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The works must be unpublished and refer to topics of optical astronomy, optical characterization, optical encoder, experimental research, planetary magnetic fields, ultraviolet radiation, lasers, algorithms and optical waves and other topics related to Physical Sciences Mathematics and Earth sciences.

Presentation of the content

In the first article we present *Laser power density effect on the properties of Sb2S3 thin films prepared by pulsed laser assisted chemical bath deposition* by GARCÍA-GUILLÉN, Grisel, GARCÍA-QUIÑONEZ, Linda Viviana, GOMEZ-RODRIGUEZ, Cristian and VERDEJA-GONZÁLEZ, Luis Felipe, in the next article *Thin-films microstructuration through photolithography* by ALVARADO-LÓPEZ, Joel Isaac, INCLAN-LADINO, Adriana, LÓPEZ-VILLEGAS, Rubén and TELLEZ-LIMON, Ricardo, in the next article *Simulation of Chaotic Oscillators of Fractional Order* by SILVA-JUÁREZ, Alejandro, SALAZAR-PEDRAZA, Miguel De Jesús, PONCE-MELLADO, Juan Jorge and HERRERA-SÁNCHEZ, Gustavo with adscription in the Universidad Tecnológica de Puebla in the next article *Neuromarketing from the perspective of a micro business* by ROMERO-ZARATE, Reyna, LÓPEZ-DE LA CRUZ, Mario and RÍOS-CARDENAS, Martín Raymundo.

Content

Article **ECORFAN Journal- Taiwan**
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Laser power density effect on the properties of Sb_2S_3 thin films prepared by pulsed laser assisted chemical bath deposition

Efecto de la densidad de energía en las propiedades de películas delgadas de Sb_2S_3 preparadas por baño químico asistido con láser pulsado

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Abstract

Antimony Sulfide (Sb_2S_3) thin films were prepared using the laser assisted chemical bath deposition technique. The precursors used in the chemical bath were antimony chloride and sodium thiosulfate, the deposit was made at room temperature on glass substrate, while it was irradiated with a wavelength of 532 nm of the pulsed Nd:YAG laser. In this work, we studied the effects of energy density (1.97×10^7 and 7.07×10^6 W/cm^2) and the irradiation time (30, 45 and 60 min) during the deposition process on the structure and the optical and electrical properties of the antimony sulfide films. The structure, composition, and optical and electrical properties were analyzed by X-Ray Diffraction (XRD), Raman Spectroscopy and X-Ray Emitted Photoelectron Spectroscopy (XPS), UV-Vis spectroscopy and photoconductivity. The results showed that the laser assisted chemical deposition technique is an effective synthesis technique for obtaining thin films of antimony sulfide for optoelectronic applications or in solar cells.

Thin Films, Laser, Power density

Resumen

Películas delgadas de sulfuro de antimonio (Sb_2S_3) fueron preparadas utilizando la técnica de deposición por baño químico asistido con láser. Los precursores utilizados en el baño químico fueron cloruro de antimonio y tiosulfato de sodio, el depósito se realizó a temperatura ambiente sobre sustratos de vidrio mientras se irradiaba con la longitud de onda de 532nm de un láser pulsado Nd:YAG. En este trabajo se estudió el efecto de la densidad de energía (1.97 X10^7 y 7.07 X 10^6 W/cm^2) y el tiempo de irradiación (30, 45 y 60 minutos) durante el proceso de depósito, en la estructura, propiedades ópticas y eléctricas de las películas de sulfuro de antimonio. Se analizó la estructura, composición, propiedades ópticas y eléctricas mediante Difracción de Rayos X (DRX), Espectroscopía Raman y Espectroscopia de Fotoelectrones Emitidos por Rayos X (XPS), espectroscopia UV-Vis y fotoconductividad. Los resultados mostraron que la técnica de depósito químico asistido con láser es una técnica de síntesis efectiva para obtener películas delgadas de sulfuro de antimonio para aplicaciones optoelectrónicas o en celdas solares.

Películas Delgadas, Láser, Densidad de energía

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Introduction

Global warming, coupled with the growing global energy demand are problems that concern us all. Global warming occurs due to greenhouse gases generated from the burning of fossil fuels to produce electrical energy. Due to this, it is necessary to look for alternative sources for the generation of energy, such as the photovoltaic solar source. Photovoltaic solar technology based on thin films uses semiconductor materials with thicknesses of several nanometers up to several microns (Ismail, Abeduljabbar, & Fatehi, 2019). In thin films of metal chalcogenides, we find Antimony Sulfide (Sb_2S_3) as absorbing material, due to its high absorption coefficient and a bandgap interval between 1.7-2.5 eV. Sb_2S_3 thin films have attracted great interest due to their potential applications in various optoelectronic devices. Although an important aspect of the Sb_2S_3 films obtained by chemical bath is the absence of crystallinity, it is necessary to subject them to post-deposit treatments or *in situ*, to improve the crystalline properties of the material and the subsequent performance of the device (Messina, Nair, & Nair, 2007; Shaji et al., 2010; Virt et al., 2017; Virt et al., 2013).

Methodology

The methodology used for the preparation of thin films was the deposition of Sb_2S_3 by means of a pulsed laser assisted chemical bath deposition (PLACBD). This procedure consists in irradiating with a pulsed laser a solution of chemical precursors at a constant temperature, which upon finding a surface nucleation occur and they grow in two dimensions, subsequently a heat treatment is necessary to obtain a thin film with the expected phase. The first step for the deposition of thin films is the cleaning of the substrates.

The substrates used were Fisher Scientific, with dimensions of 72x25x1.1 nm, which were previously washed with chromic solution, rinsed with distilled water and finally dried with hot air. After the precursor solution was prepared, 0.650 g of $SbCl_3$ (antimony trichloride, 99% Fermont brand) were weighed and dissolved in 2.5 ml of $CH_3(CO)CH_3$ (acetone, 99.5% Fermont brand) using a beaker of 100 ml, then 25 ml of a solution of 1 M $Na_2S_2O_3.5H_2$ (99.5% sodium thiosulfate, Fermont brand) was added, followed by 72.5 ml of distilled water (González et al., 2013).

Finally, the clean glass substrates were placed horizontally in a glass container and the chemical precursor solution was added. The vessel was placed in a temperature controlled bath at 40 °C and the solution was irradiated with a 532 nm wavelength of a pulsed Nd: YAG Solar Systems laser (10ns, 10 Hz) using a concave lens with the objective of expanding the light beam over a greater part of the surface of the substrates.

The lens was placed at two distances (5 and 10 cm) on the surface of the solution resulting in two energy densities, 1.97x107 and 7.07x106 W/cm^2, to irradiate the solution at different times (30, 45 and 60 minutes.) After irradiation, the film deposited at the bottom of the substrate was subjected to heat treatment at 350° in vacuum for one hour, because the deposited film was amorphous. The thin films were characterized to study their structure and optoelectronic properties.

Results

X-ray diffraction

The crystalline structures for thin films of Sb2S3 prepared by chemical bath deposition (CBD) and pulsed laser assisted chemical bath deposition (PLACBD) were subjected to heat treatment at 350 °C for one hour in vacuum. For the analysis, an Empyrean PANalytican diffractometer was used, with CuKα radiation of wavelength 1.5406 Å operated at 45 kV and 40 mA, in a mode of gracing incidence at an angle of incidence of 1 °.

The scan range (2θ) was 10 to 60 ° at a scan speed of 0.005 ° / s. Figure 1 (a, b) shows the diffraction patterns for thin films of Sb_2S_3 with PLACBD deposited for 30 and 60 minutes under energy densities 1.97X107 and 7.07X106 W/cm^2. The patterns corresponding to the CBD are included in the comparison.

The peaks identified correspond to the stibin phase of Sb_2S_3 with orthorhombic structure (PDF # 42-1393), the most intense peak is located along the plane (130), while the peaks corresponding to the planes can also be identified (110) , (020), (120), (220), (320), (211), (221), (301), (240), (231), (340), (411), (250), (530), (531) and (360) [7,11-13], this orientation can be seen in Figure.-1 (b). However, in Figure (b) there is a preferential orientation towards the plane (211), that does not exist in Figure 1 (a).

The DRX analysis showed that the thin films annealed under the different irradiation conditions were polycrystalline; the changes may be attributable to the deposition technique, the heat treatment of the films and their thickness.

