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RESULTADOS DE INVESTIGACIONES REALIZADA EN LOS CURSOS FISI 4161-64
STUDY OF LASER MILLING OF SINTERED LTCC, QUARTZ, AND PYREX SUBSTRATES FOR MESO AND MICRO FLUIDIC APPLICATIONS

Jose Manuel Castillo Colon
Mentors: Rogerio Furlan, Idalia Ramos, and Jorge J. Santiago-Aviles

This work addresses the fabrication of channels and cavities in sintered LTCC, quartz and Pyrex 7740 substrates using laser milling. An automated laser system (Universal Laser Systems, 60 W CO₂ pulsed laser, wave length of 10.6 µm, focal point diameter of ~ 130 µm) was used in the raster or vector mode. This represents a fast processes to define meso structures in tens of seconds with depths of up to 150 µm. For example, for a laser power of 75% and speed of 15% the cavity depths obtained with profilometry are: 46 µm for LTCC, 80 µm for quartz and 95 µm for Pyrex 7740. Microchannels were obtained for operation in the vector mode with widths in the range between 200 µm and 300 µm. Defects (cracks), caused by thermal stress were observed for the three types of substrates. In the case of the sintered LTCC samples the laser machining caused chemical changes, as the color of the surface changed from blue to black. The edges of the microchannels defined in sintered LTCC presented fewer defects compared to the two other materials. Also, the use of conditions that open completely the sintered LTCC layer on the region of the microchannel revealed that some parts of the microchannel present residual material on the bottom.

This work has been supported by the National Science Foundation, grant No. NSF-DMR-0353730.

SEALING AND TESTS OF MESO AND MICRO FLUIDIC OSCILLATORS IMPLEMENTED IN TRANSPARENT SUBSTRATES

Josean Paulino Sustache
Mentors: Rogerio Furlan, Idalia Ramos, and Jorge J. Santiago-Aviles

In this project we are investigating the sealing and performance of meso and micro fluidic oscillators fabricated in transparent substrates. Fluidic oscillators are devices formed with microchannels that can be used as sensors and actuators. These fluidic oscillator structures were defined directly on acrylic using a CNC equipment (meso dimensions), on quartz using thermal laser milling (meso dimensions) or in thick photoresist (SU-8) applied on quartz substrates (micro dimensions). Sealing with a thermal adhesive (Monokote) was verified to be effective (105 °C, ~ 2 minutes). Sealing tests were performed injecting different types of liquids. Tests with devices implemented in acrylic showed that liquid (water) was seen returning throughout the feedback arms of the device, a requirement for the occurrence of oscillation. Also, we observed the formation of vortices indicating that this can be a promising mixer structure. Pressure sensors are being integrated in the device in order to measure the oscillation frequency.

This work has been supported by the National Science Foundation, grant No. NSF-DMR-0353730.
The problem we are addressing is the fabrication of a gas fuel meso combustor for a compact and portable electric power generator using thermoelectric elements. A device of this type has the potential to replace batteries in portable applications that require long-term power. The possible benefits of these devices include their ability to provide greater energy and power density, higher temperatures and greater efficiency as a heat source. We proposed a fabrication sequence using Low Temperature Co-Fired Ceramics (LTCC) and graphite as structural and sacrificial materials, respectively. The cavity that defines the combustor was opened in LTCC layers by cutting around the edges with laser milling (Universal Laser Systems, 60 W CO$_2$ pulsed laser).

Several of these LTCC layers were piled up around the sacrificial layer that has the geometry of the combustor defined by CNC drilling. Several layers of LTCC were placed on top and on the bottom to seal the structure. After annealing at 850 °C for 4 hours the graphite was removed and the LTCC was sintered forming a rigid structure without collapsing of the walls. Tests with water injected through holes opened on the sealing layer revealed that the carbon was burned.

This work has been supported by the National Science Foundation, grant No. NSF-DMR-0353730

Microfluidic oscillator structures were defined with laser milling in substrates of Pyrex 7740. We used an X-660 Laser Platform (Universal Laser Systems, 60 W CO$_2$ laser, wave length of 10.6 µm) operating in the raster mode. Different laser energies and scanning velocities were used for comparison. Cracks and imperfections were induced inside the microchannels and microcavities, that compose the microfluidic oscillators, due to thermal stress. In order to investigate the possibility of elimination/minimization of these defects we annealed the Pyrex substrates at temperatures from 500 °C to 1000 °C. These temperatures are higher than that of the annealing point, 560 °C, according to specifications of the fabricant.

