1988

An Investigation of the Micro-Surfaces of Fiber Glass, Window Glass, Bottle Glass, and Quartz Crystal Through the Use of Scanning Electron Microscopy

Raymond C. Friedrichsen
University of Northern Iowa

An Investigation of the Micro-Surfaces of Fiber Glass, Window Glass, Bottle Glass, and Quartz Crystal Through the Use of Scanning Electron Microscopy

Abstract

The problem of this study is to investigate the surfaces of quartz crystal, bottle glass, window glass, and fiber glass, to determine if there are any substantial differences in their structures when compared to a fiber optic material. The investigation will be done with the aid of the scanning electron microscope {SEM).

AN INVESTIGATION OF THE MICRO-SURFACES OF FIBER GLASS, WINDOW GLASS, BOTTLE GLASS, AND QUARTZ CRYSTAL THROUGH THE USE OF SCANNING ELECTRON MICROSCOPY

A Research Paper Presented
to the Graduate Faculty
of the Department of
Industrial Technology
University of Northern Iowa

In Partial Fulfillment of the
Requirements For the Non-Thesis
Master of Arts Degree
by

Raymond C. Friedrichsen

Date:

Approved by:

Dr. Rex Pershing (Advisor) — June 9, 1988 DATE

Dr. Mohammed F. Fahmy (Graduate Faculty Member) — 6/20/88 DATE

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Background of the Problem

The field of communications has significantly changed since Alexander Graham Bell invented the telephone. Today we have telephones all over the country, almost every house has a telephone. With the help of modern day computers, telephone companies can handle billions of calls a day. These telephones have wires which lead to junction boxes with more wires which connect to more wires. There are hundreds of thousand of miles of wires throughout the United States alone.

Through the use of technology and its applications, scientists found a way to increase service, reduce the miles of wire, and cut the cost of large repair bills. The new innovation comes to us through glass, better known as fiber optics. These fibers can carry many more calls, messages, and information than was ever thought possible. This is possible through the theoretical and applied aspects of fiber optics, which will be explained in this paper.

Fiber optics is a method of carrying information from one point to another, using cables made up of glass strands with clad coating (Sterling, 1987, P. 2). This clad coating is used to protect the glass, and also to keep the light pulses within the boundaries of the glass fiber.

Glass is mono-crystalline or amorphous, this means that there is no shape or crystal structure to the glass. Using the scanning electron microscope (SEM), the researcher will look at different forms of glass to see if they have different characteristics. The structures compared using the SEM are: bottle glass, quartz, window glass, and fiber glass.

Applied research into the structures of any material requires understanding of the tools and processes which is used to do the research analysis. One of the main tools used in research today is the electron microscope, which has been available for about 40 years, and thousands have been sold. This device has features such as high resolution, very high magnification, and extraordinary depths of field which makes the SEM an important research device (Von Heimendahl, 1980 P. 36). The electronics and computer research laboratories amount to about half of the scanning electron microscope sales in the past few years due to the increased applications of microchips (Newbury, Joy, Echlin, Fiori, Goldstein, 1986, P. 45).

The SEM has become a device that will help scientists to more fully understand the crystal lattice structures of objects. "Whenever an image is formed on a viewing screen or photographic plate an electron diffraction pattern is present in the back focal plane of the object lens of the instrument. This is true regardless of whether the specimen is amorphous or crystalline. If the specimen is amorphous there is an entire structure of random formed atoms. Then the refraction pattern will contain no distinct maxima and only will consist of diffused rings scattering around a bright center spot, [of a thin amorphous carbon film]" as shown in figure 1 (Glauert, 1979, P. 196).

Statement of the Problem

The problem of this study is to investigate the surfaces of quartz crystal, bottle glass, window glass, and fiber glass, to determine if there are any substantial differences in their structures when compared to a fiber optic material. The investigation will be done with the aid of the scanning electron microscope (SEM).

Purpose of the Study

The purpose of this study is to identify the physical structure of amorphous glass materials, and contrast them to fiber optics. Then discuss how this knowledge is applied to industrial communications.

Research Questions

This study will have the following research questions:

1. What is the effect of microstructure on light transmission in the different materials under investigation?

2. How does light travel through fiber glass cables with information?

3. What will be the future impact of fiber optics concerning industrial and commercial communications?

Assumptions

This study has the following assumptions:

1. That all specimens are alike and will transmit light.

2. That by using the SEM to investigate the microstructure surface of glass specimens, the researcher will derive significant knowledge about the crystalline nature of glass.

Definition of Terms

The following terms will be used in this study and defined for its purpose:

Amorphous - Literally, without form; applied to rocks and minerals having no definite crystalline structure (Bloss, 1971, P. 26).

Cladding - The outer concentric layer that surrounds the fiber core and has a lower index of refraction (Sterling, 1987, P. 230).

Core - The central, light-carrying part of an optical fiber; it has an index of refraction higher than that of the surrounding cladding (Sterling, 1987, P. 230).

Critical Angle - The angle of incidence for glazing emergence just preceding total internal reflection (Denney & Foster, 1984, P. 72).

Crystal Lattice - The regular and repeated three-dimensional arrangement of atoms or ions in a crystal (Denney & Foster, 1984, P. 12).

Crystalline - Of or pertaining to the nature of crystals; having regular molecular and/or atomic structure (Denney & Foster, 1984, P. 12).

Crystallography - The study of crystals, including their growth, structure, physical properties, and classification by form (Bloss, 1971, P. 1).

Fiber Optic Systems - System using optical fibers for transmitting images or optical signals; in fiber-optics telecommunication systems electrical signals modulate a laser beam which is transmitted through the fibers; optical fibers can transmit far more information than a conventional cable of the same diameter (Denney & Foster, 1984, P. 72).

Glide Planes - A symmetry element in a crystal that relates parts on opposite sides by reflection plus translation parallel to the plane. The possible translation components associated with a glide plane must correspond to one half of a lattice translation (Bloss, 1971, P. 169 & 336).

Micrographs - a photograph which is taken with the scanning electron microscope (Fahmy, personal communications).

Miller Indices - A set of three or four symbols used to define the orientation of a crystal face or an internal crystal plane. The indices are determined by expressing, in terms of lattice constants, the reciprocals of the intercepts of the face or plane on the 3 crystallographic axes, and reduction in necessary the lowest integers retaining the same ratio (Bloss, 1971, P. 51).

Morphology - A branch of materials analysis dealing with the form and structure of materials (Bloss, 1971, P. 338).

Optical Fiber - A thin flexible length of transparent glass material transmitting light by total internal reflection, the fibers have polished surfaces coated with a material of suitable lower refractive index (Denney & Foster, 1984, P. 72).

Point Group - One of the thirty two crystal classes which pass through a single point (Bloss, 1971, P. 23).

Scanning Electron Microscope - A device made up of four systems: Illuminating/imaging, control, display and vacuum. Analogous to a light microscope, the SEM uses an electron beam to provide the required illumination for analysis of various items. SEM utilizes a set of electromagnetic lenses in contrast to the glass lenses used in light microscopy (Glauert, 1979, P. 212).

Scanning Electron Microscopy - A branch of electron microscopy utilizing the unique characteristics of the Scanning Electron Microscope (Glauert, 1979, P. 212).