Raman spectroscopy

Raman spectroscopy measurements were carried out at the excitation wavelength of 532 nm and 3 mW laser energy using a Raman DXRTM Thermo Scientific Microscope. Figure 2 (a) shows the Raman spectrum for Sb_2S_3 films prepared during 30 minutes of pulsed laser irradiation, obtained by CBD, Figure 2 (b) shows that of 45 minutes and Figure 2 (c) that of 60 minutes, respectively.

In the Raman spectrum, Sb_2S_3 films prepared by a pulsed laser assisted chemical bath deposition have higher intensity peaks compared to those obtained by chemical bath without irradiation. There were peaks with small variations in intensity, at the positions of 126, 155, 189, 236, 282 and 307 cm^{-1}, for all samples. It has been reported that the presence of the peaks in wave numbers 280 and 236 cm^{-1} is due to the preferential orientation along the crystalline plane (130) (Shaji et al., 2017). These bands have been reported for thin films of Sb_2S_3 (Chen et al., 2009; Han et al., 2010; Liu, Eddie Chua, Sum, & Gan, 2014). Raman's active vibration modes are identified as $10A_g$, 5B1g, $10B_{2g}$ and $5B_{3g}$. Peaks 155, 189 and 282 cm^{-1} of Figure 2 (a, b and c) correspond to A_g modes and peaks 126, 236 and 307 cm^{-1} are attributed to vibration modes B_{1g}.

X-ray Emitted Photoelectron Spectroscopy

The elemental composition and the chemical state of the antimony sulfide thin films were determined by means of the X-ray photoelectron spectra using a Thermo Scientific K-alpha XPS system that uses a monochromatized X-ray energy radiation of Al Kα 1486.6 eV. Figure 3 (a, b) shows the analysis of the chemical states of the 30, 45 and 60 minute samples where the pulsed laser assisted chemical bath deposition technique was used with energy densities of 1.97x107 and 7.07x106 W/cm^2, respectively. The spectra were obtained after surface cleaning by pickling with argon ions. The binding energy peaks were adjusted to the adventitious carbon corresponding to C1s at 284.6 eV. All peaks observed in the spectra were identified as Sb and S in the Sb_2S_3 samples.

Figure 3 (a) shows the spectra of Sb3d with a double in the link energies of ~ 530.3 and 539.7 eV for $Sb3d_{5/2}$ and $Sb3d_{3/2}$ separated by 9.4 eV, which are reported link energies for Sb^{3+} (Bierman et al., 2016; Huerta-Flores, García-Gómez, de la Parra, & Sánchez, 2015; Krishnan, Shaji, & Ernesto Ornelas, 2015; Liu et al., 2014). The spectra corresponding to S2p are presented in Figure 3 (b), which were deconvolved in individual states for $S2p_{3/2}$ and $S2p_{1/2}$ with bond energy values of 161.40 and 162. 6 with a difference of link energy (ΔE) of 1.2 eV. These binding energies are characteristic of sulfur (S^{2-}) (Ornelas-Acosta et al., 2015; Shaji et al., 2019; Vinayakumar et al., 2018; Vinayakumar et al., 2017). For the deconvolution, the peaks were adjusted using the Gaussian-Lorentz function and care was also taken to maintain the intensity ratio of $S2p_{3/2}$ to $S2p_{1/2}$ as 2:1 and the same FWHM value. The XPS results confirmed the elemental composition and chemical states of the thin antimony sulfide films in all conditions.

Optical Properties

The optical transmittance at normal incidence, T (%), and the mirror reflectance spectrum, R (%), of the samples were measured using a Shimadzu UV-1800 model spectrophotometer. Measurements were made in the UV-vis-NIR region in the wavelength range of 200 to 1200 nm. The transmittance (%T) and reflectance (%R) spectra for Sb_2S_3 thin films deposited by chemical bath and by pulsed laser-assisted chemical bath are presented in Figure 4. Figure 4 (a) shows the comparison between the transmittance and reflectance spectra of the Sb_2S_3 films prepared with irradiation for 30 minutes, in Figure 4 (b) those obtained at 45 minutes and in Figure 4 (c) those of 60 minutes.

Figure 4 (a) shows the highest percentage of reflectance in the wavelength range of 800 to 600 nm for the spectrum of the Sb_2S_3 film prepared without irradiation compared to Sb_2S_3 films prepared with irradiation at densities of 1.97x107 and 7.07x106 W/cm^2 energy. Films prepared without irradiation at 45 and 60 minutes have a higher percentage of reflectance in the wavelength range of 700 to 1000 nm compared to those obtained at 45 and 60 minutes with laser irradiation at different energy densities. According to Table 1, thin films of Sb_2S_3 prepared without irradiation have a greater thickness than those prepared with pulsed laser and their thickness increases with increasing irradiation time.

The greatest reflectance in the wavelength range of 600 to 800 nm, for films obtained with laser irradiation, was for 45 minutes with an energy density of 1.97x107 W/cm^2, the thickness of which was 152.7 nm. The difference in reflectance is due to the difference in the thicknesses of the films prepared under the different conditions and the maximum reflectance moves to longer wavelengths as the thickness of the film increases (Han et al., 2010).

The oscillatory behavior of the reflectance is explained by the interference of the light reflected from the upper and lower surface of the film. In the region between 600 nm to 800 nm, the Sb_2S_3 films prepared with laser irradiation for 45 and 60 minutes show greater reflectance than those prepared without laser irradiation. The absorption coefficient (α) for the absorption wavelength region was calculated using the equation:

$$\alpha = \frac{1}{d} ln \left[\frac{(1-R)^2}{T}\right] \quad (1)$$

Where d is the thickness of the film. The term $(1-R)^2$ considers transmission through the upper and lower surfaces of the film, while the natural logarithm factor explains how the intensity decreases due to absorption according to Beer's law.

Figure 5 (a) shows the absorption coefficients of Sb_2S_3 films prepared with and without irradiation for 30 minutes, in Figure 5 (b) those obtained at 45 minutes and in Figure 5 (c) those of 60 minutes using two energy densities, 1.97x107 and 7.07x106 W/cm^2. All graphs show high absorption coefficients (greater than 105 cm^{-1}) in the energy range of 2 to 3 eV. Based on the absorption coefficient, the energy gap values were estimated using the ratio:

$$(\alpha h\nu)^n = A(h\nu - E_g) \quad (2)$$

Where E_g is the energy gap and n = 2, 1/2 and 2/3, are the values for the direct, indirect and direct bandgap transition semiconductors, respectively, α is the frequency *h* absorption coefficient and A is a constant. The graphs of $(\alpha h\nu)^2$ versus hν (Tauc graph) for Sb_2S_3 films prepared with and without irradiation are shown in Figure 6. The energy gap values for the films obtained by irradiation for 30 minutes, Figure 6 (a), were between 2.6 to 2.7 eV.

The energy gap for Sb_2S_3 films prepared at 45 minutes and 60 minutes of irradiation were in the range of 2.5 to 2.7 eV, Figure (b) and (c). The energy gaps had no significant change for the thin films of Sb_2S_3 obtained by pulsed laser assisted chemical bath deposition, this due to the lower thickness for said films.

Photoconductivity

To analyze the effect of pulsed laser irradiation on the electrical properties of Sb_2S_3 films, conductivity was measured both in the dark and under lighting conditions. The samples were exposed to light using a tungsten halogen lamp (intensity of 240W/m^2) to measure photoconductivity maintaining a constant voltage.

For this experiment, a voltage of 100 V was applied through ohmic contacts (2 flat silver paint electrodes 3 mm long and 3 mm apart) using a Keithley 6487 current/voltage meter. Measurements of conductivity were made for periods of 20 seconds, starting with the conductivity in the dark, then under light and finally in the dark.

All samples showed photocurrent in values of the order of 10-10 and in the dark the photocurrent declined to its initial value, as can be seen in Figure 7.

Figure 7 (a) shows the photocurrent graphs for the Sb_2S_3 films prepared by chemical bath with irradiation for 30 minutes and their comparison against that obtained without irradiation, in which there is a greater photocurrent in the prepared film with pulsed laser irradiation using the energy density of 7.07x106 W/cm^2. The same effect was observed for the films produced by laser irradiation for 45 and 60 minutes, the ones with the highest photocurrent were those obtained at lower energy density (7.07x106 W/cm^2). The conductivity in the dark and the photoconductivity of the Sb_2S_3 films produced were evaluated using their respective thicknesses and the data in the graphs of Figure 7, all conductivity values are shown in Table 1.

