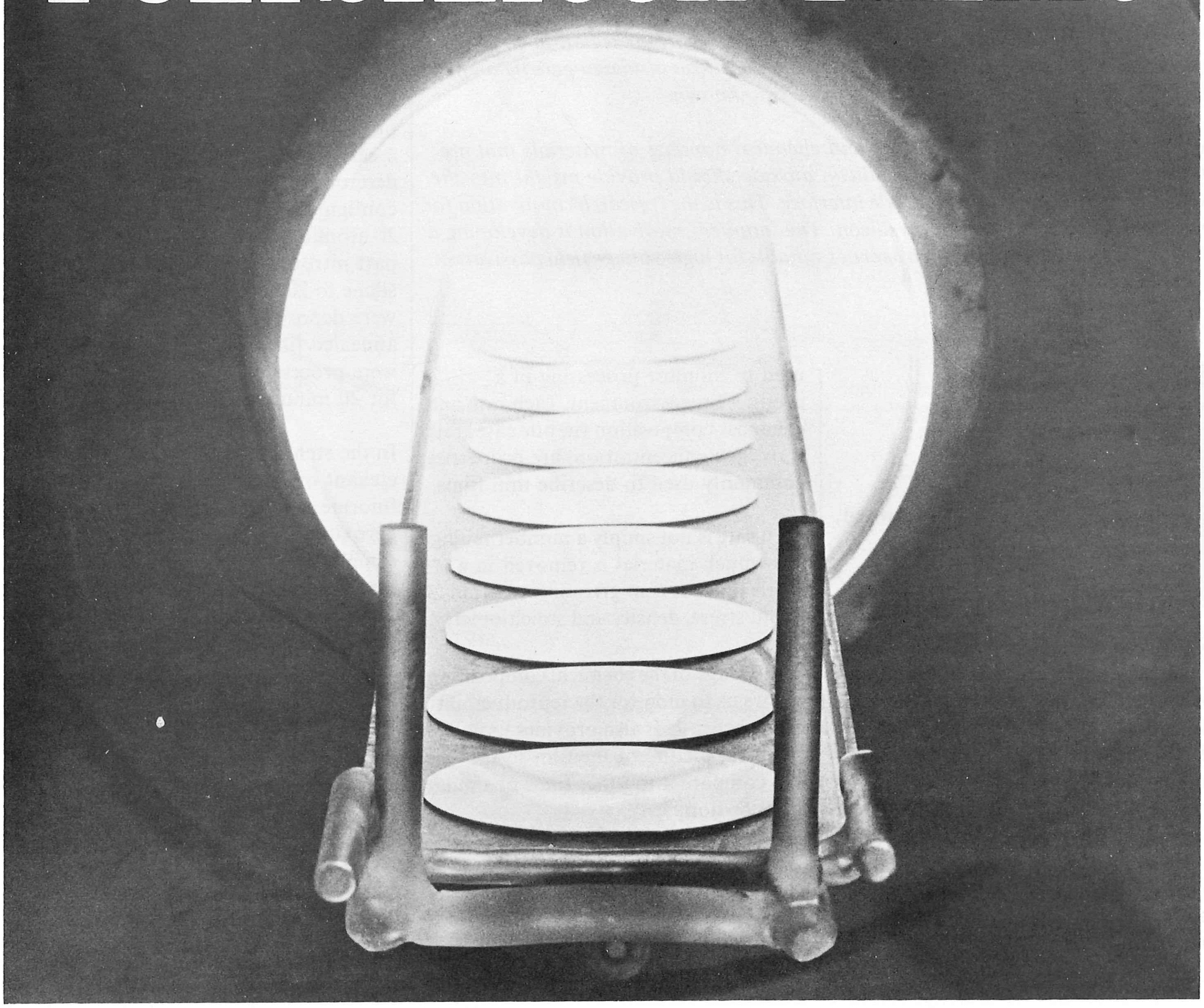
OXYGEN-DOPED POLYSILICON FILMS



OXYGEN-DOPED POLYSILICON FILMS

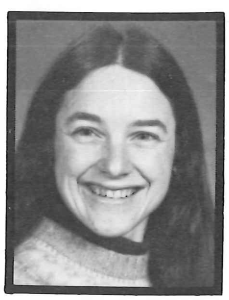
Karen presented this paper at the Fall Meeting of the Electrochemical Society (October, 1977).

The Semiconductor Research Lab has been investigating oxygen-doped polysilicon, a material used for field passivation of high-voltage microelectronic devices and integrated circuits. Originally introduced by Sony Corporation in 1975, the material was examined in the form of a thin film of 1000-5000Å applied to a silicon substrate.

Oxygen-doped polysilicon is a semi-insulating film that has characteristics between silicon and silicon-dioxide. There are other materials that lie between silicon and silicon dioxide in stoichiometry (silicon monoxide and low-temperature-deposited silicon oxides are examples). Like oxygen-doped polysilicon, these materials have special uses in microelectronic devices. They are of additional importance because they simulate, in bulk form, the structures that may exist at the atomic level within the silicon/silicon-dioxide interface.

There is an interface between silicon and any other film grown or deposited on it. The silicon/silicon-dioxide interface is a crtically important region in microelectronics (it is the controlling region of all silicon insulated-gate field-effect devices). The exact nature of this interface is unknown.

Knowledge of the atomic structure and chemical bonding of materials that are intermediate between silicon and silicon dioxide should provide insight into the nature of the silicon/silicon-dioxide interface. This is the "research" motivation for investigating oxygen-doped polysilicon. The "applied" motivation is developing a process for making a film with properties suitable for high-voltage field passivation.



Karen Seaward, Semiconductor Research Lab, ext. 5152.

SCOPE

What we are going to examine here is the within-run (within a single deposition) uniformity of three properties of oxygen-doped polysilicon: etch rate, oxygen concentration and atomic structure.

When a thin film process is developed, some properties are chosen for investigation that will eventually be used to monitor processing in a production environment. Etch rate and chemical composition (in our case, this is oxygen concentration) are properties commonly used to describe thin films.

Etch rate is not simply a number telling how much material is removed in a given time. It also gives information about stress, density and stoichiometry.

Knowledge of the chemical composition allows us to monitor the reproducibility of the process. It also provides us with a chemical picture of the film so that we can compare it to other films of similar composition.

We have examined the structure of oxygen-doped polysilicon to check the uniformity of films grown in different positions in the reactor. Two models that attempt to describe the atomic structure of these films will be discussed. Our investigation will demonstrate the difficulties and ambiguities inherent in determining the "structure" of amorphous films such as oxygen-doped polysilicon.

EXPERIMENTAL PROCEDURES

The films we examined were grown in a horizontal hot-wall reactor (see Fig. 1), which was a typical quartz-tube diffusion furnace. The reactant gases were nitrous oxide and silane with nitrogen used as a carrier gas. The proportion of gases required to achieve a certain oxygen concentration is determined by the reactor configuration. To deposit films of about 20 atomic percent oxygen, we used one part nitrous oxide to five parts 10% silane to 2000 parts nitrogen. The films were deposited at 650°C. Some annealed films were studied and these were processed at 1000°C in nitrogen for 20 minutes.

In the etching experiments, we used an etchant of 10:1 buffered hydrogen fluoride with six parts hydrogen peroxide. To evaluate the etch rate, samples were masked and etched. The resulting pattern was measured interferometrically using the fringes of equal chromatic order analysis.

We measured the oxygen concentration of the films with four techniques:

—Auger electron spectroscopy (AES)

—infrared absorption spectroscopy

—electron spectroscopy for chemical analysis (ESCA)

—electron microprobe analysis

continued on page 4

TERMINOLOGY

AES: Auger Electron Spectroscopy is an elemental analysis technique that utilizes atomic excitation by electron bombardment. When a material is electron bombarded, a certain fraction of the resulting emitted electrons are Auger electrons. The kinetic energy of the Auger electrons is proportional to the specific atomic energy levels in the emitting atom. The type of atom may then be deduced from the kinetic energy of the emitted electron.

In addition, AES may be used to detect chemical shifts in some solid materials. A chemical shift can occur when the probed energy level of an atom is altered because of the atoms surrounding it. For selected elements, the chemical shift allows us to distinguish between a pure metal and an oxidized metal.

AES is a surface tool for probing 10Å depths; but with sputter-etching, AES can be used to profile the concentration of elements in thicker films.