For this purpose we used a resistive furnace equipped with a Sentry 2.0 Digital Temperature Controller made by Paragon Industries Inc. Before and after annealing the substrates were analyzed with an optical microscope (Nikon, Eclipse, ME600). Pyrex 7740 is a promising substrate for application in the fabrication of microfluidic structures due to its compatibility with silicon substrates and possibility of sealing with anodic bonding. We observed that using successive annealing at the defined temperatures the small cracks were successfully eliminated and no deformation of the substrate caused by thermal stress was observed.
SnO$_2$ fibers were synthesized using electrospinning followed by subsequent heat treatment at 600°C. Previous research results showed that tin oxide nanofibers in the rutile structure are obtained with this technique. In the current research, the conductivity of a single fiber was measured at temperatures between 2 and 15K with a transverse magnetic field varying continuously between -9T and 9T. The measurements were done using a Quantum Model 600 Physical Properties Measurement System with a Keithley 237 High Voltage Source. The values were used to calculate the magnetoresistance, mobility and carrier concentration of the fiber. The results show small magnetoresistance values with a maximum of 2.36% at T=15K and B=9T. The values obtained for the mobility are between 120 and 169 cm$^2$ V$^{-1}$S$^{-1}$ and approximately $10^{15}$ cm$^{-3}$ for the carrier concentration. The mobility and the carrier concentration results show that the tin oxide fiber is non-degenerate.

This work was presented at the NSF PREM Site Visit (October 21, 2005) and the Second PREM Annual Meeting (November 18, 2005). It has been submitted for presentation at NCUR 2006

Figure 1. Magnetoresistance curve of a tin oxide fiber at 4 K.

Figure 2. Resistance at low temperature of a tin oxide fiber.
ELECTRICAL CHARACTERIZATION OF ELECTROSPUN ANTIMONY DOPED SNO2 NANOFIBERS

Neliza León

Mentors: Idalia Ramos, Nicholas Pinto, and Jorge J. Santiago-Avilés

Transparent and conducting tin oxide fibers are of considerable interest for solar-energy conversion, sensors and in various electrode applications. Appropriate doping can further enhance the conductivity of the fibers. The reason for the enhancement in conductivity is that the suitable dopant atoms introduce more free carriers. Tin oxide (SnO2) micro/nano-fibers were synthesized using electrospinning. Fibers were electrospun from a previously used precursor solution (a mixture of pure SnO₂ sol made from SnCl₄ : H₂O : C₃H₇OH : 2-C₃H₇OH at a molar ratio of 1:9:9:6, and a viscous solution made from poly(ethylene oxide) (PEO) (molecular weight 900,000) and chloroform CHCl₃ at a ratio of 200 mg PEO/10 mL CHCl₃ , and a dopant solution of antimony trichloride (SbCl₃) and isopropanol (2-C₃H₇OH) at a ratio of 2.2812 g SbCl₃/10 ml 2-C₃H₇OH. The percent of Sb in the precursor solution was 1.5 %. After deposition, the fibers were sintered at 400, 500, 600, 700 and 800 °C in air for two hours. Scanning electron microscopy (SEM), atomic force microscopy (AFM), profilometry and energy dispersive spectroscopy x-ray (EDAX) were used to characterize the size, morphology and composition of the sintered fibers. The results show that smooth and continuous micro/nanofibers can be obtained using this method. The electrical conductivity of single fibers measured at room temperature increases by up to three orders of magnitude when compared to undoped fibers. DC conductivity measurements over a temperature range from 300 K to 20 K suggest that the dominant conduction mechanism is three-dimensional variable-range hopping.