Making a comparison of the results of structure, composition and of the optical and electrical properties on the Sb_2S_3 thin films, it is observed that the thin films prepared at the lowest energy density are those that show greater energy gaps, as well as higher conductivity.

Conclusions

In this work, the preparation and characterization of thin films using the laser-assisted chemical bath technique demonstrated that it is possible to obtain thin films with crystalline phase, this was established by X-ray and Raman Diffraction.

The energy gaps of the thin films of Sb_2S_3 prepared by laser-assisted chemical bath had no significant change, because they showed smaller thicknesses than those obtained without laser irradiation. However, for the Sb_2S_3 thin films prepared under laser irradiation, at the lowest energy density and for all irradiation times, the conductivity was higher. The present work showed that it is possible to obtain thin films of antimony sulfide with potential for application in photovoltaic cells.

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Thin-films microstructuration through photolithography

Microestructuración de películas delgadas mediante fotolitografía

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Abstract

In recent years, micro and nanotechnology have undergone a rapid development due to their applications in different scientific areas such as metaphotonics, an emerging branch of optics that studies the interaction of light with micro and nanostructured metamaterials. Our particular interest is the development of integrated metaphotonic devices for lab-on-a-chip biosensing applications. A widely used technique for the manufacture of integrated optical devices is photolithography, which is based on the processing of UV-light-sensitive photoresists to create masks for the deposition of thin films and generate the desired devices. In this contribution, we present an experimental methodology for the patterning of plasmonic waveguides using a photolithography system for printing SU-8 photoresist masks on glass substrates. We show the necessary parameters to optimize the photoresist printing (beam waist, focal distance and fluence) under normal conditions and the characterization of the samples through atomic force microscopy. Due to the aspect ratio between the width of the waveguides and thickness of the photoresist, the obtained results approach us to the development of multilayered systems for new integrated metaphotonic devices.

Photolithography, Metaphotonics, Integrated optics

Resumen

En años recientes la micro y nanotecnología se han desarrollado rápidamente por sus aplicaciones en diferentes áreas científicas como la metafotónica, rama emergente de la óptica que estudia la interacción de la luz con metamateriales micro y nanoestructurados. Nuestro interés particular es el desarrollo de dispositivos metafotónicos integrados para aplicaciones de biosensado tipo lab-on-a-chip. Una técnica ampliamente utilizada para la fabricación de dispositivos ópticos integrados es la fotolitografía, la cual está basada en el procesamiento de foto-resinas sensibles a la luz UV que permiten crear mascarillas para depositar películas delgadas y generar los dispositivos deseados. En este trabajo presentamos una metodología experimental para la impresión de guías de onda plasmónicas haciendo uso de un sistema de fotolitografía para imprimir mascarillas de foto-resina SU-8 sobre sustratos de vidrio. Mostramos los parámetros necesarios para optimizar la impresión de la foto-resina (cintura del haz, distancia focal y fluencia) en condiciones normales y la caracterización de las muestras mediante microscopía de fuerza atómica. Debido a la relación de aspecto entre el ancho de las guías y espesor de la foto-resina, los resultados obtenidos nos acercan al desarrollo de sistemas multicapas para nuevos dispositivos metafotónicos integrados.

Fotolitografía, Metafotónica, Óptica integrada

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Introduction

In recent years, micro and nanotechnologies have been rapidly grown because of their applications in different research areas. Such is the case of metaphotonics, an emerging field of optics that studies the interaction of light with micro and nano-structured metamaterials, taking into account, both, electric and magnetic field interactions. Of our particular interest is the study of integrated metaphotonic devices for the development of a new generation of lab-on-a-chip biophotonic sensors.

The operation principle of these novel devices is based on the excitation of plasmonic resonances in metamaterials through photonic guided modes. These systems allow light focusing in submicron regions, serving as transductors for single molecule detection.

However, for the fabrication of these devices is necessary to use expensive and advanced technologies, such as electron beam lithography. An alternative is photolithography, a versatile and low-cost technique that has been widely used for the fabrication of electronic transistors and microcontrollers. Although the size of the patterns that can be printed with this technique are diffraction-limited, they can be very useful for the development of micrometric metaphotonic systems, such as metalenses, integrated gratings or plasmonic waveguides.

In this contribution, we explore the use, advantages and limitations of a simplistic photolithography setup as a platform for the fabrication of integrated metaphotonic devices. To this purpose, we developed an experimental methodology for SU-8 photoresist patterning on top of glass substrates. We describe the system and show the optimization of the principal optical parameters required for a proper photoresist micro-patterning. We also show the characterization of the fabricated samples by making use of optical microscopy and atomic force microscopy (AFM). Due to the aspect ratio between the width and thickness of the printed patterns, the obtained recipe opens new perspectives for the development of multilayered metaphotonic systems, that can be applied, for instance, as non-reciprocal waveguides or hyperbolic metamaterials for biosensing. These objectives are part of the Project "Cátedras-CONACYT" entitled "Development of communication and biosensing systems for e-health applications".

Methodology

For the photo-resist patterning, the samples were prepared as follows. First, a 1cm x 1cm glass substrate was deeply cleaned using dishwashing detergent, isopropyl alcohol and acetone, and was dried with pressurized air. After pouring some drops of SU-8 negative photoresist on the substrate, the sample was spinned-up at 3000 rpm for 30 s with a spin-coater. Finally, the sample was soft baked at 100° C for 1 minute with a hot plate.

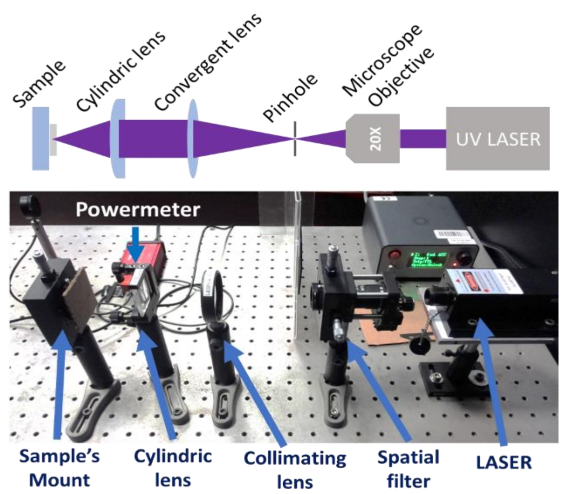

Figure 1 Schematic of the experimental photolithography system (top) and image of the experimental setup (bottom)

Once the samples were prepared, they were exposed to the UV light by making use of the experimental setup shown in Figure 1. The system consists of a UV laser operating at a wavelength of 405 nm and a maximum optical power of 50 mW. The laser beam is spatially filtered with an infinity corrected microscope objective (20X, NA=0.40) and a pinhole of 2 μm diameter.

The beam is collimated with a convergent lens of focal distance 75 mm and 2" diameter, and then focused with a cylindrical lens of 25 mm focal distance. This lens generates a line of light that was focused on the surface of the prepared sample.

To measure the optical power of light impinging the sample, we used an optical power meter (Thorlabs PM100USB with S120C detector). At the bottom of Figure 1, is shown a picture of the actual experimental setup. We must notice that the mount of the sample should be placed as precise as possible at the focal distance of the cylindrical lens to reduce the size of the line illuminating the sample.

After UV-light exposure, the sample was hard baked at 100°C for 1 minute, and then developed by washing it in cold developer (at 4° C) for 1 minute. The development process was stopped with distilled water, and the sample was finally dried with pressurized air. We must remark that all the fabrication process was performed in a dark room illuminated with near infrared light to avoid photoresist over exposure.

Results

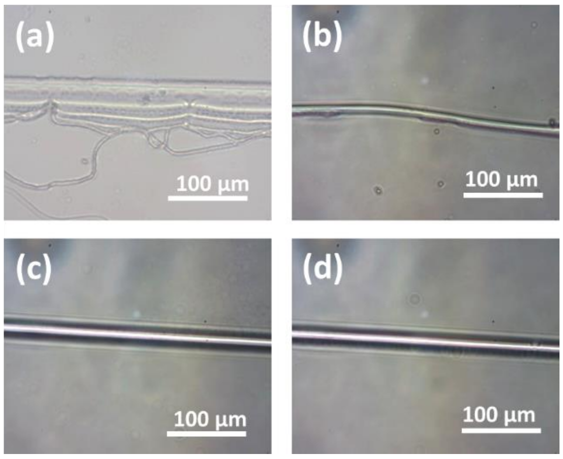

Figure 2 Optical microscope images of different samples as a function of the optical energy (optical power per unit time) (a) E=450 mJ, (b) E=2400 mJ, (c) E=1560 mJ and (d) E=1750 mJ.