Annealed: In microelectronics this term indicates that a material has been heat treated. In this article, we talk about annealed oxygen-doped polysilicon that has been heated to 1000°C for 20 minutes in a nitrogen ambient.

In applying this film to a device structure, we know that high-temperature (anything above 800°C) processing will follow the film deposition. Therefore, we characterize both as-grown and annealed conditions.

As-Grown: As-grown films are films that have been grown or deposited but that have not been annealed or otherwise altered.

Atomic Percent: Atomic percent refers to the number of atoms of a certain constituent (usually an element) in a compound. For example, silicon dioxide SiO_2 is 33 atomic percent silicon and 67 atomic percent oxygen.

CVD: Chemical vapor deposition is the process we used to deposit oxygen-doped polysilicon. In the most general sense, CVD is a vapor-phase growth process; this means the deposition of a film on a surface by means of a chemical reaction occurring from a gaseous phase at the surface. Many thin films important in microelectronics are CVD films. Examples of these are silicon nitride, polycrystalline silicon, and aluminum oxide.

Electron Diffraction: The diffraction of electrons by crystals can tell us the arrangements of atomic planes in solid materials. In our work, we prepared the thin films so that transmission of electrons through the films was possible. The diffraction patterns are recorded on photographic film; from the patterns we can calculate the spacing of atomic planes in the crystal, which, in some fortunate instances, will tell us what the crystal lattice is.

The electron diffraction patterns of as-grown oxygen-doped poly films are very diffuse rings, indicating that we have an amorphous material. After annealing, the rings are distinct, indicating polycrystalline material. If the film under study had been crystalline (single crystal), we would have observed a pattern of dots.

Electron Microprobe: The electron microprobe is used for quantitative determination of the elemental composition of solids. An electron beam is focused on the sample, and the X-rays emitted from the sample are analyzed in a crystal spectrometer. Each element emits X-rays whose characteristics depend upon the atomic energy levels involved in the energy exchange. The microprobe is useful for analysis of bulk films greater than about one micrometer thick.

ESCA: Electron Spectroscopy for Chemical Analysis is a surface analysis technique. ESCA is similar to AES in that only about 10Å of the surface is analyzed (this is about two atomic layers for our film). We can also use ESCA to detect chemical shifts. ESCA, which is substantially more sensitive than AES to chemical shifts, is primarily used to study the chemical environment of surface atoms of solids. In ESCA, the excitation is X-ray photoelectrons and the emitted particles are electrons. The chemical composition of the surface can be determined from energy analysis of the emitted electrons.

Escape-Depth Effect: AES and ESCA are both surface analysis tools that probe just the first few atomic layers of a solid. The escape-depth for the excitation source (electrons for AES and photons for ESCA) describes how far the tool probes into the surface. For quantitative determination of, for example, the amount of oxygen in a film, the escape-depth is a restricting parameter. Suppose that between 2 and 3 atomic layers are probed (we can't distinguish between 2 and 3) and the layers alternate silicon and oxygen atoms. If just two layers are probed, then we would expect an oxygen concentration of 50%. If three layers are in fact probed, then we find that we have 67 or 33 atomic percent oxygen, depending on which element was at the surface. Therefore, our measurements could vary between 33 and 67 atomic percent. We attribute the difficulty that we had getting reproducible values for oxygen concentration to this effect caused by the probing beam escape-depth.

Field Passivation: Field passivation is the growth or deposition of an oxide (or insulating) layer on the surface of a semiconductor in the field region (the electrically passive region). The purpose of field passivation is to provide electrical stability to the transistor surface by isolating it from electrical and chemical conditions in the environment. The benefits of passivation include increased break-down voltages, reduced reverse leakage current, and a higher power dissipation rating.

Fringes of Equal Chromatic Order: This is a technique of multiple-beam interferometry. White light is directed at 0° incidence to the sample and the reflected light is dispersed by a prism. Color fringes are observed when the film thickness divided by the color wavelength is a given constant value. The film thickness is calculated after measurement of the fringe wavelengths. There are some advantages in using the fringes of equal chromatic order analysis instead of the interference effects of monochromatic light. The major advantage is that very small steps (representing the film thickness) can be measured very precisely. This instrument can measure steps as small as 200Å; the precision is ±50Å up to film thicknesses of about 5000Å.

Interferometer: This is an instrument that uses the principles of light interference to measure the thickness of thin films. The thickness can be derived from the bright and dark fringes caused by constructive and destructive interference of light reflected from the film surface and the substrate surface.

Sputter-Etching: As the term is used in this paper, it is synonymous with ion-etching and ion-sputtering. While the samples were in the ESCA apparatus and in vacuum, we removed a 50Å layer of material from the surface of the samples by bombardment with a 2kV argon ion beam.

Stoichiometry: Stoichiometry means elemental composition. More specifically, it is the quantities of substances that enter into and are produced by a chemical reaction. For example, the stoichiometry of silicon dioxide is one silicon atom for every two oxygen atoms, represented symbolically as SiO_2.

TEM: Transmission Electron Microscopy is used to study microstructures and detect structures in thin films. Electrons are transmitted through a film and the diffraction of electrons takes place. For certain orientations of the crystals in the film, diffraction will be strong and bright regions will be seen. These regions define the grain size. In our as-grown film, no grains were found; however, the micrograph does show the film morphology after sample preparation. TEM is a very sensitive tool for determining grain size; 20Å resolution can be routinely achieved.

But all the data presented here are from electron microprobe measurements. We had poor reproducibility with both AES and with infrared absorption. We suspected that we had an escape-depth effect with both Auger and ESCA.

To investigate the structure, we looked at the chemical binding state of the films with ESCA. With TEM and electron diffraction we evaluated the grain size and looked for evidence of atomic species by calculating lattice parameters.

ETCH RATE

Our first evidence of nonuniformity in a deposition was the dramatic variation in etch rate with film growth position in the reactor. Figure 2 shows the etch rate variation for depositions with two different concentrations of nitrous oxide. These etch rate data are for as-grown films only. The variation is at least an order of magnitude. The data were reproducible to ±20%. The most probable cause for the etch rate variation is oxygen concentration variations, since the etchant is sensitive to oxygen concentration.

OXYGEN CONCENTRATION

In Fig. 3, the top graph is reproduced from Fig. 2 showing etch rate as a function of growth position. The graph underneath shows the variation of oxygen concentration with growth position. There is good correlation between etch rate and oxygen concentration. Instead of trying to alter the deposition conditions to achieve uniform oxygen concentration, we decided to investigate the properties of oxygen-doped poly films that have 10-30 atomic percent oxygen.

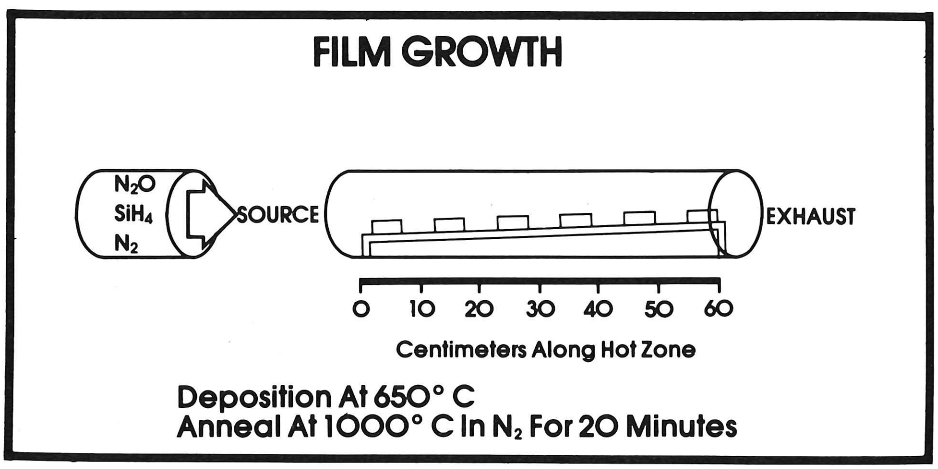


Fig. 1. The oxygen-doped polysilicon films were grown in a horizontal hot-wall reactor by passing the reactant gases nitrous oxide and silane over silicon wafers. Nitrogen was used as a carrier gas.