Space Group - The lattice typical of the crystal system repeats an object whose symmetry conforms to one of the point groups. Symmetry and scheme of repetition of an object arrayed (Bloss, 1971, P. 162).

CHAPTER 2

REVIEW OF LITERATURE

The recent breakthrough of fiber optics will change the communication world as we know it forever. With this breakthrough the influence upon industries, telephone and communication companies, and the computer industry will give new innovations to which was science fiction only ten years ago.

Being able to send thousands of messages at one time on a single strand of glass, through major communication networks and industrial computers with almost no wires, will aid in cutting down on response time and maintenance of equipment, and will also benefit both companies and consumers by saving time and money.

The ability to understand mathematical concepts, optics (physics), and electronic communication will be very important in the future for the study of fiber optics. It is believed by some sources that scientist have just broken the tip of the iceberg on fiber optics. One of the most useful tools in pursuing these developmental changes has become the SEM. The use of the SEM has brought about new innovative analysis techniques such as: comparing different materials, identifying crystallography structures, and analyse microstructures of glass. The University of Northern Iowa has an SEM which is able to magnify material of micro size up to about 200,000 times its original size. The specimen is shown on a Cathode Ray Tube monitor, and the researcher scans the specimen to find what he is looking for and, if desired, takes a micrograph to keep a permanent record of his findings.

Gibson (1985, P. 38) States, "Instruments that can see the atom are becoming essential to fabricate and diagnose electron devices. Tools are needed to observe the devices, but unfortunately the wavelength of light limits the resolution of the vulnerable optical microscope to typically several tenths of a micron." Science has the technology to look at micro specimens in 3-D, by the use of Artificial Intelligence. Not only is the electron microscope used in technology, but also in fields such as: geology, chemistry, biology, medicine, and other sciences (Bass, 1984, P. 65).

Goldstein, and Yakowitz (1977, P. 2) stated: "The scanning electron microscope (SEM) is one of the most versatile instruments available for the examination and analysis of the microstructure characteristics of solid objects. The primary reason for the SEM's usefulness is the high resolution which can be obtained when bulk objects are examined." Gibson (1985) states: "A growing number of research and development laboratories use electron microscopes for diagnostics and failure analysis."

The literature review shows that the electron microscope is a crucial device to researchers in the diagnostic and analysis of their research. The techniques for measuring the width or length of specimens is an important feature to the device's operations. This was brought out by Yamaji, Miyoshi, Kano, and Okumora (1985, P. 97) who stated that: "Since the pattern line width becomes smaller and smaller, even a small change in pattern line width gives rise to remarkable changes in the device characteristics. Therefore, it is extremely important to measure the pattern size with high accuracy and reliability."

Substructure Topology

Not only does the SEM gives you very fine accounts of width, length, and some depth, but it also allows the researcher to study topology, topography, morphology, and crystallography of surfaces and sub-surfaces. In 1985, Sasov stated that: "The main aim of an overwhelming majority of microstructure investigations is the study of the inner structure of objects. Data on the inner structure of a sample can be obtained as a shadow image from transmitted and low-attenuated radiation. Shadow images correspond to the non-destructive structure and this determines their value for the investigators. Full 3-Dimensional reconstruction of micro-objects in millimeter and micron ranges are necessary in defectoscopy, material science as well as in biology, geology, physics, chemistry, medicine, etc. In all cases computerized microtomography in SEM obtains unique data, which cannot be obtained by any other method of investigation (P. 1109-10)."

Scientists have the ability with the aid of the SEM to open doors which they though were impossible to have opened. The researcher can now understand how many scientists felt when they finished a project, only to find that they had a different perspective when they examined the results on the SEM micrographs. When the readings and research on fiber optics was concluded, and the results were seen on the SEM, the researcher's conclusions were tarnished by the reality of the SEM micrographs. These pictures brought reality where there was only imagination.

The SEM is an advanced tool introduced into the field of technology and science; whose potentials include micro-research from the studies of cell biology to fiber optics. Although, one of the major setbacks of the SEM is that questions raised will outnumber the answers for a number of years.

The literature used for this study shows that the electron microscope is a major breakthrough in the science field, and crosses over into many other fields. One such field is communications. With the use of the electron microscope and artificial intelligence, the human mind is the only barrier.

The four specimens were examined to determine whether glass or crystals could work for light transmission and/or reception devices in communications.

Seippel (1981, P. 14) states: "Fiber optics is the science that deals with the transmission of light through extremely thin fibers of glass, plastic, or other transparent material. Optical fibers are dielectric waveguides for electromagnetic energy at optical wavelengths. The fibers provide a path for a single beam of light or in multiples, such as the transposition of a complete image. These fibers are provided as a single fiber or cable bundle. They may be bent or curved (within limits) to meet the needs of special routing." Sterling (1987, P. 2) states: "Fiber optics is simply a method of carrying information from one point to another by a thin strand of glass or plastic that serves as a transmission medium."

CHAPTER 3

METHODOLOGY

The literature survey for this research study was conducted using available resources at the Wagner Resource Center of the Industrial Technology Center, and the Universtiy of Northern Iowa Library. The scanning electron microscope(SEM), located in McCollum Science Hall, was also used to investigate the microstructure of the research materials; bottle glass, window glass, fiber glass, and quartz. This study will examine both specimens for their likeness and differences. The comparison between crystal and amorphous structures of materials uses in this study was done according to the standards of crystallography and crystal chemistry (Bloss, 1971).

Such analysis comprises the following steps:

1. Determining the crystallography background materials of selected samples.
   a. Determine chemical background.
   b. Look for lattice structures.
   c. Determine if the specimen is usable for fiber optics.
2. Preparing the specimens for examination.
   a. Select specimens and mount in bakalite.
   b. Clean and polish the specimens.

c. Etch the specimens with HF acid, and then coat with gold.

d. Examination and analysis of the specimens structural features using the SEM.

e. Micrograph the structures of the specimen for permanent record keeping.

f. Analyze all evidence, formulate conclusions, and report data and conclusions.

Data Collection

The laboratory data collected for this study was from the scanning electron microscope (SEM) technique. The specimens were put in the microscope and their structure displayed on the CRT screen by electrons beaming directly from the Cathode Ray Tube. When the specimen was positioned in a place of interest, and its structure revealed, there was a micrograph taken. There was only one session, and eight micrographs were taken. The micrographs were completed on the first exposure.

The micrographs are labeled and have a bar scale on them for specific magnification measurements. These micrographs were used to help determine how glass can transfer information by the use of light.

Visual inspection of each micrograph was used to confirm the findings of the literature researched.

CHAPTER 4

BACKGROUND STUDY OF QUARTZ

Quartz is a crystal structure which is made up of Silica (SiO_2). This is the second most utilized raw material of Silica after clay (Jones,1978, P. 18). The reason quartz was studied as a possible fiber light transmitter is because glass also has a chemical composition of Silica, and a small percent of ground quartz is used to make the glass. The difference between quartz and glass is the structure makeup which indicates that quartz is crystalline and glass is non-crystalline.

This paper investigates the reasons that quartz or any other crystal material cannot be used as successful light transmitting fiber optic material. Successful investigation depends upon there understanding of Glide planes, Miller indices, Space Groups, and Point Groups (See Definitions).

Quartz exists in two forms; high and low quartz, which is determined by temperature. Quartz is also right handed or left handed, determining the direction of twist (figure, 2) and enantiomorphous form (mirror image).