In Figure 2 are show the images obtained with an optical microscope of some fabricated samples. In these images can be observed a qualitative dependence of the shape of the printed pattern as a function of the optical energy (optical power per exposure time) at which the samples were exposed.

In Figure 2a can be observed that the printed line is not well defined because the optical energy (*E*=450 mJ) was too low, meaning that the sample was underexposed. By the other hand, when the optical energy was too high (*E*=2400 mJ), the sample was overexposed, reducing the size of the pattern as well as the adhesion of the photoresist to the substrate, leading to a deformation of the pattern (Figure 2b). When the optical energy of impinging light was between *E*=1400 mJ and *E*=2000 mJ, the line patterns where well defined, with good adhesion, low lateral roughness and almost without deformation.

To complete the characterization of the samples, we measured the topography and transverse profile of the patterns with an atomic force microscope (AFM).

In Figure 3a is shown the topography of a 100 µm x 100 µm region of a sample exposed to an optical energy of E=1600 mJ (40 mW for 40 seconds). From this image, the average height of the pattern was about 2.1 µm respect to the surface of the substrate. The black arrow line indicates a region where the transverse profile of the pattern was measured (Figure 3b). From this profile, the width of the pattern was about 28.5 µm, being confirmed a low lateral roughness of the photoresist.

The results in Table 1 summarize the widths of different samples exposed at different optical energies, being indicated the optical power and exposure time as well.

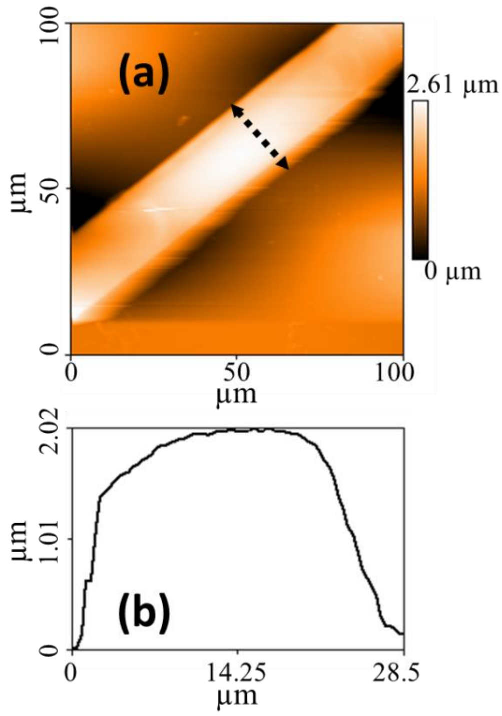

Figure 3 (a) AFM image of the topography of the line patterned on the SU-8 photoresist exposed at E=1600 mJ. The black-dotted arrow line indicates the region where the profile (b) was measured, which reveals that the width of the structure was about 28.5 µm

Optical Power (mW)	Exposure time (s)	Optical energy (mJ)	Width (µm)
40	35	1400	29.9
40	40	1600	28.5
40	45	1800	29.2
40	50	2000	23.8

Table 1 Width of the lines patterned on the SU-8 photoresist as a function of the optical power and exposure time (optical energy)

Conclusions

In conclusion, through the methodology developed for a simple non-commercial, simple and low-cost photolithography system, we were able to fabricate patterns on negative SU-8 photoresist of 2 µm thickness, being obtained an average resolution of the patterns around 28 µm. This resolution can be further improved by using lenses with larger numerical aperture and having a more precise control of the position of the sample relative to the focal plane of the cylindrical lens, such that the waist of the beam is focused as close as possible to the surface of the sample. Due to the aspect ratio between the width and height of the printed lines, is possible to use them as masks for the fabrication of multilayered plasmonic waveguides.

The low cost of the proposed system and easiness of the methodology bring us a first approach for the development of a platform to fabricate integrated metaphotonic devices that can be applied in different research areas, such as lab-on-a-chip biosensing or optical communications, outstanding areas that are in continuous progress.

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Simulation of Chaotic Oscillators of Fractional Order

Simulación de Osciladores Caóticos de Orden Fraccional

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Abstract

In 1695 the theory of fractional calculus was introduced, but it only developed as a pure mathematical branch. Currently several research groups have focused on the control, the implementation of filters, PID controllers, synchronization, the implementation of circuits of chaotic systems of fractional order, etc. Currently, the number of applications of fractional calculus is increasing rapidly, these mathematical phenomena have allowed us to describe and model a real object more accurately than the classical "integer" methods. Along with the development of the fractional calculation, it was shown that many fractional-order nonlinear dynamic systems behave in a chaotic manner. This is the type of non-linear systems that are addressed in this research topic with the focus on derivatives of arbitrary order, where numerical simulations of chaotic behavior are presented in non-linear, fractional-order autonomous models. The case studies are six chaotic oscillators of fractional order; The systems of Lorenz, Rössler, Financiero, Lui, Chen and Lü, whose attractors are obtained by applying the definitions of the Grünwald-Letnikov definitions and the predictive corrective method of Adams-Bashforth-Moulton.

Caos, Sistemas de orden fraccional, Osciladores

Resumen

En 1695 se introdujo la teoría del cálculo fraccional, pero solo se desarrolló como una rama matemática pura. Actualmente varios grupos de investigación se han enfocado en el control, la implementación de filtros, controladores PID, la sincronización, la implementación de circuitos de sistemas caoticos de orden fraccional, etc. En la actualidad, el número de aplicaciones de cálculo fraccional crece rápidamente, estos fenómenos matemáticos han permitido describir y modelar un objeto real de manera más precisa que los métodos clásicos "enteros". Junto con el desarrollo del cálculo fraccional, se demostró que muchos sistemas dinámicos no lineales de orden fraccionario se comportan de manera caótica. Este es el tipo de sistemas no lineales que se abordan en este tema de investigación con el enfoque en las derivadas de orden arbitrario, donde se presentan las simulaciones numéricas del comportamiento caótico en modelos autónomos no lineales de orden fraccional. Los casos de estudio son seis osciladores caóticos de orden fraccional; Los sistemas de Lorenz, Rössler, Financiero, Lui, Chen y Lü, cuyos atractores se obtienen aplicando las aproximaciones de las definiciones de Grünwald-Letnikov y el método predictor corrector de Adams-Bashforth-Moulton.

Chaos, Fractional order systems, Oscillators

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Introduction

With the development of fractional calculus and chaos theory, chaotic systems of fractional order have become a subject of study to assess their characteristics, design them with analog and digital electronics, and propose applications [1]. Models of fractional order systems allow describing and modeling a real object more accurately than using classic "integer" methods.

The biggest difference between the models of fractional orders and of whole order is that those of fractional order depend on the history of the system, since they have memory [2]. That is why traditional numerical methods must adapt or propose new methods to simulate oscillators of fractional order [3-7].

Approximation of fractional order systems

Fractional calculation is a generalization of integration and differentiation to the fundamental operator of non-integer order ${}_aD_t^q$ described in (1), where a and t are the limits of the operation and $q \in R$. In this way, the numerical calculation of the derivatives of fractional order are made with approximations and in this work the definition of Grünwald-Letnikov (G-L) [1,3], described in (2) is applied,

$$ {}_aD_t^q = \begin{cases} \frac{d^q}{dt^q}, & \text{q} > 0, \\ 1, & \text{q} = 0, \\ \int_a^t (d\tau)^q, & \text{q} < 0. \end{cases} \quad (1)$$

$$ {}_{(k-L_m/\square)}D_{t_k}^q f(t) \approx \frac{1}{\square^q} \sum_{j=0}^{k} (-1)^j \binom{q}{j} f(t_{k-j}) $$
(2)

Where L_m is the memory length, $t_k = kh$, h is the step size of the calculation and $(-1)^j \binom{q}{j}$ are the binomial coefficients denoted by $c_j^{(q)} (j = 0,1,\ldots)$. The following expression can be used for its calculation [4]:

$$ c_0^{(q)} = 1, \ c_j^{(q)} = \left(1 - \frac{1+q}{j}\right) c_{j-1}^{(q)} \quad (3)$$

Then, the general numerical solution of the fractional differential equation ${}_aD_t^q y(t) = f(y(t), t)$, can be expressed as

$$ y(t_k) = f(y(t_k), t_k) h^q - \sum_{j=v}^{k} c_j^{(q)} y(t_{k-j}) \quad (4)$$

For the term of memory expressed by the summation, the principle of "short memory" can be used. Then the lower index of the sums in the relationships (4) will be $v = 1$ for $k < (L_m/h)$ y $v = k - (L_m/h)$ for $k > (L_m/h)$, or without using the principle of short memory, v = 1 is made for all k.