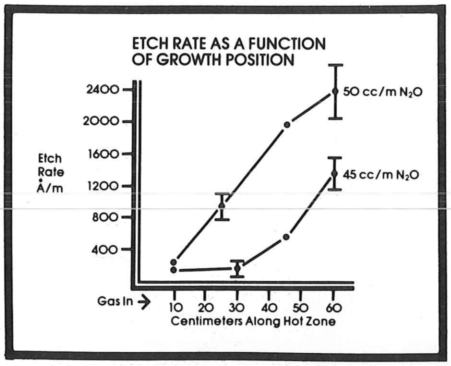


Fig. 2. Etch rate dramatically increases with greater distance along the hot zone of the furnace.

In Fig. 4, the etch rate is shown directly as a function of oxygen concentration. Also on the graph are etch rate values for annealed CVD silicon dioxide and thermal silicon dioxide. (These are the two most commonly used silicon dioxide films in microelectronics.) Apparently, the etch rate of silicon-oxygen films in the solution depends on structure as well as oxygen concentration, since the CVD oxide and thermal oxide etch slowly for having such high oxygen concentrations.

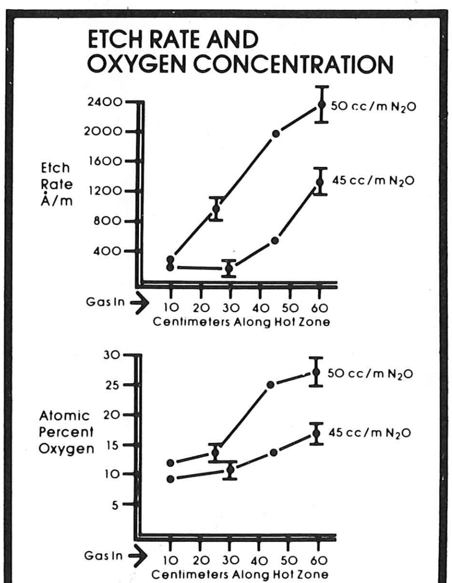


Fig. 3. These graphs show etch rate and oxygen concentration in relation to growth position in the reactor. There is a strong correlation between etch rate and oxygen concentration.

STRUCTURE

Structure Models

Conceptually, we can consider two models of oxygen-doped polysilicon films. In reality though, the structure may fall somewhere between the two models.

One model is the **microscopic mixture model** in which there is a mixture of silicon and silicon dioxide. The mixture is represented as silicon tetrahedrally bonded to silicon, and silicon tetrahedrally bonded to oxygen.

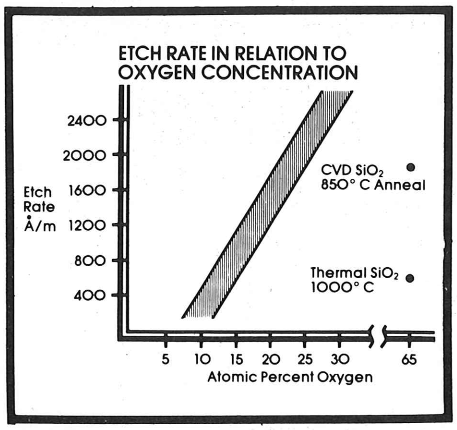


Fig. 4. Here, etch rate is shown as a function of oxygen concentration. The etch rates for CVD SiO_2 and thermal SiO_2 are very slow considering their high oxygen concentrations. This fact led us to conclude that the etch rate of silicon-oxygen films depends on structure as well as on oxygen concentration.

The other model is the **random bonding model** in which there are five tetrahedral structures. For example, we can have silicon bonded to four oxygen atoms, silicon bonded to one silicon and three oxygen atoms, silicon bonded to two silicon and two oxygen atoms, and so on. If these tetrahedra occur randomly, we can calculate the percentage of each type that will occur for a given film stoichiometry. Figure 5 includes two examples of this.

These calculations are from work published in 1971 by H.R. Philipp of General Electric. The various tetrahedra are shown at the top. In the upper histogram, the distribution of tetrahedral structures is shown for a film of Si_2O This film would have 33 atomic percent oxygen. From the calculations, the distribution is skewed and the predominant bonding is silicon bonded to three silicon atoms and one oxygen atom.

The lower histogram shows the distribution for silicon monoxide. The symmetrical shape is no surprise statistically for a film that is half silicon and half oxygen. Keep in mind that these are calculated distributions based on the assumption that the tetrahedra occur randomly.

Still to be determined is which of the two models, microscopic mixture or random bonding, describes the oxygen-doped polysilicon films.

Grain Size

To evaluate the grain size of oxygen-doped poly and to examine the within-run uniformity of grain size, we looked at the films with TEM and electron diffraction.

The upper pictures of Fig. 6 are for as-grown films. The bright field image at the upper left shows, we believe, an amorphous film. The appearance of large irregular grains is an etch artifact of sample preparation. The grain size is less than 20Å. In the diffraction pattern there is no distinction between samples within a deposition. We also looked at the annealed films since differences might be more evident after high temperature processing. The two lower pictures in Fig. 6 show that the annealed films are polycrystalline. We measured a grain size of 50Å from the electron diffraction pattern. Again we detected no difference in grain size for films deposited within a run. Calculated lattice parameters for the annealed films matched those for silicon but we found no match for any documented oxide forms.

Bonding

Since we were still seeking evidence of either preferential bonding in the form of silicon and silicon dioxide, or random bonding, we looked at the ESCA spectra of the films. To assess the chemical binding state of silicon in the oxygen-doped polysilicon films we looked at the distribution of silicon 2p electrons. See Fig. 7.

The peak at 99eV represents silicon bonded tetrahedrally to silicon, and the peak at about 103eV represents silicon bonded to four oxygen atoms as in SiO_2. The film analyzed here was grown at the source end of our reactor.

The **surface spectra** indicated by the solid lines show definite peaks indicating Si-0 and Si-Si bonding. Since the surface of the films has a native oxide, the samples were sputter-etched with argon ions to examine the bulk of the films. For the etched spectra we can draw two conclusions. One is that we appear to have a distribution of peaks between 103 and 99eV. We could also conclude that the sputter-etching has damaged the film so that we are looking at ion-damaged material.

We also analyzed ESCA spectra of a film grown at the exhaust end of the reactor. The surface spectra, represented with solid lines in Fig. 8, are very similar to the surface spectra for source-end samples shown in Fig. 7. After sputter-etching we see a difference in the energy distributions. Again, we do not know if we are seeing the effect of ion-damage.

The as-grown films have indistinguishable ESCA spectra regardless of where they were grown in the reactor, but the annealed films show some difference after sputter-etching. Because of the possiblity of damage after sputter-etching, we cannot definitely say that the films are made up of a distribution of tetrahedral structures.

However, we did notice that ESCA specra of thermally-grown SiO_2 showed only the 103eV peak after ion-sputtering. This says that the tetrahedra that make up SiO_2 are stable to the etching beam.

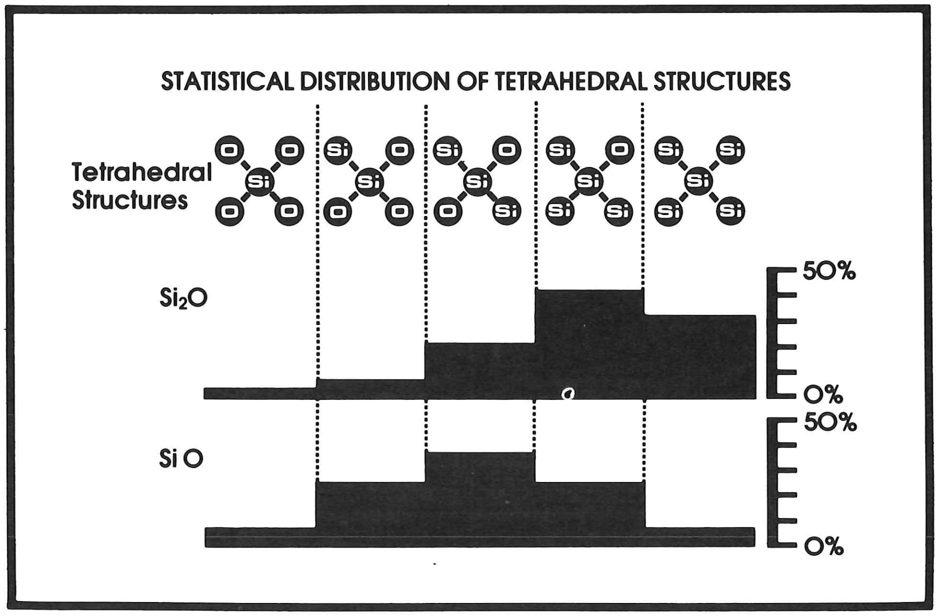


Fig. 5. In the random bonding model, there are five types of tetrahedral structures. Assuming that the tetrahedra occur randomly, it is possible to calculate the percentage of each type that will occur for a given film stoichiometry. Calculated distributions are shown for two examples, Si_2O and SiO (silicon monoxide).