This work was presented at the NSF PREM Site Visit (October 21, 2005) and the Second PREM Annual Meeting (November 18, 2005). It has been submitted for presentation at NCUR 2006.
UV PHOTOCONDUCTION PROPERTIES OF TIN OXIDE (SNO2) NANOFIBERS

Glendalys Figueroa Freytes

Mentors: Idalia Ramos, Nicholas Pinto, and Jorge Santiago-Avilés

The study of tin oxide (SnO2) nanofibers is important for applications such as nanoelectronic devices and gas sensors. Tin Oxide (SnO2) fibers with diameters ranging from 60nm to several microns were synthesized using electrospinning. A SnO2 nanofiber field effect transistor was made by first depositing a single nanofiber onto a Si/SiO2 substrate. The fiber was sintered at 700°C for two hours. Electric contacts were made by evaporating silver over a metallic grid. I-V measurements were done by applying a bias to the drain electrode and using the Si substrate as a back gate at room temperature and in air. The I-V measurements where done using a Semiconductor Characterization System (Keithley 4200). Photoconduction properties of a single tin oxide nanofiber were studied using a UV lamp of 254nm and 365nm in wavelength. A small field effect was observed when a gate voltage was applied to SnO2 nanofiber. An increment in the SnO2 nanofiber current upon exposure to 254 and 365 nm UV illumination was observed. At VDS=8V the conductivity of the fiber is 0.40 S without UV, 4.18 S for 254 nm UV and 43.2 S for 365 nm.

This work was presented at the NSF PREM Site Visit (Oct 21, 2005) and the 2nd PREM Annual Meeting (Nov 18, 2005). It has been submitted for presentation at NCUR 2006.

Figure 1. A substantial increase in conductance upon exposure to UV light and with the increment in wavelength is shown.

Figure 2. Photoresponse of the SnO2 nanofiber to sequential UV illumination at wavelengths of 254 nm and 365 nm with VDS=1V and VG=-10V.
THE IONIZED GAS OF THE NEARBY STRUCTURE W80

N. Santiago Figueroa, Shalane Figueroa Vélez, and P. Baez,  
Mentors Juan C. Cersosimo and Rafael J. Muller (UPRH)  
J. C. Testori (Instituto Argentino de Radioastronomía, CONICET, Argentina)

The continuum emission of the galactic region located at G85-0.5 is well defined by the weak 11 cm emission (see figure 1). Extended 3 degree in diameter, the region is catalogued as W80. The optical image is composed of the North America and the Pelican Nebulae complex (see figure 2). In this work we show the results of the study obtained from the radiorecombination line observations made with single dish at a frequency near of 1.4 GHz. These observations are sensitive to ELDWIM and we investigate its distribution and the physical parameters of the component of the interstellar medium in the direction of W80. The results obtained suggest that the low density ionized gas is extended about 3000 pc along the line of sight. We identify four structures shown in figure 2; the distance and physical parameters obtained for the different structures are explained in table 1.

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</table>

Acknowledgment: This research was supported by NASA Training Grant NNG05GG78H (PR Space Grant) and NASA Cooperative Agreement NCC5-595 (PR NASA EPSCoR)
DUAL INPUT AND GATE FABRICATED USING A SINGLE CHANNEL A–SEXITHIOPHENE THIN FILM FIELD EFFECT TRANSISTOR

Rut Rivera - Petra Mercado High School, Humacao, PR 00791
Rosana González
Mentor: Nicholas J. Pinto

We have used a split gate field effect transistor configuration to construct a dual input logic AND gate. The device in this configuration consists of a source, a drain and two gate terminals that are positioned between the source and the drain terminals and why lie under the insulating dielectric layer. The active semiconductor used in this device was a-sexithiophene. This is a commercially available organic semiconducting molecule and can be evaporated to form uniform thin films under reduced pressure. The transistor operation was controlled by applying either 0 or -10 V to each gate electrode. When -10 volts was simultaneously applied to both gates the device was conductive. Any other combination of gate voltages rendered the device resistive.

This shows that the device operates like a logic AND gate. The electric field charge mobility in this device was calculated to be $\sim 10^{-4} \text{ cm}^2/\text{V.s}$ and is partially attributed to the substrate topography which is not planar. The device ON/OFF ratio was ~5. These device parameters are expected to improve via the use of purified starting materials, pretreated substrates and a more planar channel topography. A significant advantage of this configuration is that AND logic devices with multiple inputs can be fabricated using a single -sexithiophene channel with multiple gates and which in turn will lead to the fabrication of more compact electronic circuitry at reduced cost.