Obviously, truncating the memory length implies an inaccuracy. If $f(t) \le M$, The following estimate can be established to determine the memory length L_m, providing the required accuracy ε:

$$ L_m \ge \left(\frac{M}{\varepsilon |\Gamma(1-q)|}\right)^{1/q} \quad (5)$$

An evaluation of the effect of short memory and the convergence ratio of error between short and long memory are described in [7].

For the numerical simulation of the fractional order system, a method based on the predictor-corrector scheme of type ABM [4] has also been proposed, the method is based on the fact that the fractional differential equation $D_t^q y(t) = f(y(t), t), y_0^{(k)}, k = 0,1, \ldots, m-1$ is equivalent to the integral volterra equation

$$ y(t) = \sum_{k=0}^{[q]-1} y_0^{(k)} \frac{t^k}{k!} + \frac{1}{\Gamma(q)} \int_0^t (t-\tau)^{q-1} f(\tau, y(\tau)) d\tau. \quad (6)$$

Discretizing (6) to $t_n = nh \, (n = 0,1, \ldots, N)$, $h = T_{sim}/N$ and using the principle of short memory as in [8] the numerical approximation of the solution is obtained $y(t_n)$ and the order of precision is preserved. The corrective scheme is shown in (7).

$$ y_{\square}(t_{n+1}) = \sum_{k=0}^{m-1} \frac{t_{n+1}^k}{k!} y_0^{(k)} + \frac{\square^q}{\Gamma(\alpha+2)} f(t_{n+1}, y_{\square}^p(t_{n+1})) $$

$$ + \frac{\square^q}{\Gamma(\alpha+2)} \sum_{j=0}^{n} a_{j,n+1} f(t_j, y_n(t_j)), \quad (7)$$

Where

$$ a_{j,n+1} = \begin{cases} n^{q+1} - (n-q)(n+1)^q, & , \\ (n-j+2)^{q+1} + (n+j)^{q+1} + 2(n-j+1)^{q+1}, \\ 1, \end{cases} $$

$$ a_{j,n+1} = \begin{cases} \text{si j=0}, \\ \text{si } 1 \le j \le n, \\ \text{si j=n+1}. \end{cases} \quad (8)$$

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As shown in [1], both numerical methods described in the time domain; GL and ABM have approximately the same order of precision and a good match of numerical solutions.

Fractional Systems Stability

The stability of nonlinear systems of fractional order is very complex and different from the linear system of fractional order [3]. The main difference is that, for a non-linear system, it is necessary to investigate the stationary states by evaluating (5), that is, the system's equilibrium points $E^* = (x_1^*, x_2^*, x_3^*)$.

$$ {}_aD_t^q f(t) = f(x) = 0 \quad (11) $$

According to the stability theorem defined in [8], the equilibrium points are asymptotically stable for a commensurate system, that is $q_1 = q_2 = q_3 = q_n \equiv q$ if all own values $\lambda_1, (i = 1,2,\dots,n)$ of the Jacobian matrix $J = \partial f / \partial x$, where $f = [f_1, f_2, \dots, f_n]^T$, evaluated at break-even points E^*, satisfies the condition [10]:

$$ |\,arg(\mathrm{eig}(J))| = |\,arg(\lambda_i| > q\frac{\pi}{2}, i = 1,2,\dots,n. \quad (12) $$

To determine the stability of a fractional order system considered immeasurable, that is $q_1 \neq q_2 \dots \neq q_n$ and assuming that m is the LCM of the denominators u_i of q_i, where $q_i = v_i/u_i$, $v_i, u_i \in Z^+$ for $i = 1,2,\dots,n$ and $\gamma = 1/m$, the system is asymptotically stable if $|\,arg(\lambda)| > \gamma\frac{\pi}{2}$. For all the roots of\ lambda in the following equation

$$ det(\,diag([\lambda^{mq_1}\lambda^{mq_2}\dots\lambda^{mq_n}]) - J) = 0 \quad (13) $$

The condition for systems derived from an immeasurable order is

$$ q > \frac{2}{\pi}\mathrm{atan}\left(\frac{|\beta_i|}{q_i}\right), i = 1,2 \quad (14) $$

This condition can be used to determine the minimum order for which a nonlinear system can generate chaos [10].

Simulation of Chaotic Attractors

In this work the chaotic systems of fractional order of: Lorenz (15), Rössler (16), Financial (17), Lui (18), Chen (19) and Lü (20) are calculated and simulated.

Where x, y, z are the state variables and $0 < q_1, q_2, q_3 < 1$ It is the fractional order. The systems are represented by nonlinear differential equations because they present multiplication of variables in one or more equations.

$$ \begin{cases} D^{\alpha_1}x = \sigma(y - x), \\ D^{\alpha_2}y = x(\rho - z) - y, \\ D^{\alpha_3}z = xy - \beta z, \end{cases} \quad (15) $$

$$ \begin{cases} D^{\alpha_1}x = -y - z, \\ D^{\alpha_2}y = x + ay, \\ D^{\alpha_3}z = b + z(x - c), \end{cases} \quad (16) $$

$$ \begin{cases} D^{\alpha_1}x = z + x(y - a), \\ D^{\alpha_2}y = 1 - by - |x|, \\ D^{\alpha_3}z = -x - cz, \end{cases} \quad (17) $$

$$ \begin{cases} D^{\alpha_1}x = -ax - ey^2, \\ D^{\alpha_2}y = by - kxz, \\ D^{\alpha_3}z = -cz + mxy, \end{cases} \quad (18) $$

$$ \begin{cases} D^{\alpha_1}x = a(y - x), \\ D^{\alpha_2}y = cx - ax - xz + cy, \\ D^{\alpha_3}z = xy + bz, \end{cases} \quad (19) $$

$$ \begin{cases} D^{\alpha_1}x = a(y - x), \\ D^{\alpha_2}y = xz + cy, \\ D^{\alpha_3}z = xy - bz, \end{cases} \quad (20) $$

Table 1 shows the equilibrium points and their corresponding eigenvalues for stability analysis of the 6 chaotic systems of fractional order, where it is verified that, based on the signs of the eigenvalues and if they correspond to real or imaginary, it is observed that all the systems present asymptotic instability, chair node, chair focus, which are necessary to generate chaotic behavior.