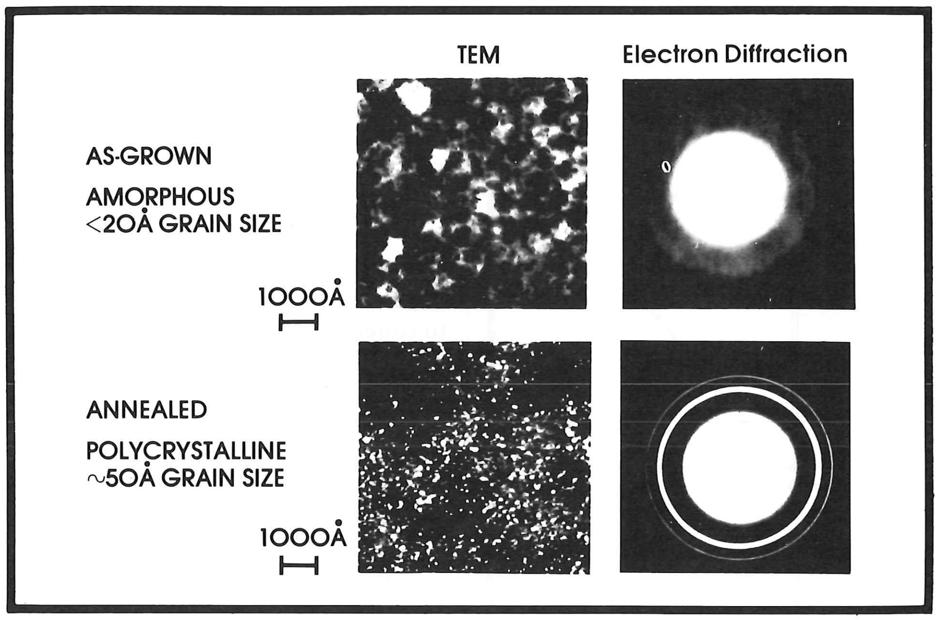


Fig. 6. To evaluate the grain size of oxygen-doped polysilicon and to examine the within-run uniformity of grain size, we studied TEM and electron diffraction photos.

We could not determine any specific chemical species from the ESCA work, but we do have evidence of some particular compounds from infrared absorption analysis. Infrared absorption showed the Si_2O_3 characteristic peak at 11.5 microns for the as-grown films. However, the annealed films showed characteristic SiO_2 absorption at about 12.5 microns and no peak at 11.5 microns.

CONCLUSIONS

We can draw some conclusions about the within-run uniformity of oxygen-doped poly films. First, etch rate and oxygen concentration are low at the source end of the reactor and high at the exhaust end. The structure of films grown in different positions (that is, films of 10-30 atomic percent oxygen) is similar. There is no detectable difference

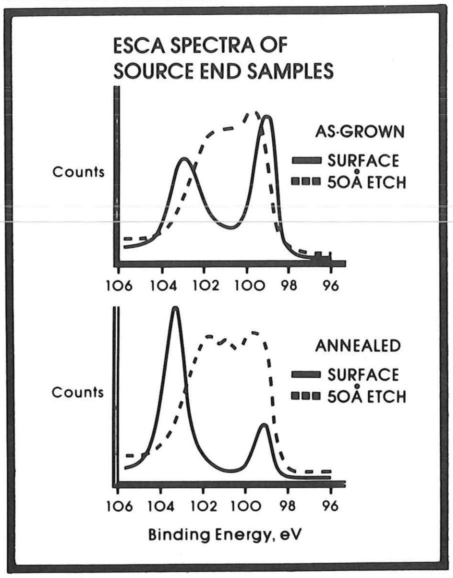


Fig. 7. To assess the chemical binding state of silicon in the oxygen-doped polysilicon films, we looked at the distribution of silicon 2p electrons with ESCA. These spectra are from a sample grown at the source end of the reactor.

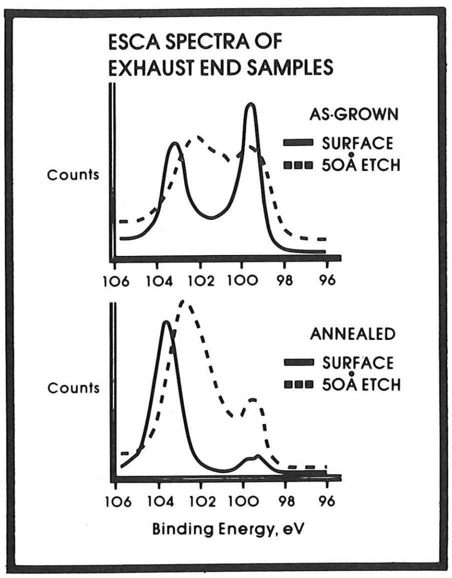


Fig. 8. We also used ESCA to evaluate a film grown at the exhaust end of the reactor. The surface spectra, indicated by solid lines, are similar to those shown in Fig. 7 for a film grown at the source end.

in grain size for annealed films within this range of oxygen concentrations or for as-grown films. And there is no distinguishable difference in bonding within the bulk.

As we anticipated, the structure of these films is different from that of silicon dioxide. The ESCA data for sputtered samples suggest the existence of tetrahedral structures of a nature intermediate between silicon and silicon dioxide. However, the ESCA spectra after ion-sputtering may simply represent ion-damaged films.

We did not see a change in energy or peak-width after ion-sputtering a silicon dioxide film or after ion-sputtering a silicon crystal. This suggests that we do not have a mixture of silicon and silicon dioxide since we saw very broad peaks after sputtering. However, this is very weak evidence to imply that we do not have a microscopic mixture.

If we do have such a mixture, we would expect two phases to be evident in the electron diffraction patterns of the as-grown films. We did not see two phases here, although in the TEM pictures we apparently have two phases. But we can achieve the same effect by a similar preparation of polycrystalline silicon (undoped), which is supposedly a single-phase material. Therefore, we have no direct evidence suggesting that the films are a microscopic mixture.

In conclusion, we remain uncertain about the exact bonding configuration in oxygen-doped polysilicon films.

ACKNOWLEDGEMENTS

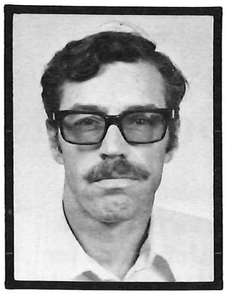
I would like to acknowledge V.C. Kannan for the TEM and electron diffraction work, and Jim Hurd for Auger analysis and ESCA consultation. Both Hurd and Kannan work in the Materials Research Lab (part of Applied Research). I would also like to thank Mike Matthews of the Analytical Support Lab for his work on infrared absorption.

Left to right: **Sherry Munion, Jack Sachitano, Diane Harrison, Shuichi Sato, Tad Yamaguchi, Karen Seaward, Sal Emmi, Lorraine Mercer and Arlene La Fon. Margie Lust not shown.**

The Semiconductor Research Lab is part of Tek Labs' Applied Research group. SRL is responsible for providing Applied Research with advanced semiconductor devices. The group is also responsible for advanced device process development, technology monitoring and assessment (with special emphasis on Japanese activity) and consultation.

DESIGNING FOR SAFETY

Rich presented this paper at Midcon in November, 1977.



Richard Nute,
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Most designers of electronic instrumentation have less expertise in designing for safety than in other areas. This article describes how an engineer can prepare for safety testing, how to determine compliance with safety standards, and suggests some design ideas to improve the safety of electronic products.

INTRODUCTION

Except in consumer electronics, designing electronic circuits and packages for safety has been only an *incidental* design activity.

As electronic engineers, of course, we are familiar with electric shocks. We know how to design to avoid shocks—or do we? Seldom has the safety of our designs been challenged.

The people who use our products are usually professional people familiar with electronics and with the operation of sophisticated equipment. Injuries seldom result from using our products. We've been lucky so far.

So far there has been no pattern in the few safety-related incidents we have seen, but more and more non-professional people have access to the sophisticated equipment we are producing today.

To protect ourselves from liability, we must protect the user from injury. In today's world, the product must be *deliberately* designed for safety.