When the temperature is above 573 degrees Celsius the quartz point group is 62-, and when the temperature is below 573 degrees Celsius the point group is 32-(Smith, 1982, P. 222). When quartz drops from high quartz to low quartz the point symmetry goes from 6-fold to 3-fold. The point group of low quartz is a subgroup of high quartz (Smith, 1982, P.35) (Figure 3).

What is meant by left-handed and right-handed inversions is that the space groups twist left or right and no chemical bonds are broken. A left-handed space group is $P6_422$, and a right-handed space group is $P6_222$ as shown in figures 4 (A & B), (Bloss, 1971, P. 318-9). The P represents a Primitive Hexagonal Lattice. This crystal lattice emphasizes the elements of point group 622 which occurs through each point of the PHL indefinitely; throughout the structure. The subgroups 4 & 2 indicates height above the hexagonal lattice base plane in angstroms. High quartz has a frame work of corners shared by SiO_4 tetrahedra which twists to an SiO_2 structure during low quartz inversion. Low quartz has a space group of $P3_121$ (left-handed) and $P3_221$ (right-handed). This P represents a Primitive Triagonal Lattice structure. The point group 321 has an array through each point of the PTL, which occurs indefinitely through the structure. The subgroup 1 & 2 indicates height above the triagonal lattice base plane in angstroms. This is shown by the optical rotation of the crystal structure.

When quartz is melted at very high temperatures it will cool and solidify. All quartz will be known as high quartz at this state, but as it cools some will stay as high quartz through rapid cooling while other slower cooling material will become low quartz. These cooling changes bring about crystal changes which will react on the way light is reflected or refracted. The refractive index of quartz works like a prism, and spreads light out into its different color wavelengths. Using the reflective index equation N_1 Sin θ_1 = 1.46, and N_2 Sin θ_2 = 1, where 1 is the refractive index of water, and 1.46 is the refractive index of quartz. Solving this equation; 1.46 Sin θ = 1, and the arcsin O = 1/1.46 which equals 40.37 degrees. This is the maximum total internal reflection for quartz. The refractive index angle of quartz is greater than the refractive index angle of fiber glass. Quartz refracts light where fiber glass reflects light, this is the reason quartz cannot work as a fiber optic light transmitter.

Another reason is that when quartz is melted it doesn't always retain its original structure. If high quartz is melted down it could cool into low quartz. Also quartz is a brittle substance which fractures easily, so it would be hard to shape into thin strands. A significant characteristic of quartz is its high reflective index.

Figure 5 is a micrograph taken with the scanning electron microscope of a quartz crystal. The micrograph shows that light couldn't be transmitted through quartz because of the impurities located within the mineral. This micrograph also shows flux flow cooling done in layers. These layers seen in the photo cool according to the impurities within the mineral. Since different impurities cool faster then others, the micrograph reveals which strands cooled first. This cooling determines if the mineral will cool into high or low quartz. Figure 6 shows the crystalline structure 350 times magnification which would indicate massive particle interference of light. With the above information it can be concluded that quartz wouldn't work as a mineral that is efficient in the transmission of light.

GLASS

Glass structure, unlike quartz, is non-crystalline or known as amorphous which is formed by rapid cooling from the molten state or slow harding of gelationous material, and there is no cleavage (Berry, 1959, P. 180). The glass industry uses enormous quantities of Silica (SiO_2) in the form of glass sand resulting from the breakdown of sandstone (Jones, 1972, P. 18). The Silica is used to add strength and stability to the glass.

Most glasses are naturally transparent to light, which means they allow lightwaves to pass through almost freely. The liquid nature of glass when molten allows it to be formed into sheets, blown, forged or spun into fibers. Glass is much like other materials, yet it is unique. It can support a load, may be shaped, broken, or cut, yet when viewed with an electron microscope it looks more like a molten liquid than a solid as shown in figures 7 and 8 which shows phase separated region (non-crystalline) in nature. From the micrographs it can be seen that bottle glass and window glass have the same characteristics. These characteristics show no structure or form. The addition of different ingredients to glass can alter in shape, color, weight, or tensile strength (Considine, 1976, P. 1024).

With all the techniques available for glass forming, Corning Glass works estimates that there are over 750 different types of glass available, and are used in over 50,000 different ways (Gregor, 1976, P. 87).

There are six main different types of glass that are of wide industrial use: Soda-lime, Lead-alkali, Borosilicate, Aluminosilicate, 96% Silica, and Fused-silica (Gregor, 1976, P. 87).

Fiber Optic glass is made up of fused-silica glass. This is made into thin fibers by melting down the glass and then forcing it through small holes by pressure and drawing. This is done under very high temperatures while still in a molten state, and with very little moisture present. Corning has found out that when the water molecules (H_2O) are not present the glass is smoother and clearer (Gregor, 1976, P. 91-3).

CHAPTER 5

Fiber Optics

Fiber optic glass is one of the greatest breakthroughs in the history of communication. Messages can be transmitted through these fiber cables by the use of light photons. The fiber glass cables consist of a glass fiber, a light guide or cladding, twisted copper wire, ploypropylene binder, corrugated bronze shield, rip cord, and a protective jacket (polyuinyl choride) as shown in figure 9. The reason for the twisted copper strands around the fiber glass is to protect the fibers. These cables must endure hardships such as: extreme cold or heat, ice, high winds, and rodents which chew on the cables. One band or cable of fiber glass can consist of thousand of fiber transmitting and receiving systems as shown in figure 10. This microphoto shows the researcher a 35 strand fiber glass cable surface taken with the SEM at 150um using 15 kv.

Figure 11 is a close up of the fiber cable showing how thin the glass strands are, and figure 12 shows a vertical view of the glass fibers imbedded in the cladding material. From this view the sub-surface layers of the cable can be seen. These micrographs show the researcher the makeup of the fiber optic core structure in specific detail.

The index of refraction of glass is 1.5 with light velocity at 200,000 km/s, but what is of particular importance to fiber optics is that the index of refraction of glass can be changed by controlling its composition (Sterling, 1987, P. 40). The angle of incidence must equal the angle of reflection, yet must be greater than the critical angle for light to be reflected. Using Snell's law; $n_1 \sin \theta_1 = n_2 \sin \theta_2$, shows the relationship between the angles of the incident and refracted rays. An example of this, assuming that there are two layers of glass (fiber core and cladding), is $n_1 = 1.46$ (cladding) and $n_2 = 1.48$ (core). Using Snell's law, $\theta_c = \arcsin(1.46/1.48) = \arcsin(0.9864) = 80.6$ degrees, this is the angle of total reflection we would get as light zigzags down the fiber glass as shown in figure 13 (A & B) (Sterling, 1987, P. 40).

A human hair has a size of about 100um, where fiber sizes are expressed by giving the core size followed by the cladding size 50/125, this means 50um core diameter followed by 125um cladding diameter (Sterling, 1987, P. 48). From the above data, the fiber is shown to be half the size of a human hair.

Fiber optics are classified in two ways: by there material makeup, and by their refractive index of the core and the way the fibers propagates (Sterling, 1987, P. 48). The material makeup is ultra-transparent silicon dioxide with a small percent of fused quartz. If sea water were as clear as a fiber, one could see to the bottom of the deepest ocean trench, the 32,177 feet deep Mariana Trench in the pacific.