SCHOTTKY EFFECTS IN DOPED CONDUCTING POLYMER THIN FILMS AND NANOFIBERS

Rosana González
Mentor: Nicholas J. Pinto

We present non-linear diode-like current voltage characteristics in thin films and nanofibers of polyaniline/polyethylene oxide. The substrates used in this work were doped Si/SiO$_2$ wafers over which gold electrodes were pre-patterned. Then the substrates were cut through the gold leads. This resulted in the gold leads being separated from the doped silicon via the oxide layer. Thin films or nanofibers were placed over the cut wafer making contacts to the gold leads on top of the wafer and to the doped silicon below the silicon dioxide layer.

Electrical measurements of gold lead/polymer/gold lead result in a linear current voltage characteristic curve similar to that of a resistor. However, electrical measurements of gold lead/polymer/doped silicon show a non-linear current voltage characteristic curve similar to two back to back diodes. This non-linear effect is much more evident in the case of nanofibers as compared with thin films. We believe that the non-linear behavior is an effect due to Shottky contacts between the metal and the polymer. The temperature dependence of this non-linear behavior will also be presented.
CONFINEMENT INDUCED INSULATOR-METAL TRANSITION IN DOPED POLYANILINE

Raúl Pérez, Neliza León,
Mentors: Idalia Ramos and Nicholas J. Pinto

Camphor sulfonic acid (CSA) doped polyaniline dissolved in m-cresol and also in chloroform (CHCl₃) was confined in dielectrically inert porous membranes with average pore diameters of 20 nm and electrically characterized as a function of temperature. The resistance of the confined polymer exhibits a weaker temperature dependence at low temperatures when compared to cast films. Confinement is seen to have a greater effect on the more disordered samples.

Reduced activation energy plots of the confined and cast films of the polymer show that confinement leads to a gradual cross-over in charge transport from insulating to metallic at low temperatures. Confinement induced suppression of phonons and suppression of microphase separation into the non-dopable forms of polyaniline along the polymer chain are proposed to be responsible for this transition.

DUAL INPUT AND GATE FABRICATED FROM A SINGLE CHANNEL POLY(3-HEXYLTHIOPHENE) THIN FILM FIELD EFFECT TRANSISTOR

Raúl Pérez
Mentor: Nicholas J. Pinto

A regio-regular poly(3-hexylthiophene) (RRP3HT) thin film transistor having a split-gate architecture has been fabricated on a doped silicon/silicon nitride substrate and characterized. This device demonstrates AND logic functionality. The device functionality was controlled by applying either 0 or -10 volts to each of the gate electrodes. When -10 volts was simultaneously applied to both gates, the device was conductive (ON), while any other combination of gate voltages rendered the device resistive (OFF).

The p-type carrier charge mobility was about 5x10⁻⁴ cm²/V·sec. The low mobility is attributed to the sharp contours of the RRP3HT film due to substrate non-planarity. A significant advantage of this architecture is that AND logic devices with multiple inputs can be fabricated using a single RRP3HT channel with multiple gates.
DIELECTRIC SPECTROSCOPY ON KDP TYPE SINGLE CRYSTALS

Jesús Castro

Mentor: Nicholas J. Pinto

This work was designed to study the dielectric properties of single crystals of Ammonium Dihydrogen Phosphate (ADP), Rubidium Dihydrogen Phosphate (RDP) and Potassium Dihydrogen Phosphate (KDP). The ADP crystals have a transition temperature of 136 K, the RDP crystals have a transition temperature of 146.8K and the KDP crystals a transition temperature of 100.3K. The transition temperature of the crystals measured was not the temperature expected perhaps because the samples were not pure. The slow evaporation method was used to grow the three different crystals in separate containers. The tetragonal symmetry found in those crystals is $a = b \neq c$, the $c$ is the ferroelectric axis in the RDP and KDP crystal, and the anti-ferroelectric axis in ADP. Each kind of crystals were cut in $a$ and $c$ direction and polished using water and a piece of filter paper. The surfaces of the crystals were painted with silver paint or evaporating the silver and an electrical connection were made with gold wires. Electrical measurements were made using a Hewlett-Packard Impedance Analyzer as a function of temperature.
MEASUREMENT OF SEPARATION/POSITION ANGLE OF SELECTED BINARY STARS

Desiree Cotto, Ileana Rosado De Jesús, D. Centeno, Valmin Miranda Sanfeliz, C. Martinez