A NEW DISCIPLINE

Generally, designing for product safety is not taught in electrical engineering schools. But if you were to take an EE course in product safety engineering, the final exam might look something like Fig. 1.

The fact that most of us have trouble answering these questions suggests that we're not deliberately designing for safety even though our products are generally safe.

THE TRADITIONAL RESPONSE

The engineer who is comfortably established in his job and has a number of design successes often questions the new safety requirements. No one has ever suggested his designs might not be safe, but he feels he is being told that he has been wrong for all these years. That's not really what is being said, but that's the way he reads the situation. His reaction is not against safety, but against a new design constraint. "Why should it be a problem now?", he wonders.

1. Explain and trace the change in the law from "let the buyer beware" to "let the seller beware."
2. Identify the research in electric shock justifying today's national and international requirements. Identify the authors of that research.
3. Identify the national and international organizations which publish safety standards for electronic equipment. Describe the authority each organization has for enforcing compliance with safety standards.
4. Define the following.
   - voluntary standard.
   - consensus standard.
   - proprietary standard.
   - mandated standard.
   - third-party certification.
5. Explain why a fuse is always rated for voltage.
6. Describe a mechanical test analogous to a dielectric-withstand test.
7. Describe the failure mechanism of a polymeric insulator in an energized circuit that is likely to result in ignition of that insulator.
8. Define leakage current.
9. Explain the criteria for selecting a component if failure of that component is critical to maintenance of safety under equipment failure conditions.

Fig. 1. A hypothetical final exam for an EE product safety engineering course.

However, an engineer new to his carreer does not question the safety requirements. In college he saw many efforts to save the world's environment. Safety is an issue consistent with those efforts. Deliberately designing for safety is his way of contributing to a better world.

LEARNING THE NEW DISCIPLINE

Since there are few schools that teach designing for safety, an engineer has to identify his own learning resources.

The hardest and most costly way is to wait until you are faced with a liability claim.

Learning product safety engineering is a bootstrap operation. There are no formal resources. There are a few textbooks on safety, but they don't discuss the "nitty-gritty" of electronic product design.

Feedback from field applications of the product is one source of information on safety. Unfortunately, in many organizations, there is no systematic way to handle this category of feedback or it is addressed only in a cursory manner.

Much of the safety-related feedback is never really investigated or understood. It is too easy to blame the user: "He should have known better." This attitude may someday result in a liability claim.

The best way to learn the safety discipline is to submit a product to a third-party safety certifying agency for independent testing. The agency will test for things you probably take for granted. With the first submittal, there are frequently many surprises.

To have a product you thought safe come back with a long list of non-complying features is a shock. If he doesn't give up in exasperation first, the astute engineer can learn a lot from this experience.
Standards can provide some insight into the specifics of designing electronics for safety. However, standards are not tutorial, so terms are not explained. The neophyte, therefore, is likely to misunderstand them.

SAFETY STANDARDS

In the language of safety standards, safety concepts are characterized by the phrase "protections from ..." because the difference between "safe" and "unsafe" is gray.

Safety standards define measurable degrees of *protection.* The courts decide whether that degree of protection is *safe.*

Let's identify some safety concepts which commonly appear in safety standards for electronic equipment.

PROTECTIONS FROM EMANATIONS

Electronic equipment can produce hazardous radiation (emanations). A cathode-ray tube, for example, can produce X-radiation. This emanation and others may be readily measured and controlled with shielding and attenuating materials.

HEAT

Sometimes heat sinks get hotter than the standards allow. But, a more serious problem is that heat can cause long-term degradation of insulating materials.

Every insulator has a temperature rating, and this rating must not be exceeded even under the equipment's worst-case operating conditions. If the temperature rating is exceeded, then early insulation failure is likely.

The insulation between windings of a transformer is a good example of a failure that creates a reliability problem and may also result in a hazardous situation. If a short causes the transformer to overheat, a primary-to-secondary insulation failure could create a shock hazard or a fire hazard.

Other insulations (on wire, for example) are equally important. A thorough safety investigation of electronic equipment includes measuring and recording insulation temperatures, and making sure the temperature does not exceed its rating.

MECHANICAL STRENGTH

The equipment enclosure must have enough mechanical strength so that other protections are not compromised by normal use or foreseeable misuse. This means that the equipment must be subjected to certain mechanical abuses *before* the other protections are measured.

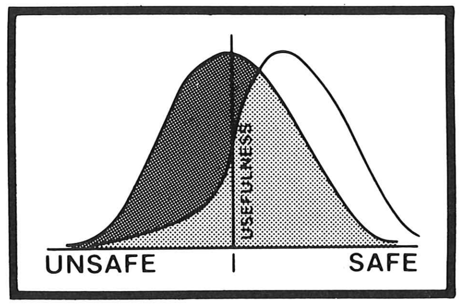

Fig. 2. Most products are neither totally safe nor totally unsafe. A product near the extremes of safe or unsafe is not very useful. A product's position on this continuum is determined by protection from a hazard that the product provides. Whether or not that degree of protection is acceptable is determined by a safety standard.

FAULT-CONDITION TESTING

The equipment must not create a hazard simply because it fails. Most standards require tests to determine whether or not a design will compromise any of the protections if any component fails.

Deciding which components are significant to safety when they fail is a challenge to the design engineer.

For example, let's say a fold-back power-limiting power supply detects an over-power fault and shuts down. The design, though, provides self-reset because the fault might be temporary. Each time the supply resets, it generates full power for a fraction of a second. Continuous cycling in this manner could start a fire because the supply continues to put short bursts of full power into the fault.

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ext. 6545

DESIGN
Roydn Jones
ext. 6513

LASER TRI
Brad King
ext. 7742

BENCH TO
Ray Nelke
ext. 6074

LSI TEST
Warren Finke
ext. 6873

SSI TEST
Oris Nussbaum
ext. 6779

TEK LABS REORGANIZATION

The Component Development group was formed recently as part of an overall Tek Labs reorganization.

The basic charters of the groups now in Component Development have not changed and there has been little change in project work. But there have been significant changes in management responsibilities. Also, Display Devices Engineering and Storage CRT Engineering have been restructured.

We have put together an organization chart to help engineers and managers in other organizations find the right group and the right people in Component Development.

—Aris Silzars, Component Development manager

CTRON DEVICE ENGINEERING
nko
51

CHNICAL SERVICES
rown
85

TABLE STORAGE
Virgin
86

TERIALS AND PROCESS DEVELOPMENT
Engstrom
98

VICE MANUFACTURABILITY
rnold
68

OLITHOGRAPHY AND PROCESSING
ope

DESIGN AND DIGITIZING
ung

FICATION AND DOCUMENTATION
harry

eltz

AR IC DESIGN
Vilson

ON TECHNOLOGY APPLICATIONS

ED/MECHANICAL DESIGN

G

M

TEST

HIGH FREQUENCY CRT ENGINEERING
Dennis Hall
ext. 7048

REAL TIME CRT ENGINEERING
Ken Hawkins
ext. 7781

ELECTRON DISPLAY OPTICS
Ellen Mickanin
ext. 6554

SIGNAL PROCESSING DEVICES
Larry Riley
ext. 7944

ENGINEERING TUBE LAB

BULBS
Dick Trythall
ext. 7510

GUNS
Ed Cowles
ext. 5400

SEALING
Ken DeClercque
ext. 7941

DRAFTING
Dale Smith
ext. 7512

PLATING
John Armstrong
ext. 7852

MAINTENANCE
Al Chappell
ext. 7722

LARGE SCREEN DVST'S
Bill Mason
ext. 5378

TEST AND EVALUATION
Connie Wilson
ext. 6344

ANALYTICAL SUPPORT LAB
Gene Hansen
ext. 7456

CRT MATERIALS
Ralph Mossman
ext. 7514

PROCESS DEVELOPMENT
Gordon Sletmoe
ext. 7507

COLOR TUBE FEAS.

MASK SHOP
Mel Wright
ext. 5308

SILK SCREEN
Mel Wright
ext. 5308

WAFER FABRICATION
Rob Rugh
Page Bldg. 50

FILM DEVELOP.
Bob Burns
ext. 6363

THICK FILM
Jim Wrobel
ext. 5362

THIN FILM

PACKAGING

To remove organization chart, loosen staples and pull out sheet.

PROTECTIONS FROM FIRE

It's easy for an electronics design engineer to forget that fire is one of the most serious considerations in electronic product safety.