Impurities are added on purpose to increase or decrease the refractive index of glass, Germanium or Phosphorous increase the index, while Boron or Fluorine decrease the index.

The refractive index of the core shows differences in fiber classification:

1. When the height of the pulse is decreased there will be a loss of signal power, because the input pulse injected into a fiber will not be as strong as the output pulse emerging from the fiber.

2. By the path followed by light rays as they travel down the fiber.

3. By the relative index of the refraction of the core and cladding for each type of fiber.

How Fiber Glass is Produced

Optical fibers are manufactured in clean rooms. The air in these rooms is filtered to keep out the tiniest particles of dust. Even the smallest specks of dirt could harm the fiber as it is made. Figure 14 is a close-up showing the researcher the susceptibility of transparent fiber glass in regard to dust.

Workers in these areas wear clothing made of lint free fabric (Billings, 1986, P. 36). An optical fiber starts out as a hollow glass tube. The tube is mounted on a machine that rotates it, and a special gas is fed into the tube. Then a torch moves back and forth along the tube heating it to 1600 degrees Celsius. With each pass of the torch some of the hot gas inside forms a fine layer of glass on the inner wall of the tube. A series of different gases can be fed into the tube, and several different kinds of glass are added to the inside wall using this method. When the addition of glass is complete, the gas remaining inside the tube is gently sucked out. Then the temperature is increased to 2000 degrees Celsius to cause the hollow tube to collapse into a solid gas rod called a perform. This perform is the size of a broomstick, and a yard long.

The perform is cooled and carefully inspected. Light from a laser is used to make sure the core and cladding of the glass perform is perfect. Then the perform is placed in a furnace where it is heated to 2200 degrees Celsius. At this temperature, the tip of the perform can be drawn or pulled like taffy into optical fiber thinner than human hair. As soon as it is drawn, the fiber passes through a tiny funnel where it is coated with fast drying plastic, this is for protection. A fiber may be drawn up to six miles long, and wound on a spool for easy handling and storage (Billings, 1986, P. 40-2).

Transmission of Information

Communication is the linking between two points and passage of information between them. This information is transferred in the form of a signal. This signal is transmitted with the help of electronics, and involves three activities: encoding, transmission, and decoding figure 15 (Sterling, 1987, P. 15). The fibers work in pairs, one strand is the signal sender, and the other strand is the signal receiver.

Encoding is the process of placing information on a carrier. A carrier is a signal with no information until it is modified into modulation. Once this is done the information can be transmitted. At the receiving end, the decoding device separates the information from the carrier.

How fiber optics works is an analog signal that is converted to a digital signal through an analog-digital converter. This is because receivers have no way of knowing what an analog signal looked like when it starts out, but digital signals have a defined shape due to a numbering system (0 & 1), so distortion can be reduced, and the signal can be put back to the same perfection as it was sent. The eight bit converted pulse of light is transmitted through the fiber, the receiver detects the digital code and changes it back to analog where it is rebuilt into an understandable transmission. In digital systems, the capacity of carrying signals is in bits per second known as baud rate.

Fiber optics can be used in almost any environment, because it is not interfered with by electricity, static electricity, pumps, motors, or other factors which effect electronic transmissions, and the reception is extremely clear.

Fiber Optics for Industrial Communications

Fiber optics communication is making its way into homes, business, and the industry. In 1987, long distance optical-fiber trunk circuits began a major breakthrough by replacing copper installation circuits. The application for fiber optics can be used in: space communications, public communication, defense, traffic systems, mining, manufacturing, medical treatment, sea, network and data communication. The list is endless.

Its not only the application, but also the function: no electromagnetic induction, no shorts or sparks, no cross talk, small transmitter/receiver, no radio wave interference, no electric conduction, light; thin; and easy-to-bend, water-fire-corrosion proof, easy to distribute, visible light transmission, and very easy to use (Sterling, 1987, P. 13).

Whether a person realizes it or not, fiber optics will affect everyone's life. In 1978, Vista-United Telecommunications at Walt Disney World near Orlando, Florida, was the first to use fiber optics commercially in the United States (Billings, 1986, P. 17-8). American telephone and telegraph has a service that connects Boston, New York City, Washington D.C., and Richmond, Va. The fiber trunk line is no bigger than a garden hose, and is spread out over 780 miles. This light cable carries eighty (80) thousand calls at once (Billings, 1986, P. 20).

TAT-1 is a transatlantic telephone cable laid between the United States and Europe. The cable was made of copper and completed in 1956, and carried fifty-one calls at a time. TAT-7 was completed in 1983, and can carry eight thousand calls at once. The first fiber optic cable TAT-8 will be finished by July 1988, and will be able to handle forty (40) thousand calls at one time. There is also a fiber cable called HAW-4/TPC-3, which is the first transpacific fiber optic cable between California, Japan, Hawaii, and Guam (Bell, 1988, P. 41-2). By the 1990's fiber optic cables will link most major countries through the world.

According to Bell (1988, P. 42) more than 20 companies from various countries can link an electronic mailbox which can store or forward text, data, graphics, even digitized voice between any kind of terminal, phone, computer, telex, facsimile for the party to collect whenever convenient.

In major industry research, development, and implementation, they are working in three areas: intelligent network, broadband fiber communications, and open network architecture. The reason for this push is that companies realize that without fiber optics uses they will fall behind in the 1990's.

Using Television communications to sell products will be a major part of consumer purchasing in the future, and manufacturers want to advance with the development of technology.

New technology of fiber optics has grown in the past decade, and in the next decade copper wire will be replaced with fiber glass. More communication will be done with the transmission of light then ever through possible. We are in the age of light as it has never been known before.

CHAPTER 6

CONCLUSION

The results of this study provided the data necessary to describe the capabilities of the SEM with regard to glass, quartz, and fiber glass micro-structures. The micrographs in this paper taken by the SEM show different surface structures. Examining these surface structures shows the difference between the specimens as to why or why not light can transmit through them. In addition, the SEM did show any contamination, fracture, scratches, breaks, or impurities, within the structures of these specimens.

Having this knowledge, scientist will be able to look at micro-structures to understand the functions or deficiencies of microscopic objects.

Summary

The results of the research with the SEM were excellent, because there was only one lab session, and the micrographs came out perfect. The micrograph's contrast, resolution, and depth of field was immaculate. The fiber and quartz specimens showed clear topology of where they were damaged due to polishing.

The importance of the use of the SEM was evident when looking at the specimen's micrograph. This instrument shows in micrographs what couldn't have been explained in words.

The precise preparation of the samples has a lot to do with the outcome of the experiment. The specimens must be properly placed in bakalite, polished six different times; each time with a different polishing material, and finer than the previous one. Then the specimens must be etched with a strong acid (HF), and finally the specimens must be coated with gold.

The fiber glass specimens' micrographs show that their structural arrangement allows the transmission of communication messages in the form of light pulses. The reason for this is because fiber glass has the highest clarity of any substance made by man. This paper has explained the many different ways how the advancement of technology will benefit the communications industry.

Discussion

The researcher's experience with the SEM has been very successful, as seen by the results of the micrographs. More research should be done with this device through the Industrial Technology Department. Using the electron microscope will improve a student's understanding of his research, because he can see the results, instead of accepting a theory. The Industrialized World will not wait for anyone, as Alfthan (1985, P. 517) states, "technological innovations are bound to have far-reaching repercussions not only on the number of jobs available on the labor market but also on the content and organization of work and hence on the skills, qualifications and attitudes required of the workforce."