Mentors: Rafael J. Muller, Juan C. Cersosimo

A precise, simple and straightforward method for measuring separation of binary stars—when using a CCD camera—allows us to corroborate the ephemerides posted in the Sixth Orbit Catalog of the USNO-Washington Double Star Catalog site. This simple procedure, which uses pixels for direct measurement of separation of binary stars, is also useful for astrometric measurements. The problem of measuring the position angle of binaries is also solved with a simple setup routine of the CCD. The data used for this research was obtained at the National Undergraduate Research Observatory (NURO) Telescope. NURO is a Consortium of Undergraduate Institutions with small observatories that have observing time at a research grade 31-inch Shmidt-Cassegrain telescope (Figure 1), located 20 minutes east of Flagstaff, Arizona, 7,200 feet above sea level at Anderson Mesa. This facility, owned by the Lowell Observatory allows us to gather data at a much faster pace than possible in our campus at sea level in Puerto Rico. The 31-inch is equipped with a Tektronix 512 X 512 CCD camera with cryogenic cooling to -110º C (a new camera was installed recently but our data was gathered using the 512 X 512.) ea level in Puerto Rico.

Although the data used is obtained in this telescope, the procedure described here can be used when any CCD camera is coupled to a telescope.
FABRICACIÓN Y CARACTERIZACIÓN DE NANOTUBOS POR EL MÉTODO CVD

Elixia M. Benson-Avillán, Ednaída I. Cintrón Sánchez
Mentor: Claudio Guerra-Vela, Nicholas Pinto,

En los últimos años se ha desarrollado la idea de crear nanotecnología con el propósito esencial de llevar la miniaturización de los componentes electrónicos integrados a niveles mayores. Uno de los elementos más prometedores en este proceso es el nanotubo de carbono cuyo diámetro es de unos 3nm. La posibilidad de desarrollar una tecnología con nanotubos parece ser real y promete transformar la vida de todos nosotros más allá de la electrónica. Como institución educativa de frontera el Departamento de Física de la UPRH ha desarrollado un proyecto de producción y caracterización de nanotubos de carbono por el método CVD (Chemical Vapor Deposition), en un esfuerzo por integrar a sus estudiantes en las corrientes de progreso científico más importantes en el mundo.

En esta presentación explicaremos el proyecto y mostraremos fotografías de los nanotubos producidos, así como los resultados de los procesos de caracterización hechos por nosotros. Patrocinado por NSF-NUE Integration of Nanoscience into the Undergraduate Curriculum: From Fabrication to Practical Aplication of Nanodevices Proposal#0407137). Para mayor información visite nuestra página http://cuhwww.upr.clu.edu/~nsfnue/.

ACEITE VEGETAL COMO COMBUSTIBLE SUSTITUTO DEL DIESEL

Iro García
Mentor: Abraham Ruiz

El aumento en los costos del petróleo ha hecho que se intensifique la búsqueda de fuentes renovables de combustible para los motores de combustión interna. El aceite vegetal que usamos para cocinar es una alternativa prometedora. Se puede usar aceite vegetal como combustible mediante dos maneras: 1) procesándolo químicamente para producir biodiesel, 2) o usarlo directamente sin procesar. En el primer caso el vehículo no necesita ningún cambio o alteraciones.

El biodiesel se hecha en el tanque y listo. Para hacer el biodiesel se requiere mezclar el aceite + alcohol (etanol o metanol) + hidróxido sódico (como agente catalítico) = > biodiesel + glicerina. La glicerina se va al fondo y se extrae el biodiesel. Si el aceite es usado el proceso es un poco más complicado. El futuro del biodiesel en Puerto Rico es incierto a menos que se industrialice la producción y se pueda comprar en estaciones de distribución.
ACEITE VEGETAL COMO COMBUSTIBLE SUSTITUTO DEL DIESEL

En cambio el uso directo de aceite vegetal como sustituto del diesel puede ser más atractivo. Las modificaciones requeridas al auto son pocas. Un tanque para el aceite y un sistema de calentamiento.