The use of flammable materials as insulation is a major problem. To illustrate, assume a capacitor shorts on an etched-circuit-board at the furthest point from the power source and the board conductor's high resistance creates heat when current flows through it. The circuit board base material is flammable and may burst into flames.

Unfortunately, in many designs, insulation materials are chosen primarily for their circuit performance rather than flammability. When the designer considers flammability he may find his choice of materials severely limited.

Tradeoff decisions of flammability versus performance are very difficult. For example, Du Pont's Delrin is a very popular plastic because of its electrical and molding properties. But it's more flammable than other materials.

The tradeoff can usually be resolved by wrapping the material with nichrome wire and applying maximum circuit power to the material to see if the questionable material ignites.

In low-voltage semiconductor circuits, power is the most significant factor to consider in deciding where protections must be employed. In high voltage circuits, arcing may be the source of ignition.

PROTECTIONS FROM ELECTRIC SHOCK

There are two basic protection systems for electric shock: protective grounding and double insulation.

In the standards, discussions of electric shock protections look closely at "accessible" parts. Therefore, many safety standards define accessibility probes ("standard fingers") to determine accessibility of parts.

Protective-grounding is a system in which all accessible conductive parts that could become live from a single failure within the equipment are grounded through the protective grounding conductor of the power cord.

Double insulation is a system in which all such accessible conductive parts are protected with an independent insulation system.

If you are considering using a protective-grounding system, remember that the protective grounding conductor and accessible conductive parts must not carry current under normal use. The system is a safety system only: it must not be used for any other purpose. See Fig. 3.

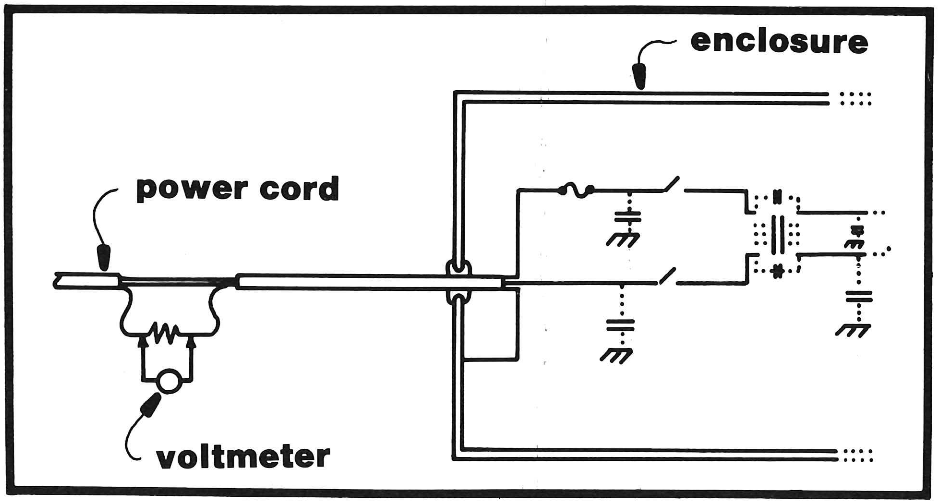


Fig. 4. Sources and measurement of residual current in the protective grounding system.

There are two ways to measure how much protection the protective grounding system provides.

The first is to measure the impedance of the system. It must not exceed 0.1 ohm at a current of 25 amperes rms.

The second is to calculate the residual current from the voltage measured across a 1500-ohm resistor connected in series with the protective grounding system. This current is called *leakage current*. See Fig. 4.

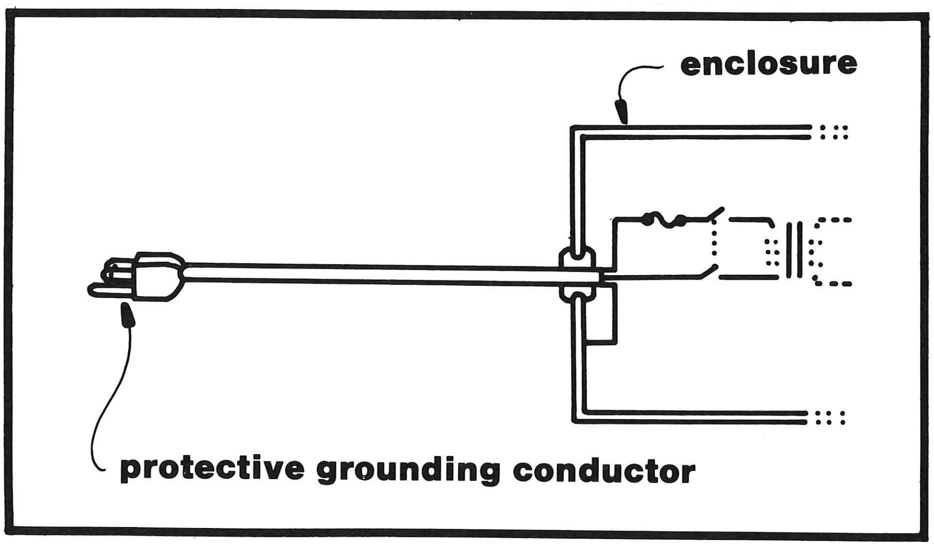


Fig. 3. Protective grounding is a safety system for connecting conductive accessible parts to ground. The conductor is not used as a current-carrying conductor.

Even though the accessible parts are grounded, there still should be sufficient insulation or spacing between the equipment circuits and the accessible parts. The key word here is "sufficient"—how much is sufficient?

Let's look at the primary circuit, rated for 120 volts. Obviously, the insulation or spacings should not break down at 121 volts, or even at 150 volts. The question is: what margin should the insulation or spacing have?

A chair must be capable of holding a maximum load of, say, 300 pounds. But at what load should a structural failure occur in an extreme case? The difference between the two loads would be the *margin.*

The rule of thumb for testing the margin of an insulating system is that the system must withstand twice the circuit voltage plus 1000 volts.

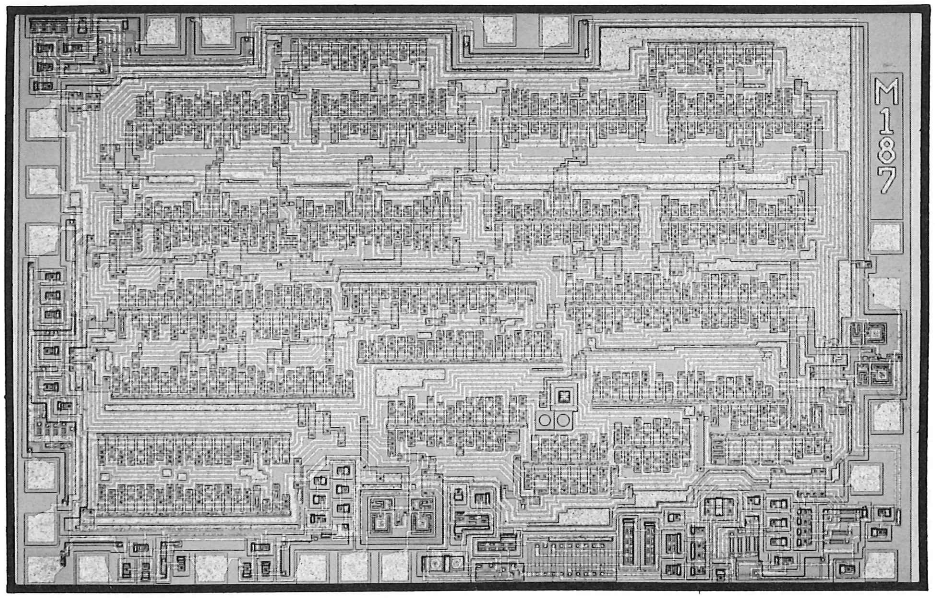
A primary circuit rated for 120 volts should sustain 1240 volts. This is the *dielectric-withstand test.*

FOR MORE INFORMATION

For questions about designing for product safety, call Rich Nute (ext. 6649).

I^2L PROCESS CIRCUITS NOW AVAILABLE IN-HOUSE

The first circuit (an M187 4-decade Digital Voltmeter) fabricated with Tek's in-house I^2L process was released to production in November. This demonstration of I^2L capability means other IC's can now be designed with I^2L logic.



A 35X magnification of an M187, an I^2L digital voltmeter. I^2L (integrated injection logic) is a bipolar process used to fabricate MSI and LSI logic circuits. Merging NPN and PNP transistors to form the basic gate structure leads to a much higher packing density than conventional TTL. I^2L operates at very low power levels which leads to high reliability.