Trained personnel on the SEM will have a marketable skill which industry will use. Alfthan (1985, P. 517) states that, "If workers are to reap their share of the benefits, however, they must be given the sort of training and education that will equip them to meet the challenge posed by these new work demands." And fields using the SEM will require these new work demands.

Fields which are starting to use the SEM are beginning to explore a whole new science era. Doors will open with the SEM which before was never thought possible. Not only will scientists be able to theorize, but now they will be able to confirm theories. Knowledge to operate the SEM could be obtained through course instruction added by the University of Northern Iowa's Industrial Technology department.

The only handicap the SEM has is the operators ignorance of using this device. Having a wonderful device such as an SEM and not using it is like not giving a student full opportunity for a complete education.

APPENDIX A

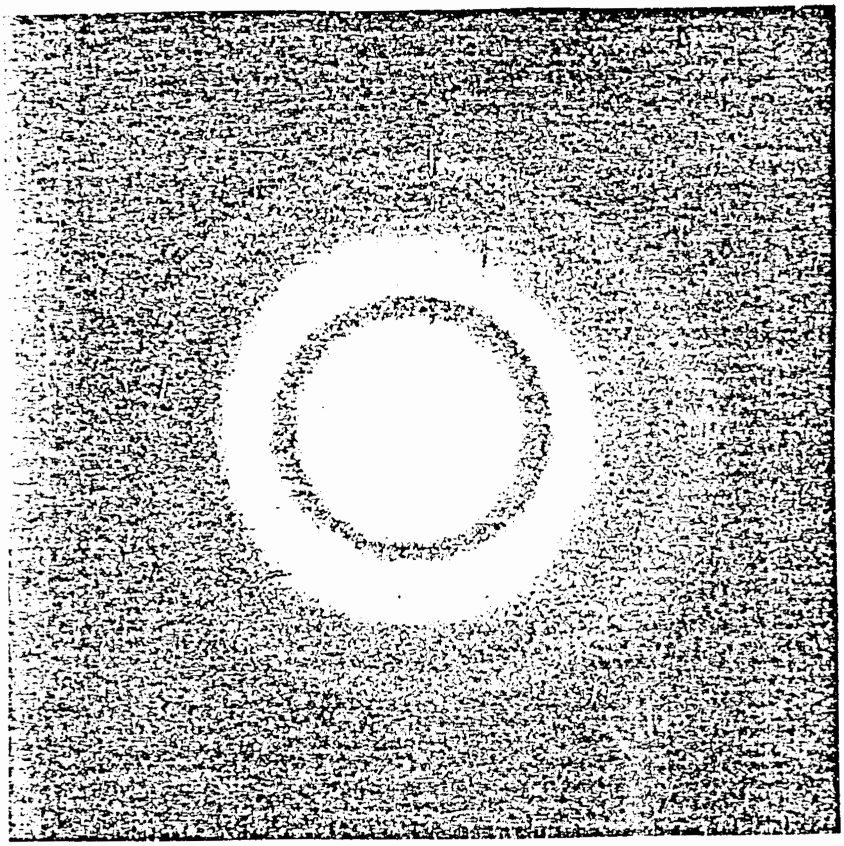


FIGURE 1 Electron diffraction pattern from a thin carbon film, showing the diffuse scattering around the bright center spot and no distinct diffraction maxima. (Glauert, 1979, P. 196).

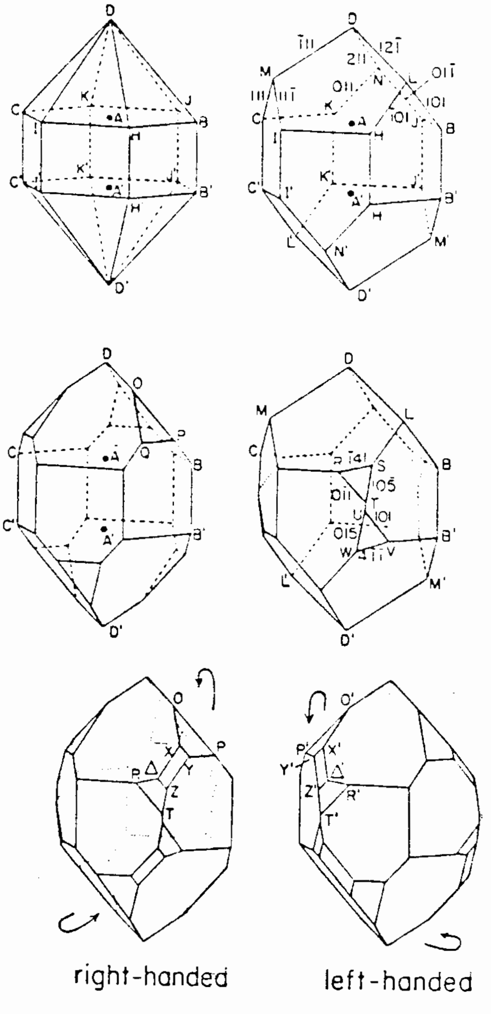


FIGURE 2 Stereograms of quartz crystals showing right and left handed twists. (Smith, 1982, P. 223).

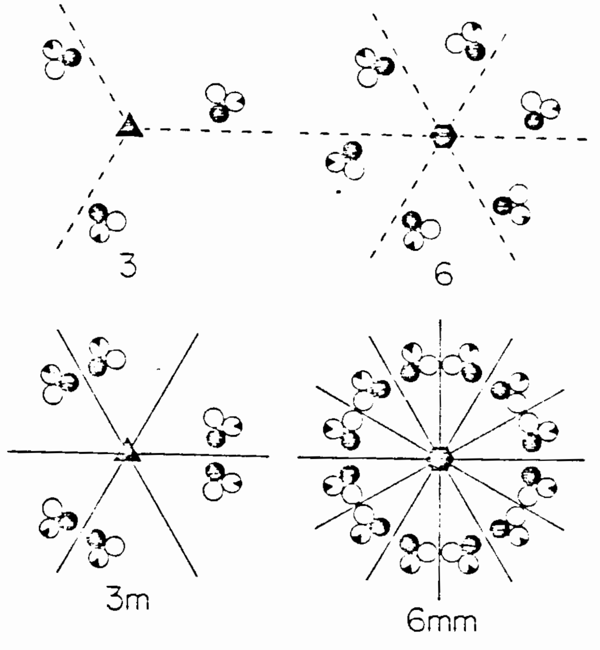


FIGURE 3 The types of crystallographic point symmetry in 2-D. Dashed lines are merely visual aids, while solid lines represent mirror symmetry. Low quartz (3M) is a subgroup of high quartz (6MM). (Smith, 1982, P. 34).