	Balance points	Own values
(1)	$E_1 = (0,0,0)$, $E_2 = (\sqrt{(\beta\rho - \beta)}, \sqrt{(\beta\rho - \beta)}, \rho - 1)$, $E_3 = (-\sqrt{(\beta\rho - \beta)}, -\sqrt{(\beta\rho - \beta)}, \rho - 1)$.	$\lambda_1 \approx -13.8546,\ \lambda_{2,3} \approx 0.0940\ \pm 10.1945i$ $\lambda_1 \approx -13.8546,\ \lambda_{2,3} \approx 0.0940\ \pm 10.1945i$ $\lambda_1 \approx -22.82776,\ \lambda_2 \approx 11.8277$, $\lambda_3 \approx -2.6667$
(2)	$E_{1,2} = \left(\frac{c \pm \sqrt{c^2 - 4ab}}{2}, -\frac{c \pm \sqrt{c^2 - 4ab}}{2a}, \frac{c \pm \sqrt{c^2 - 4ab}}{2a}\right)$	$\lambda_1 \approx 0.47595$, $\lambda_{2,3} \approx 0.007017 \pm 4.57910\,j$ $\lambda_1 \approx -9.98800$, $\lambda_{2,3} \approx 0.249007 \pm 0.96808\,j$
(3)	$E_1 = (0, 1/b, 0)$, $E_2 = (\sqrt{(c - b - abc)/c}, (1 + ac)/c, -(1/c)\sqrt{(c - b - abc)/c}$, $E_3 = (-\sqrt{(c - b - abc)/c}, (1 + ac)/c, (1/c)\sqrt{(c - b - abc)/c}$.	$\lambda_1 \approx 8.898979, \lambda_2 \approx -8.898794$, $\lambda_3 \approx -0.1$, $\lambda_1 \approx -0.7608747$, $\lambda_{2,3} \approx 0.3304373 \pm 1.411968\,j$
(4)	$E_1 = (0,0,0)$, $E_2 = (\sqrt{(bc/(hk)}, \sqrt{(bc/(hk)}, b/k)$, $E_3 = (-\sqrt{(bc/(hk)}, -\sqrt{(bc/(hk)}, b/k)$.	$\lambda_1 = -1, \lambda_2 = -5, \lambda_3 = -5$, $\lambda_1 \approx 4.387767$, $\lambda_{2,3} \approx 0.4438837 \pm 3.346383\,j$.
(5)	$E_1 = (0,0,0)$, $E_2 = (\sqrt{b(2c - \mu}, \sqrt{b(2c - \mu)}, 2c - \mu)$, $E_3 = (-\sqrt{b(2c - \mu}, -\sqrt{b(2c - \mu)}, 2c - \mu)$.	$\lambda_1 = -3, \lambda_2 \approx 23.8359, \lambda_3 = -30.8359$, $\lambda_1 \approx -18.4280$, $\lambda_{2,3} \approx 4.2140 \pm 14.8846$ j, $\lambda_1 = -18.4280$, $\lambda_{2,3} \approx 4.2140 \pm 14.8846$ j,
(6)	$E_1 = (0,0,0)$, $E_2 = (\sqrt{bc}, \sqrt{bc}, c)$, $E_3 = (-\sqrt{bc}, -\sqrt{bc}, c)$.	$\lambda_1 = -3, \lambda_2 \approx 20, \lambda_3 = -36$, $\lambda_1 \approx -22.6516, \lambda_{2,3} \approx 1.8258 \pm 13.6887\,j$ $\lambda_1 \approx -22.6516, \lambda_{2,3} \approx 1.8258 \pm 13.6887\,j$

Table 1 Balance points and their corresponding own values

Next, we describe the way in which the Lorenz fractional system (15) is adapted to obtain the numerical solution of the system by applying the definition of Grünwald-Letnikov,

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similarly it is done for the other systems that are analyzed in this work

$$x(t_k) = (\sigma(y(t_{k-1}) - x(t_{k-1})))\square^{q1} - \sum_{j=v}^{k} c_j^{(q_1)} x(t_{k-j}),$$

$$y(t_k) = (x(t_k)(\rho - z(t_{k-1})) - y(t_{k-1}))\square^{q_2} - \sum_{j=v}^{k} c_j^{(q_2)} y(t_{k-j}),$$

$$z(t_k) = (x(t_k)y(t_k) - \beta z(t_{k-1}))\square^{q_3} - \sum_{j=v}^{k} c_j^{(q_3)} z(t_{k-j}).$$

Where T_{sim} is the simulation time, $k = 1,2,3,\ldots,N$, for $N = [T_{sim}/h]$, and initial conditions $x(0), y(0), z(0)$. Binomial coefficients $c_j^{(q_1)}, \forall i$ They are calculated according to the relationship (3). To determine the minimum order of the fraction for which the Lorenz system is chaotic with the parameters $(\sigma, \rho, \beta) = (10,\ 28, 8/3)$ the relationship (14) is used. In this case the minimum order commensurate for $q_1 = q_2 = q_3$ is $q > 0.9941$. In the case of immeasurable orders the stability at the equilibrium point can be investigated by the characteristic equation $det(\lambda^{\gamma}\text{I-J}) = 0$ for $\gamma = 1/m$ where m is the LCM of the denominators of u_i, if $q_i = v_i/u_i,\ v_i, u_i \in Z^+$ and the stability condition meets$|\,arg(\lambda)| > \gamma\pi/2$.

All six systems were evaluated under the same integration step size conditions. $h = 0.005$ and simulation time $T_{sim} = 100s$. The algorithms were programmed with Matlab R2019a, in double precision, the type of rounding error and machine epsilon of 2.2204e-16, a list of parameters used for the simulation of the systems applying the GL and ABM algorithm are given in the Table 2.

	Coefficients	C. I. $x(0), y(0), z(0)$	Fractional order
(1)	σ=10, ρ= 28, $\beta = 8/3$	(0.1, 0.1, 0.1)	$\alpha_1 = \alpha_2 = \alpha_3 = 0.995$
(2)	a=0.5, b=0.2, c=10	(0.5,1.5,0.1)	$\alpha_1 = 0.9, \alpha_2 = 0.85, \alpha_3 = 0.9$
(3)	a=1.0, b=0.1, c=1.0	(2,-1,1)	$\alpha_1 = \alpha_2 = \alpha_3 = 0.9$
(4)	$a = e = 1, b = 2.5$	(0.2,0,0.5)	$\alpha_1 = 1.0, \alpha_2 = 0.9, \alpha_3 = 0.8$
(5)	a=35, b=3, c=28, d=-7	(-9,-5,14)|	$\alpha_1 = \alpha_2 = \alpha_3 = 0.9$
(6)	a=36, b=3, c=20	(0.2,0.5,0.3)	$\alpha_1 = 0.98, \alpha_2 = 0.99, \alpha_3 = 0.98$

Table 2 Parameters used in the simulations of the 6 attractors of fractional order

The results of the numerical simulation applying the definition of Grünwald-Letnikov are given in Figures 1 and 6 respectively, where the creation of a chaotic oscillator sensitive to the initial conditions is shown.

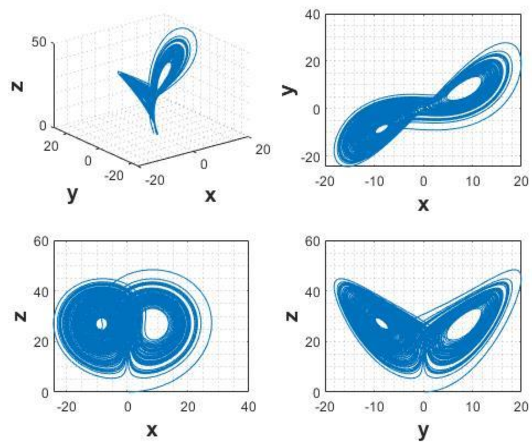

Figure 1 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Lorenz system, applying GL

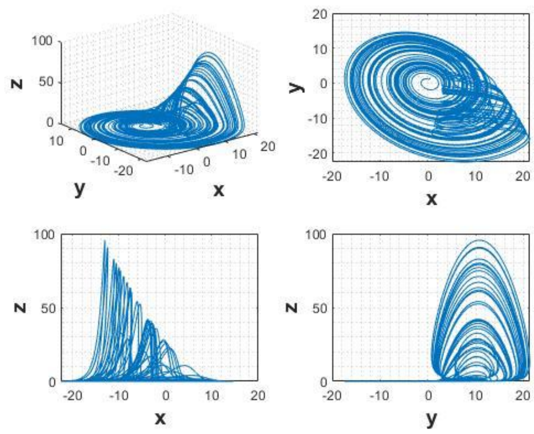

Figure 2 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Rössler systems, applying G-L

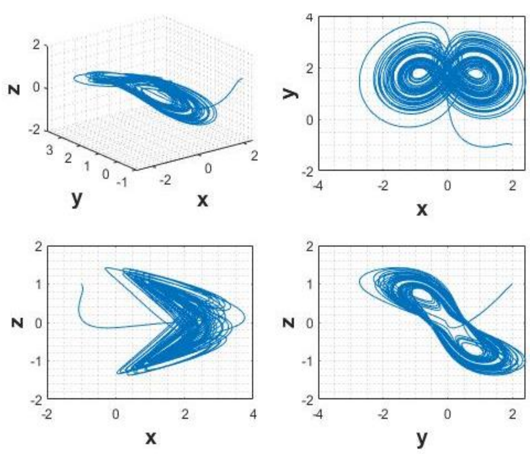

Figure 3 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Financial system, applying GL

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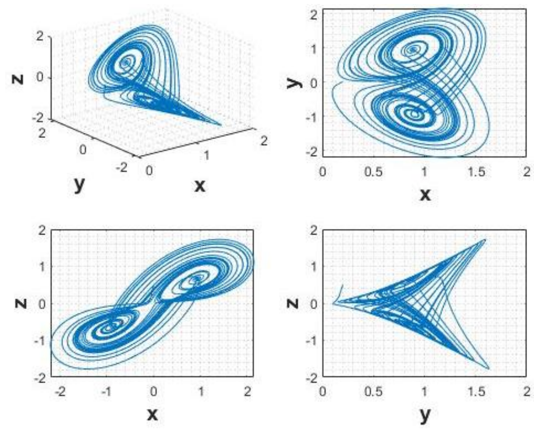