IMPLICATIONS

The I^2L process was obtained by modifying Tek's 200 $\Omega/\square$ process; thus, both I^2L and standard bipolar devices can be fabricated on the same chip. This allows both analog and digital circuitry to be used in the same design.

The high-gain NPN's available with the I^2L process allow high-current buffers to be used on the same chip. This is useful when interfacing a digital circuit to a bus or a display.

For Tek's I^2L process, miminum gate delays measured on maximum fan-out devices were 50-100 ns. This means our I^2L circuits can operate with maximum clock rates of 2 MHz.

I^2L ADVANTAGES

Using I^2L has advantages for the system designer.

First, an I^2L circuit operates at very low power levels. A typical I^2L gate dissipates about 50 μW of power. This means significant power savings over TTL even for small circuits.

Second, I^2L has a very high packing-density. Circuits with up to 500 gates can be placed in a single package for both cost and space savings. Finally, lower power and fewer parts means higher reliability.

MORE INFORMATION

For further information on Tek's I^2L process and possible applications, contact Don Larson on ext. 6318 or Randy Young on ext. 5090.

"LOST" INSTRUMENTS MEAN LOST PROFIT SHARING

If you're moving Tektronix property from one area to another, be sure to notify the people responsible for that property.

Examples of people to notify are open stock areas, Instrument Control and similar honor-system facilities.

In November, Instrument Control started a weekly inventory of its on-the-shelf instruments to identify losses. The expense of the inventory plus the time lost during each Monday morning shutdown makes the Instrument Control operation hard to be cost-effective.

Is a weekly inventory really necessary? The November 7 inventory revealed that 11 instruments were missing from the previous week! The average value of the instruments in Instrument Control's Rental Library is about $1500.

There are other costs. For every missing instrument, a Mysterious Disappearance Report must be filled out, a copy sent to Security and an inventory adjustment made. Security enters the MDR into a computer and attempts a match with other information already on file. If it appears that the instrument has been stolen, police reports are filed. All of which adds up to lost time, money and profit sharing for each of us.

To avoid all this extra expense, don't forget to let people know if you're moving an instrument from one place to another.

For more information call Ray Barrett on ext. 5653.

T&M PUBLICITY GROUP TO PUBLISH SOFTWARE NEWSLETTER

In February 1978, the T&M Publicity group will issue a new company-wide, company-confidential publication called **Software News**. The newsletter will contain items of interest to designers and users of software, firmware and computer-related hardware at Tektronix. George Dunn is the editor of **Software News**. George, previously with the STS Manuals group, has broad experience with programming, writing and editing.

Those who responded to the **Agenda**, **Tekweek**, and **Cyber News** requests for names for the newsletter mailing list will receive a confirming note. If you have not previously submitted your name and would like to receive Software News, call the mailroom on ext. 5407.

T&M Publicity is a service group whose functions include publishing **Engineering News** and **Forum Report**. Editing, graphics and production support are also provided to employees submitting material for publication in trade magazines or professional journals, or who are presenting papers at conferences.

For more information on **Software News** and how to submit material, call George at ext. 5674. For more information on the T&M Publicity group, call me at ext. 6601.

—Joyce Lekas, manager

IDP ANNOUNCES NEW PRINTER

The Information Display Products division has announced the 4642, an impact matrix printer for use with 4020 series computer display terminals and the 4051 BASIC Computing System.

The 4642 (which is RS 232 compatible) prints 60 characters per second in up to 80 columns of print (at 10 characters per inch). A front panel switch also allows the user to print 132 columns (16.5 per inch). The printer uses a 5 X 7 dot matrix and prints upper and lower case characters.

The 4642 Printer can also print double-width characters. An option allows the printer to handle multi-part forms (the original plus four copies) and tab stock (fan-fold) paper.

For more information, call Mike Taylor on ext. 2319.

PLOT 10 EASY GRAPHING

Information Display Products division has released PLOT 10 Easy Graphing, a small and simple-to-use graphing package designed for 4010 family terminals as well as the new 4025 Computer Display Terminal.

PLOT 10 Easy Graphing is a FORTRAN IV package that should satisfy the demand for a small program that can create presentation-quality graphs without the services of an experienced programmer.

The Easy Graphing package includes a high level graphing language very similar to the PLOT 10 Interactive Graphic Package. Features include: line graphs with symbols, bar charts with selectable shading, centered titles, movable legend, adaptable axis labeling, plotter on/off control, saving and retrieving command files, changing data elements ... and uses only 16K of 16-bit word memory or a PDP-11.

The Display Manager option adds other features including pie-charting. The Data Manager option includes such features as ATTACHing and reading data files from, for example, an on-line lab experiment or summary reports from a management information system.

Also included is the ability to conversationally graph complex functions such as:

X=C/D*SIN(3.14159+Z)**.5

The whole package will run on an IBM TSO in 132K bytes.

For more information, call Will Gallant on ext. 2785.

IN PRINT

Ken Hawken (Display Device Engineering), Keith Taylor (Logic Development Products Engineering) and Hale Farley (Systems Field Office) were co-authors of a recent article in **Electronics** on the 7834 Fast Storage Oscilloscope's 2,500 cm/us stored-writing speed and ability to display pulses with rise times as fast as 1 nanosecond.

The title of the article is "Rapid Writing Rate Lets Storage Oscilloscope Grab 1-Nanosecond Single-Shot Signals." The article discusses the tradeoffs of storage and speed, the basics of direct view storage tube operation and applications of the superfast tubes.

The article appears in the 22 December 1978 issue of **Electronics** on pages 73 through 77. For a copy, call the library on ext. 5388.

Emmanual Sang (Applied Research, Tek Labs) and Robert Culter (formerly with Display Devices Engineering, now with Fluke, Inc. in Seattle) were the authors of "Oxide Transfer Storage for a Diode Array Scan Converter," an article that appeared in a recent issue of *The Proceedings of the IEEE.*

The article describes a method for producing long-term storage on a diode array target scan converter. The authors state that the storage is achieved by a simple target pulsing sequence which causes a charge transfer from the diodes to the adjacent oxide. High-resolution storage of single-shot subnanosecond events can be obtained with storage times, in continuous readout, of greater than 30 minutes.

For a copy of the article, call the library on ext. 5388. The article appeared in the July 1977 issue of *The Proceedings of the IEEE, Vol. 65, No. 7 on pages 1072 and 1073.*

NATIONAL COMMUNICATION CONFERENCE CALL FOR PAPERS

The National Communication Conference sponsors have called for papers for the NTC'78 on December 4-6, 1978. Subjects include communication theory, switching and systems; computer communications; the social implications of technology and standards coordination and liaison.

Authors are invited to submit a one-page summary and a draft of the manuscript (no more than 3000 words—about 10 pages double-spaced and typed) by May 15, 1978.

For more information, or help with the manuscript, call Bill Furlow (ext. 5674) or Al Carpenter (ext. 5468).

PROFILE

T&M PUBLICITY

This is the first of a series of profiles of departments of interest to the Tektronix engineering and scientific community. The information is abstracted from the recently published **Engineering Sourcebook** (Who/What/Where/When). For a copy of the sourcebook, call Jacquie Calame (Technical Communication) on ext. 6867.

Left to right: **George Dunn (technical writer), Bill Furlow (technical writer), Mary Francis (secretary), Al Carpenter (technical writer), Joyce Lekas (manager), Burgess Laughlin (technical writer), Jane West (secretary) and Bob Down (technical writer). Wyn Giluck (technical writer) and Ken Arthur (technical writer), not shown.**

WHAT

The T&M Publicity department (formerly Technical Information) helps engineers communicate with one another...within the company via technical newsletters and outside the company via trade journal articles, conference presentations and product publicity.

While not in the business of generating information, the staff can edit your paper or article and handle all the mechanics for you. For example, if you plan to present a paper at a conference, they can help you with the writing and with defining the graphics that best illustrate your ideas. The department can also handle all the typing as well as provide slides and coaching for your talk. They will contact magazine editors and conference program directors on your behalf when necessary.

Internally, **Engineering News** and **Software News** serve the same purpose but for different communities within Tektronix. **Engineering News** provides technical information primarily for hardware design engineers and for chemists, physicists and other scientific people in the engineering community. **Software News** provides software, firmware and computer hardware information and a communication medium for the rapidly growing community of firmware and software designers and users.