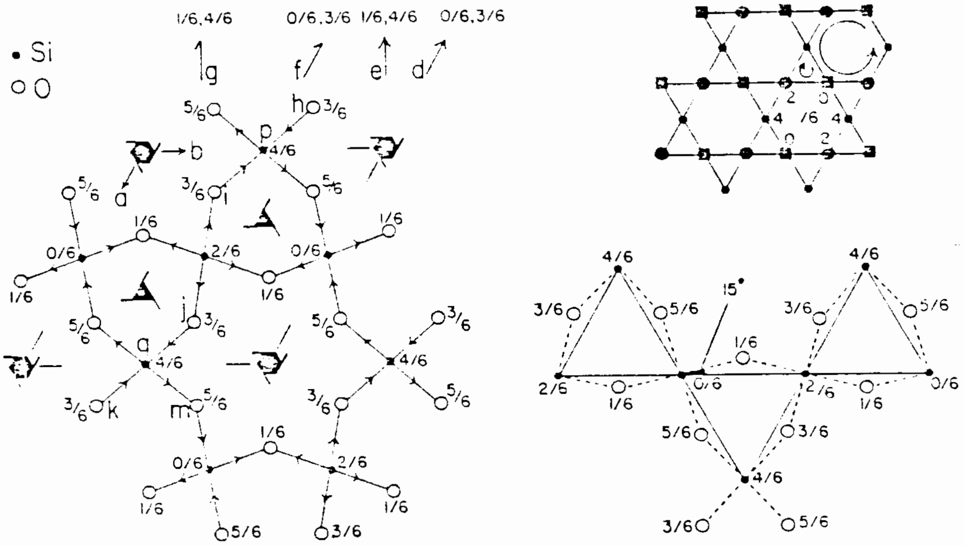


FIGURE 4A Crystal structure of high quartz (right handed). 6_2 axis of symmetry. (Smith, 1982, 263).

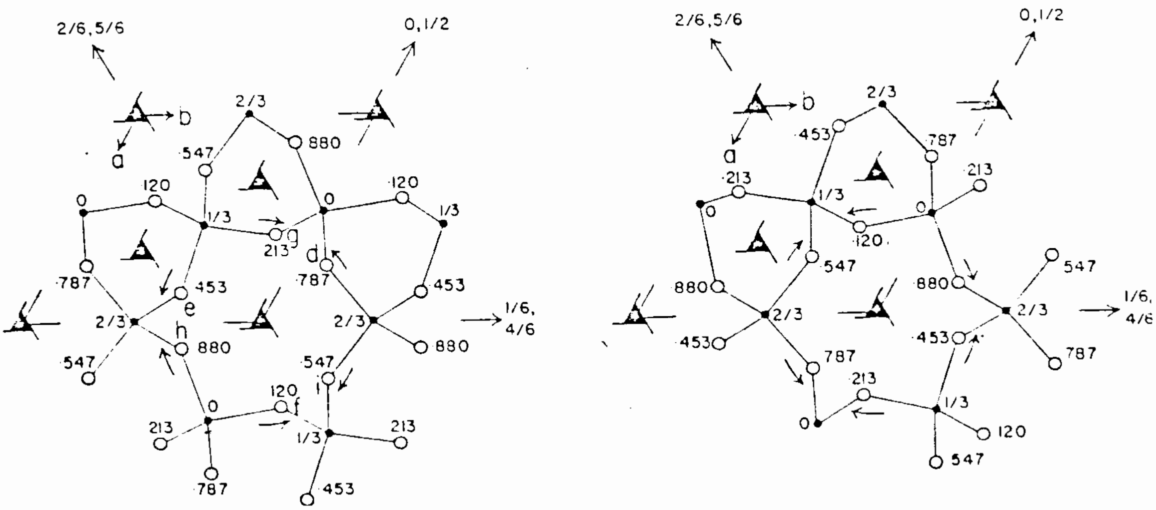


FIGURE 4B Crystal structure of low quartz (right handed). 3_2 axis of symmetry. (Smith, 1982, P. 265).

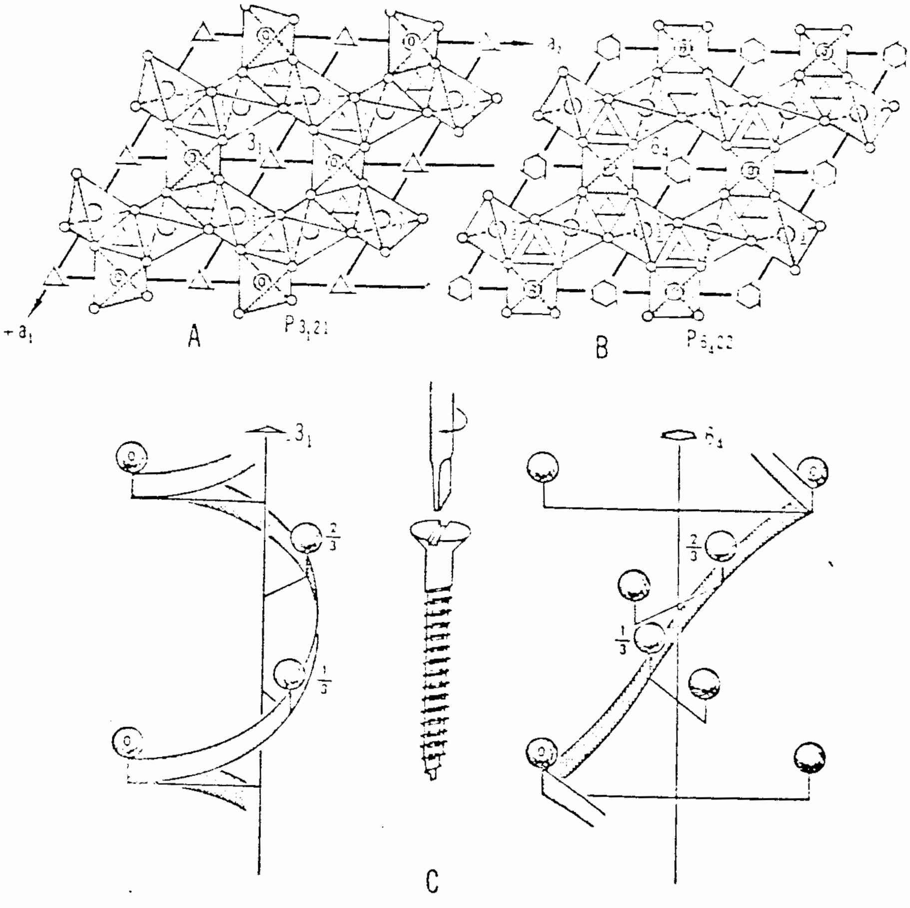


FIGURE 4C A. The structure of right-handed low quartz. B. The Structure when heated above 573 degrees celsius. C. This illustrates right and left handed quartz crystal rotations. (Bloss, 1971, P. 319).

FIGURE 5 SEM micrograph of Quartz surface showing stress fracture as viewed at 400X, magnification. Magnification bar is 75um.