Figure 4 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Liu systems, applying G-L

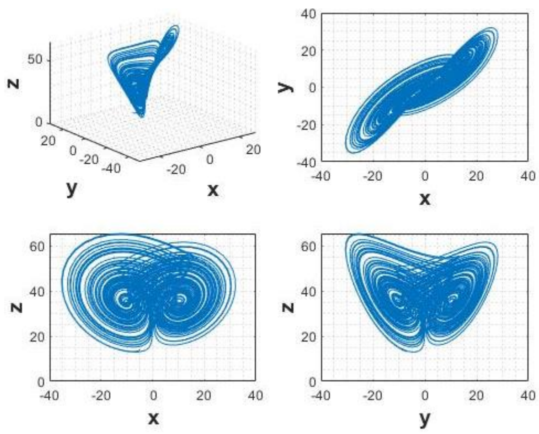

Figure 5 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Chen system, applying G-L

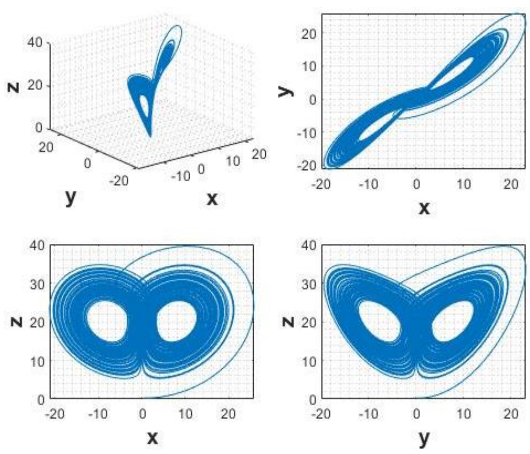

Figure 6 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Lü system, applying G-L

Similar to the previous one, the six chaotic systems of fractional order that are analyzed in this work for the Adams-Bashforth-Moulton method are adapted with the Predictor-Corrector scheme.

This method is suitable because it only requires the initial conditions and for the unknown function it has a clear physical meaning since it is consistent with the Grünwald-Letnikov method, as well as the Caputo, Riemman Louville and FDE12 method..

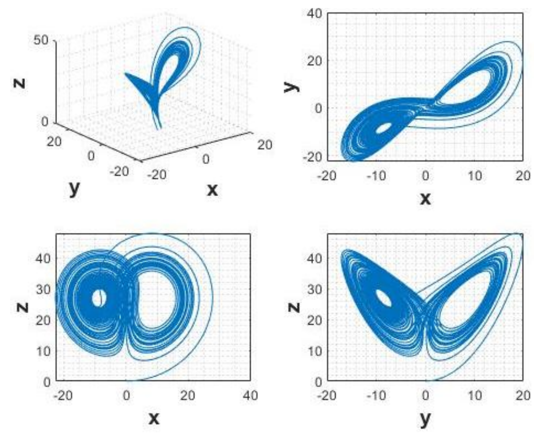

Figure 7 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Lorenz system, applying ABM

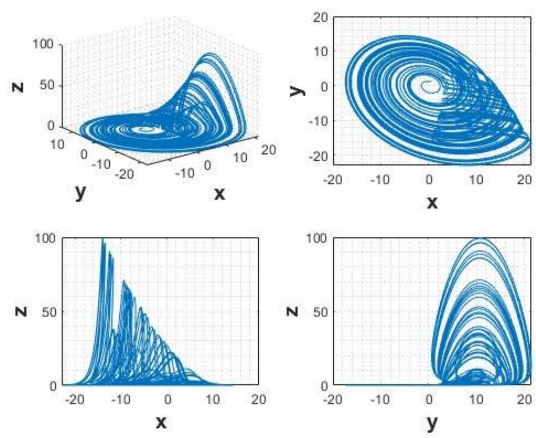

Figure 8 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Rössler system, applying ABM

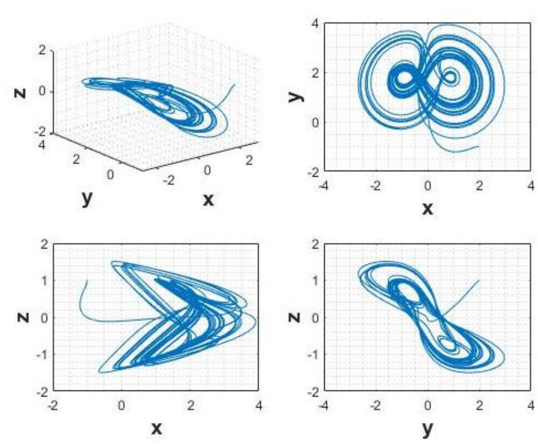

Figure 9 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Financial system, applying ABM

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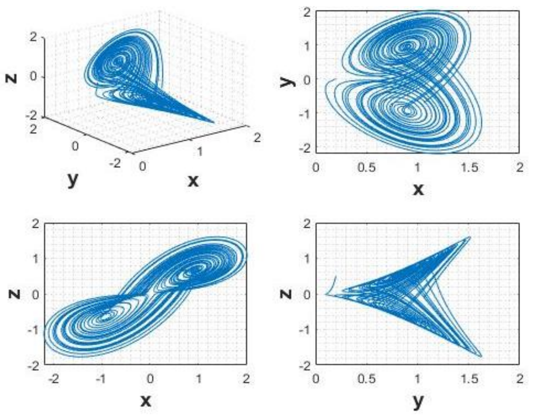

Figure 10 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Liu system, applying ABM

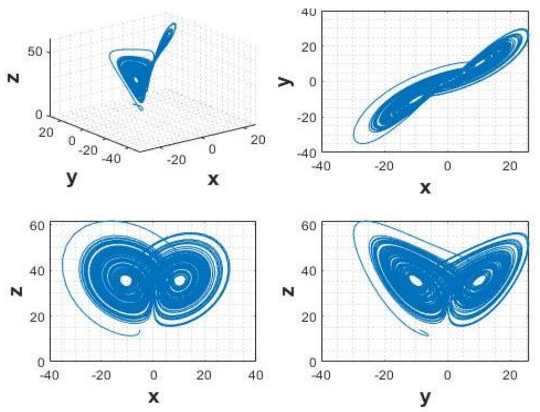

Figure 11 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Chen system, applying ABM

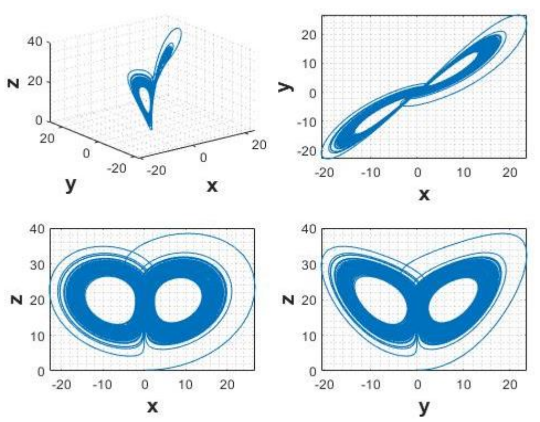

Figure 12 Results of the numerical simulation in 3D, xy, xz and yz planes respectively of the Lü system, applying ABM

Conclusions

The application of the definition of Grünwald-Letnikov and the corrective predictor method of Adams-Bashforth-Moulton to simulate chaotic oscillators of a fractional order have been shown. Stability conditions for commensurate and immeasurable systems were considered for this.

The results of both methods provide the numerical approximations of the solution of the differential equations of fractional order, which implies that they can be implemented in hardware, one of the problems is that both are based on memory use, that is why as future work Implementation differences will be investigated using analog electronics such as FPAA's and digital as FPGA's.

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Neuromarketing from the perspective of a micro business

Neuromarketing desde la perspectiva de un micronegocio

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Abstract

The micro-business are small enterprises which ones are characterized because they have 10 workers limited invoicing, due to low income, nevertheless, it´s been calculated that in 2002 the 50% of the population in "Ciudad Nezahualcóyotl", México, was included in order to get economical resources in daily basis. The micro-enterprises in many occasions do not take into account to perform a marketing research to identify the characteristics (like real and trustable preference) of shoppers-costumers thinking it´s irrelevant. The main purpose of this research was to aid the micro-entrepreneur to improve when taking decisions when buying supplies, applying, neuroscience and marketing technical analysis which ones have been refered in neuromarketing research.