En Europa se usa el agua caliente del propio motor y/o una resistencia eléctrica. (Hay dispositivos comerciales para modificaciones profundas en el auto y poder usar aceite vegetal http://www.elsbett.com/). Es necesario calentar el aceite para reducir su viscosidad que es entre 11 y 16 veces mayor que la del diesel mineral. El motor se arranca con diesel y cuando el aceite alcanza los 80°C se cierra el diesel y se abre el aceite. En necesario apagar el motor con diesel por que si no se hela la grasa en los filtros y cilindros y al otro día el carro no prende. Esto es principalmente crítico en los países fríos.

Nuestro trabajo consistió en modificar un Mercedes 240D modelo 1982 para que funcione con aceite de freír usado directamente. Lo novedoso del proyecto es que el calentamiento del aceite lo hacemos con el tubo de escape. Simplemente llevamos la línea desde el tanque de aceite que está en el baúl hasta la bomba de inyección, pegada al tubo de escape con abrazaderas según se ve en la figura 1

Así aprovechamos el calor desechado por el motor para calentar el aceite. Hasta el momento hemos recorrido más de 400km recorridos usando aceite de freír usado únicamente. Excepto por el olor no se nota diferencia apreciable entre el funcionamiento con diesel o aceite. Sin embargo, el sistema de calentamiento es efectivo si el carro está en reposo. En movimiento, el aire enfria la línea y el aceite no sobrepasa los 55°C.

Para resolver esto hemos fabricado una serpentina (vea la figura 2)

Figura 1

Figura 2
La inclusión de la investigación y la labor creativa son fundamentales para el desarrollo integral de los estudios subgraduados. Los miembros del Departamento de Física y Electrónica reconocen la importancia de estos elementos como parte fundamental de la labor académica. La aplicación del conocimiento en la búsqueda de nuevas verdades y la interpretación del mundo que nos rodea, permite el desarrollo del pensamiento crítico; es una herramienta académica innovadora para motivar y satisfacer la curiosidad intelectual de los/las estudiantes. Además contribuye al desarrollo social y cultural agilizando la inserción en el ciclo económico de Puerto Rico y del mundo.

La inmersión de estudiantes en investigación subgraduada se hace desde los inicios del programa de Bachillerato de Física Aplicada a la Electrónica, en 1987, mediante el ofrecimiento del curso Investigación Subgraduada (FISI 4161). La usual contratación de Profesores con peritaje en investigación capturó el interés de los estudiantes de Bachillerato para involucrarse en tan digna tarea. El esmero y dedicación de los profesores ayudó a ellos mismos a transformar las técnicas de enseñanza debido al desafío que implica investigar y formar a estudiantes en la disciplina.

La consecuencia de estos esfuerzos condujo a aumentar el ofrecimiento debido al interés de los estudiantes en hacer investigación. En consecuencia se atendió la demanda de los estudiantes, incluyendo los curso de Investigación Subgraduada (FISI 4162 FISI 4163 y FISI 4164). Los cuatro cursos mencionados se ofrecen regularmente desde agosto de 1993. El compromiso permitió a la academia refinar las estrategias de enseñanza-aprendizaje, que en esencia son el modelo tomado por el constructivismo, el método de prueba y error.

Después de dieciséis años de esfuerzo, el Departamento cuenta con una decena de profesores que escriben propuestas, consiguen fondos externos y hacen presentaciones en reuniones internacionales de ciencia, y publican periódicamente en revistas de circulación internacional. En el Departamento hay dos laboratorios dedicados a la investigación y un laboratorio de instrucción equipado con instrumentos de primera línea en el que se ofrecen dos cursos de concentración. También otras facilidades de investigación son los recursos del Observatorio Astronómico de Humacao, en el cual la preparación obtenida por los estudiantes les facilita tener opción de seguir estudios graduados en astrofísica y ciencias del espacio.

Vale destacar el compromiso de la Institución (UPRH) que hace posible la investigación subgraduada, es por ello que me complace reconocer a las diferentes administraciones que están y han colaborando en este esfuerzo. El reconocimiento es también extendido a los profesores por la labor de adiestramiento a los estudiantes. La revista de investigación subgraduada fue concebida para que sea un instrumento administrativo que permita la visibilidad de esta actividad, pero además es un documento dirigido a los estudiantes, profesores y la comunidad científica de Puerto Rico, con el propósito de divulgar las actividades académicas que han sido pioneras en el Sistemas UPR junto con otros Recintos. Este instrumento estará además disponible en la Internet para permitir el acceso a todas las comunidades.