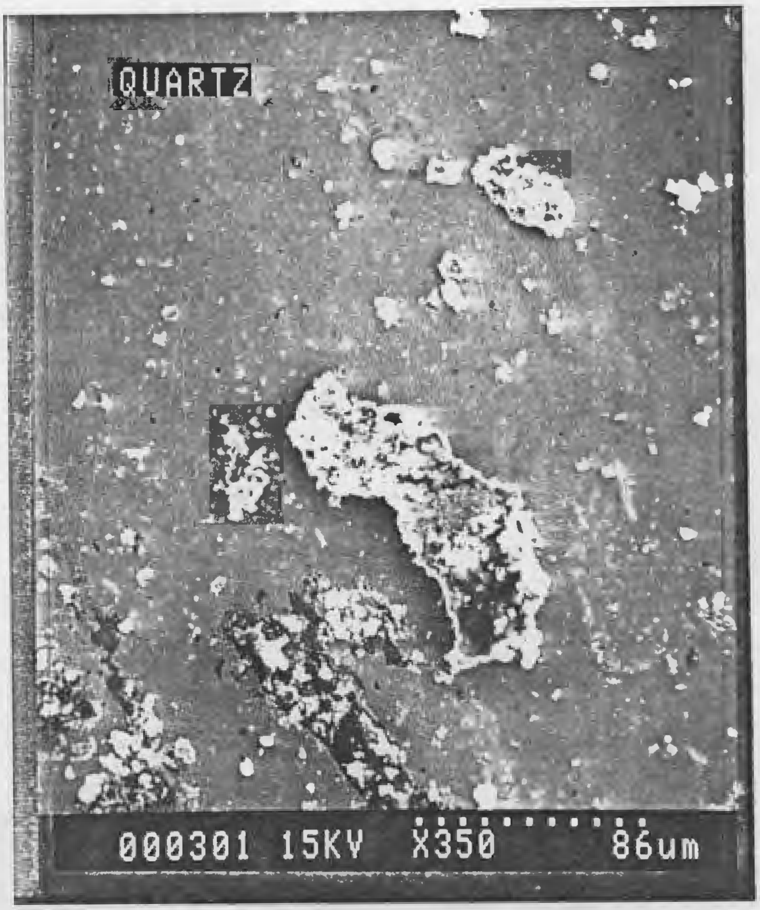


FIGURE 6 SEM micrograph of Quartz surface. Magnification used is 350X. Magnification bar is 86um.

FIGURE 7 Bottle glass surface as revealed by SEM. magnification used is 400X. Magnification bar is 75um.

FIGURE 8 Window glass surface structure. SEM Magnification 700X, magnification bar is 43um.

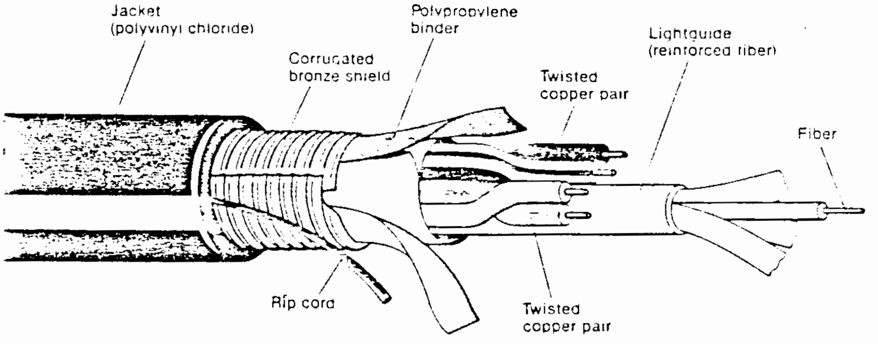


FIGURE 9 Fiber ready cable consists of fiber strands with protective coverings running parallel with twisted pairs of copper wire. The PVC jacket protects from fire and weather. The rip cord allows the wires and fiber to be exposed easily for connection. The corrugated bronze shield provides structural support. (Bell, 1988, P. 42).

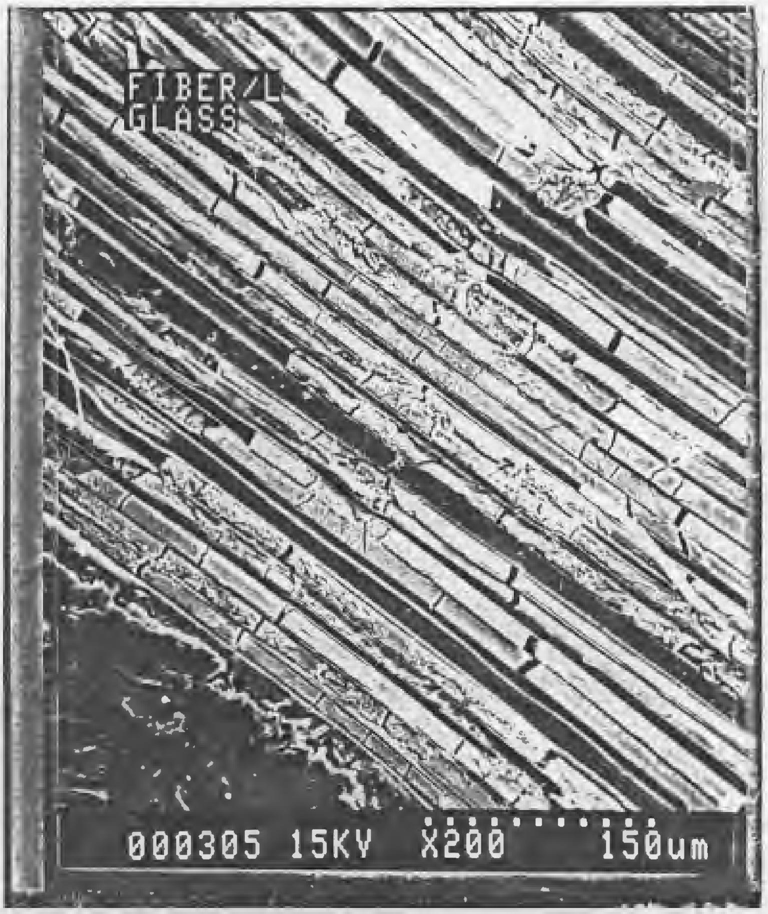


FIGURE 10 SEM micrograph of fiber glass (lengthwise). Magnification is at 200X, magnification bar 150um.