WHEN

If you are presenting a slide show or writing a paper for a conference, bring in your rough notes about six weeks before the paper or slide show due date.

The editors of **Engineering News** and **Software News** require at least five weeks lead time to publish contributions in those newsletters.

WHERE

The editors are located at 50-462 (across from the central elevator on the fourth floor of the Technical Center).

The graphic designers and illustrators who provide the slides and illustrations (Ric Anderson, Andrea Fowler, Scott Sakamoto and Joe Yoder) are located at 58-065 (in the Industrial Design area).

WHO

The manager of the department is Joyce Lekas (ext. 6601). If you have a question, call Joyce or one of the technical editors:

—Product articles and information, Ken Arthur (ext. 5674), Bob Down (ext. 5674) and Wyn Giluck (ext. 5674).

—Technology articles and slide shows, Al Carpenter (ext. 5468) and Bill Furlow (ext. 5674).

—Engineering News, Burgess Laughlin (ext. 5468).

—Software News, George Dunn (ext. 5674).

IEEE TAKES POSITION ON RENEGOTIATION ACT

In October, 1977, the IEEE submitted its official position on the Renegotiation Act of 1951 to Sen. William Proxmire and Rep. Joseph G. Minish, sponsors of amendments to the act.

THE RENEGOTIATION ACT

The Renegotiation Act of 1951 established the Renegotiation Board whose purpose was to recoup "excess" profits made by government contractors during the Korean War.

However, in September the Senate Banking, Housing and Urban Affairs Committee adopted the Cranston-Lugar bill which would deactivate the Renegotiation Board except in a national emergency at which time the president could reinstate the renegotiation process with an executive order.

Proxmire and Minish proposed amendments to the Renegotiation Act that would require product line renegotiation of sales to the federal government and would severely limit the "standard commercial article" exemption contained in the original act.

IEEE POSITION

The IEEE position is that extending the Renegotiation Board and adopting recently proposed amendments to establish renegotiation along product lines would limit corporate investment in research and development.

The position paper stated that the "IEEE feels it is in our national interest to facilitate and promote R&D funding in all product line areas regardless of the state of profit or loss which that product line might currently represent."

The IEEE position further stated that "profits invested into an intra-corporate pool for independent research and development" should be exempt from the renegotiation process. The position also related that those funds should be "allocated at the discretion of the company" providing the funds.

—abstracted from an IEEE news release.

TEKTRONIX POSITION

Chuck Frost, Tektronix Public Affairs Director, commented that "Most of Tektronix' sales to the federal government have been exempt from renegotiation as sales of 'standard commercial articles' or 'classes' of articles as defined in the Renegotiation Act."

Frost also stated that "Tektronix has opposed efforts to expand the renegotiation laws to include standard commercial articles."

If you have questions about Tektronix' position, call the Public Affairs department on ext. 6292.

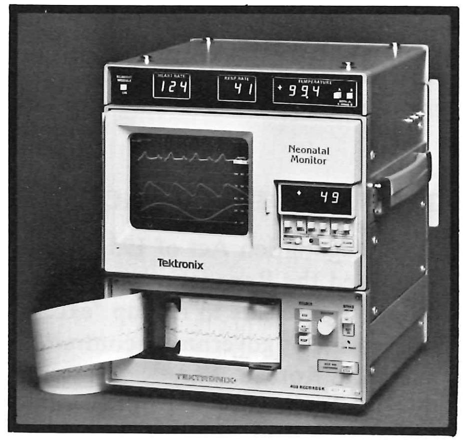
VITAL SIGNS FROM READOUT MODULES FOR PATIENT MONITORS

New digital readout modules are available as options for three Tektronix portable patient monitors.

The new modules allow simultaneous viewing of four vital signs in digital form: heart rate, respiratory rate, temperature and blood pressure.

The three new options are the Opt. 06 for the Tektronix 413 Neonatal Monitor, and Opt. 07 and 08 for the Tektronix 414 Portable Patient Monitor.

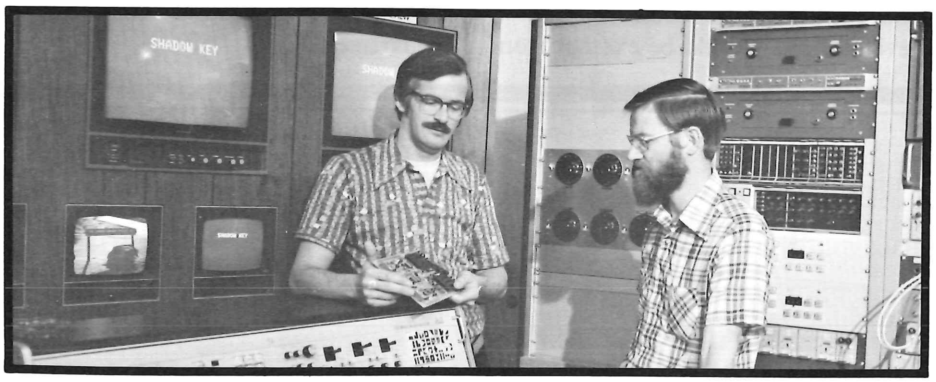
Using the Tektronix 414 Option 08 to watch arterial pressure as well as the other vital signs, a doctor can insert an arterial catheter while observing the patient's condition.



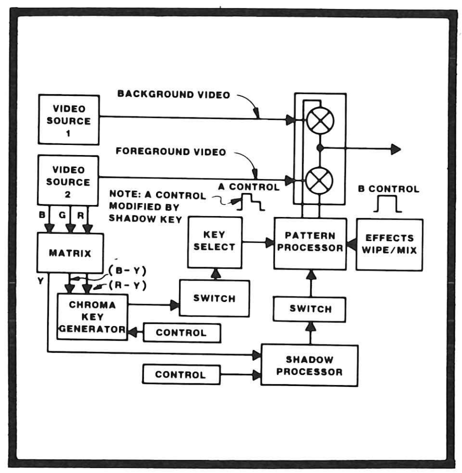
New digital readout modules allow users to simultaneously view heart rate, respiratory rate, temperature and blood pressure. Shown here is the Tektronix 413 Neonatal Monitor with the Option 06 digital readout at the top of the unit.

PATENTS RECEIVED

To further promote internal technical communication, Engineering News *will publish abstracts of patents received by Tektronix engineers. All back up material for the patents is on file in the Patents and Licensing Office (D.S. 50-419). For more information about patents in general, call ext. 5266.*



Bruce L. Rayner (left) and Gerald G. Taylor, Grass Valley Group. Their phone number is 916-273-8421 (ext. 211 for Bruce and 210 for Gerald).



VIDEO EFFECTS GENERATOR

This patent covers a shadow generator used with an RGB (red-green-blue) chroma keyer for video special-effects.

Chroma-key is normally a two-dimensional switching process that occurs between two video signals so that one appears inserted into the other (an example: a TV newscaster's image inserted into a film background).

In special effects situations such as actors using miniature stage sets, it is desirable to have a three-dimensional effect. This can be created by using the luminance information from the shadow detail in the original picture and linearly keying it into the final chroma key.

EN INDEX

For a copy of an issue or article, call Jane West on ext. 5674.

Maureen Key If you have moved, please call Ext. 5407
60 553

ON THE COVER

The cover shows a tray of silicon wafers being removed from a diffusion tube after oxygen-doped polysilicon has been deposited.

Vol. 5, No. 2, February 1978. Editor: Burgess Laughlin, ext. 5468. Art Director: Scott Sakamoto. Technical Illustrator: Joe Yoder. Published by the T&M Publicity Dept. (part of Test and Measurement Operations) for the benefit of the Tektronix engineering and scientific community in the Beaverton, Wilsonville and Grass Valley areas.

Why EN?

Engineering News serves two purposes. Long-range, it promotes the flow of technical information among the diverse segments of the Tektronix engineering and scientific community. Short-range, it publicizes current events (seminars, new services available, and notice of achievements by members of the technical community).

Contributing to EN

Do you have an article or paper to contribute or an announcement to make? Contact the editor on ext. 5468.

How long does it take to see an article in print? That is a function of many things (the completeness of the input, the review cycle and the timeliness of the content). But the *minimum* is three weeks for simple announcements and about five weeks for articles.

The most important step for the contributor is to put his message on paper so that the editor will have something to work with. Don't worry about problems with organization, spelling or grammar. The editor will take care of those when he puts the article into shape for you.