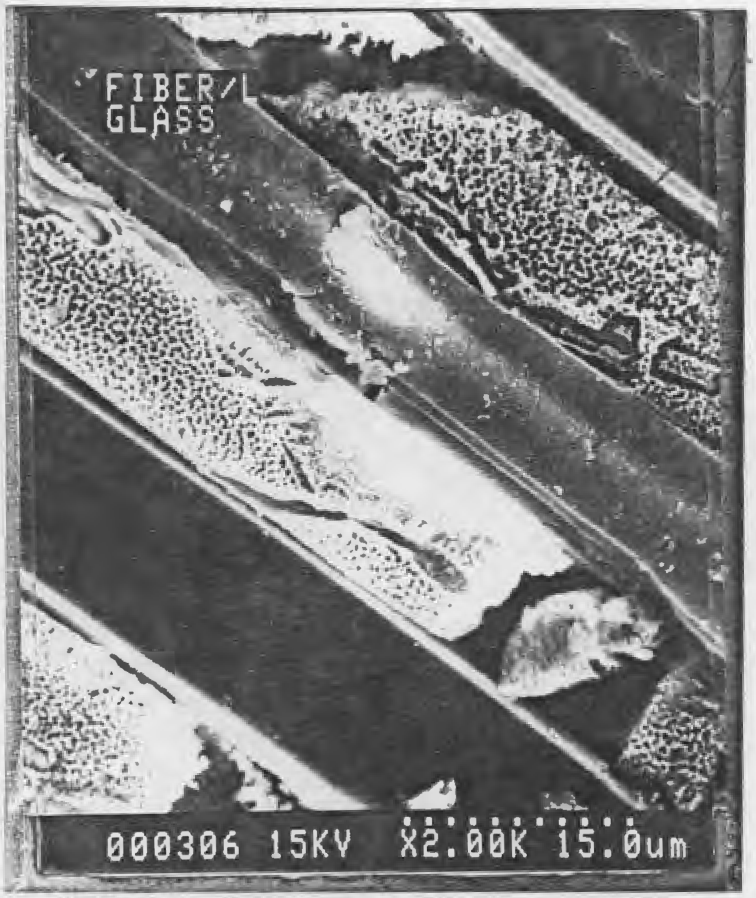
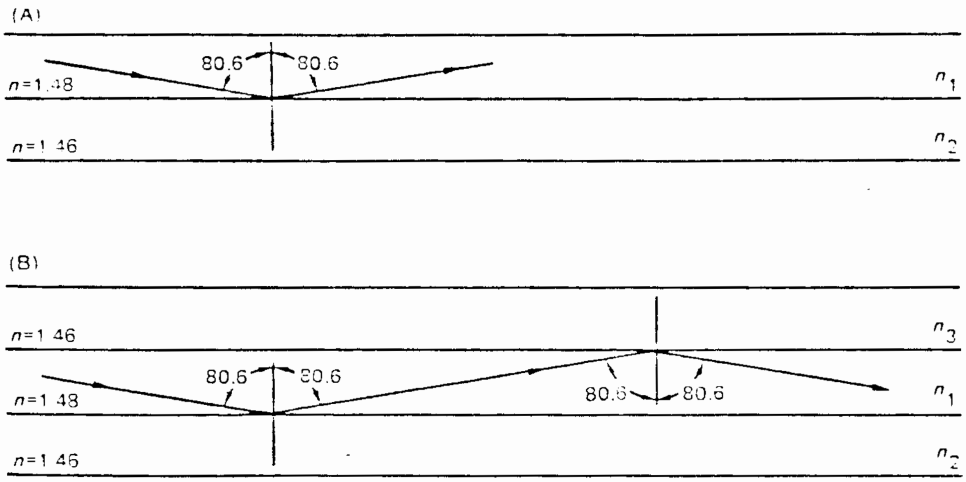
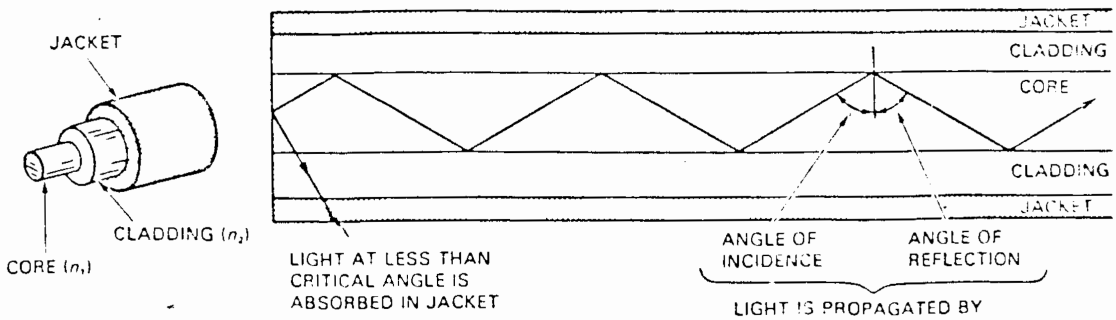


FIGURE 11 Fiber glass microstructure (lengthwise). Magnification is at 2000X, magnification bar 15um.

FIGURE 12 SEM micrograph of fiber glass (vertical) viewed at a magnification of 550X, magnification bar 55um.



<u>FIGURE</u> 13A Practical example of refraction, and total reflection in muli-media with different index of refractions. (Sterling, 1987, P. 43).



<u>FIGURE</u> 13B Total internal reflection in an optical fiber. (Sterling, 1987, P. 47).

FIGURE 14 SEM micrograph of a fiber glass strand. After the material fractured, as shown. Magnification is at 4000X, magnification bar 7.5um.

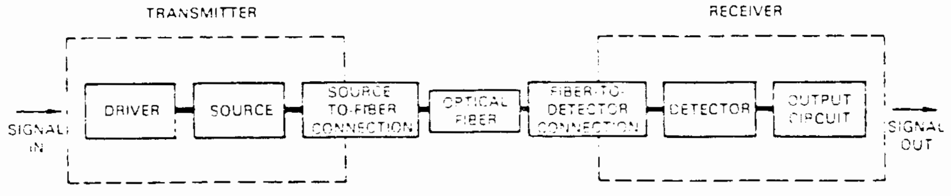


FIGURE 15 Basic fiber optic link.
(Sterling, 1987, P. 2).

REFERENCES

1. Alfthan, T. (1985). Developing skills for technological change. International Labour Review. Vol. 124 No. 5, P. 517-29.

2. Bass, A.B. (1984). The microscopic world in living detail. Technology Review, Vol. 87 No. 7, P. 66-71.

3. Bell, Turdy E. (1988). Communications. IEEE Spectrum, Vol. 25 No. 1, P. 41-3.

4. Berry, L.G., (1959). Mineralogy., W.H. Freeman and Co. San Francisco and London.

5. Billings, Charlene W., (1986). Fiber Optics., Dodd, Mead, and Co. New York.

6. Bloss, Donald F., (1971). Crystallography and crystal chemistry. Holt, Renehart, and Winston, Inc. New York.

7. Considine, Douglas M. (Edit by) (1976). Van Dostrand's Scientific Encyclopedia, fifth edition. Van Nostrand Reinhold Co. and Inc.

8. Denney, R.C. & Foster, Stephen (Edit by) (1984). Barnes & Noble Thesaurus of Physics. Harper & Row, Publishers.

9. Gibson, J.M. (1985). Tools for probing the 'atomic' action. IEEE Spectrum, Vol. 22 No. 12, P. 38-44.

10. Glauert, Audrey M. (1979). Practical Methods in Electron Microscopy: Volume One. North-Holland, Inc.

11. Gregor, T.G. (1976). Manufacturing Processes: Ceramics. Prentice-Hall, Inc.

12. Goldstein, J.I., & Yakowitz, H. (1975). Practical Scanning Electron Microscopy. New York: Plenum Press.

13. Jones, J.T. & Berard, M.F. (1972). Ceramics. Iowa State University Press.

14. Newbury, D.E., Joy, D.C., Echlin, P., Fiori, C.E., & Goldstein, J.I. (1986). Advanced scanning electron microscopy and x-ray microanalysis. New York: Plenum Press.

15. Sasov, A.Y. (1985). Computerized microtomography in scanning electron microscopy. Scanning Electron Microscopy, Vol 3, P. 1109-20.

16. Seippel, Robert G. (1981). Optoelectronics. Reston Pub. Co.

17. Smith, Joseph V. (1982). Geometrical and Structural Crystallography., John Wiley & Sons, New York.

18. Sterling, Donald J. (1987). Technician's Guide to Fiber optics. Delmar Publishers Inc.

19. Von Heimendahl, M. (1980). Electron Microscopy of Materials: An Introduction. New York: Academic Press.

20. Yamaji, H., Miyoshi, M., Kano, M. & Okumura, K. (1985). High accuracy and automatic measurement of the pattern linewidth on very large scale integrated circuits. Scanning Electron microscopy. Vol. 1, P. 97-102.