Micro bussines, Investigation of market, Neurosciences, Marketing, Neuromarketing

Resumen

Los Micronegocios en México, son empresas muy pequeñas que se caracterizan porque tienen hasta 10 trabajadores y de facturación limitada, por los pocos ingresos que genera, sin embargo, se calcula que en 2002 el 50% de la población en Ciudad Nezahualcóyotl, México, se conformaba de estos como forma para conseguir recursos económicos de manera recurrente. Los microempresarios en muchas ocasiones no consideran importante realizar investigación de mercado para identificar las características (como preferencias reales y confiables) de sus consumidores-compradores, por percibirlo como irrelevante. Con esta investigación se pretendió auxiliar al microempresario en mejorar la toma de decisiones en la compra de insumos aplicando técnicas de análisis de las neurociencias y de marketing, que han sido referidas en investigaciones de neuromarketing.

Micronegocios, Investigación de mercado, Neurociencias, Marketing, Neuromarketing.

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Defining neuromarketing. Part of the Neurology is defined as “Part of the medicine that deals with the anatomy, physiology and pathology of the nervous system. It is the medical specialty that treats nervous system disorders. ”Or“ Part of the medicine that deals with the prevention, diagnosis, treatment and rehabilitation of diseases that involve the nervous system (central, peripheral and autonomous) ”.

From the neurology there are scientific fields that we know as neurosciences and we define them as “Field of science that is responsible for studying all aspects related to the Nervous System; from its structure, function, development (phylogenetic and ontogenetic), biochemistry, pharmacological applications, pathology, and how these different elements interact to give way to cognition and human behavior, mainly. ”

We mention some neurosciences that serve as a reference in the compression of your field of work: neuropharmacology, neuroendocrinology, neurosurgery, neuropathology, neuropsychiatry, neurobiology, neuropsychology and cognitive neuroscience that is based on a scientific study that unites disciplines such as neurobiology, psychobiology or cognitive psychology itself, studying the mental processes involved in behavior and its biological basis

Neuromarketing is the application of neuroscience techniques to traditional marketing research. It attempts to measure brain activity in its different aspects in the search for metric responses linked to emotions, moods, excitations and other unconscious responses that determine buying behavior. We will mention the main techniques used by neurosciences and their application:

Functional Magnetic Resonance Imaging (FMRI): doctors perform the FMRI to examine the functional anatomy of the brain, determine exactly the part of the brain that is controlling essential functions such as thinking, speech, movement and sensations, a process called brain mapping; evaluate the effects of a stroke, trauma or degenerative disease on the functioning of the brain; control the growth and functioning of brain tumors; Guide the planning of surgery, radiation therapy, or other invasive treatments of the brain.

Electroencephalography (EEG): A common technique with this technology is to measure the asymmetry of activity between the left and right regions of the frontal cortex (Davidson, Ekman et al., 1990). The scientific literature in this regard suggests that superior activity in the left region is associated well with positive emotional states, or with the intention of approaching an object (Harmon-Jones, 2003). In some cases, this technique has been used to measure momentary responses to television spots (Ohme, Reykowska et al., 2009; Ohme, Reykowska et al., 2010) although there is some controversy over whether it is necessary to make longer measurements, up to 60 seconds, to obtain results applicable with this technique (Hustler, Stevens et al., 2008).

The main advantage of the EEG over the FMRI is the cost, since equipment can be obtained for less than $ 10,000.

The coordinated activity of neurons produces magnetic fields in addition to the electric currents measured by the EEG. The intensity of these fields is really small but can be measured by a technique called magnetoencephalography or MEG (Wikipedia, 2011c).

EEG and MEG are conceptually similar techniques, but MEG offers superior signal quality and a very high temporal resolution. However, its costs are much higher: a complete equipment including a magnetically insulated room can cost about 2 million dollars. Therefore, it is not a technique as popular as EEG among neuromarketing consulting agencies.

Electromyography or EMG is a medical technique that involves the application of small low-voltage electrodes in the form of needles in the muscular territory that you want to study to measure the response and connectivity between different electrodes; It measures electrical activity generated by the muscles, and neuromarketing consultants use it primarily to monitor facial muscles associated with involuntary emotional responses. When we are subjected to a stimulus (for example, a television commercial), the muscles of our face move involuntarily in reaction to what we are seeing. Some of these expressions are of very short duration and difficult to detect with the naked eye.

The direct competence of this technique omits the use of measuring equipment giving input to less expensive processes and similar results as the one mentioned below.

Facial Action Coding System (FACS). It is not a technology in itself, but, in some cases, the observation of facial expressions is done by recording the subject's face and performing a manual coding of the muscles that are activated during exposure to the stimulus. The best known and used facial coding system was developed by Paul Ekman in the seventies (Ekman, Friesen, 1978). At present, there is computer software that allows the automatic coding of facial expressions (Azcarate, Hageloh et al., 2005; Salah, Sebe et al., 2009) and some companies market such software packages for use in market research.

We can find in Spain an interesting case of neuromarketing. Where the Neurobiomarketing agency, with offices in Milan and Barcelona, offers neuromarketing services internationally. Its measurement system (Mind Heart Eyes Hands) uses technologies such as EEG, eye-tracking or EDA recording to analyze the reactions of subjects to advertising spots (and other pieces). In collaboration with McCann Erickson Spain and Universal McCann they have created a database with the reactions of more than 400 subjects to different audiovisual pieces. Neurobiomarketing has several proprietary algorithms (patent pending) for the analysis of advertising pieces and they are continuously experimenting with different technologies.

Qualitative research and organoleptic study

Qualitative research provides information about motivations, inhibitions, thoughts, feelings, emotions and their reactions to certain products or services, the tools for collecting information are topic guides, observation guides.

Also called motivational studies, they study the true internal motives of the consumer so that they oril it to the purchase.

From the point of view of the psychological motivational field in the mechanism of buying any product there is a conflict between motivations and psychological phenomena, in the mind of the consumer;

Thus, when the motivation exceeds the brakes, the balance in the mind is broken and the subject is on the edge of the purchase or vice versa when the brakes exceed the motivations people do not buy.

Motivation is what is dormant internally (needs, desires) and tries to direct the behavior towards a specific end.

One of the limitations of qualitative research is that the results of cannot be projected to the universe, a mathematical rigor cannot be applied to qualitative research, some motivational researchers exaggerate in the use of "psychologisms" not providing clear and operational recommendations to Your clients.

As these are not revealed easily or exactly by consumers when they are directly questioned, motivational researchers use the resources of clinical psychology. One of the pioneers in qualitative or motivational research was Dr. Ernest Dichter - Viennese Psychoanalyst - who, in the 1950s, adapted his psychoanalytic techniques to the study of consumer buying habits in order to determine which were the motivators of the consumer.

Qualitative research covers aspects that quantitative research does not cover. The results of both types of research are not replaceable, but complementary. With qualitative research, the reason for the reaction of consumers, whether they are many or few, will be determined afterwards, through quantitative research. Qualitative research enriches the design of the instrument to be used in a quantitative phase.

Organoleptic tests: evaluate the physical characteristics of the product (color, smell, taste, texture, absorption, size, etc.) through the senses, in this type of test the product is tasted to be evaluated. Organoleptic tests represent the foundation of neuromarketing techniques, considering observations of the unhandled reaction of the market segment that is studied objectively.

“When we use techniques based on verbal statements to investigate certain especially sensitive issues (politics, sex ...), the consumer may be tempted to lie or respond using the stereotype of the right thing. Even if the consumer is willing to tell us the truth in his verbal statements, he may not know the answers we intend to obtain.

According to most estimates, 95% of thoughts, emotions and learning occur at the unconscious level.

ZALTMAN, G. (2003): How Customers Think. Boston (MA), Harvard Business School Press, 40 The micro businesses in Ciudad Nezahualcoyotl (particular case)

In April 1963, the municipality of Ciudad Nezahualcóyotl was officially erected, representing the birth of municipality 120 for the State of Mexico, with limitations and deficiencies in public services was initially developed based on family work that was favored with the proximity and relative easy access to the Federal District, by 1985 60% of the companies located in the municipality were family members and therefore they entered the micro classification;

We have the data that in 2002 almost 51% of the operations of purchase and sale of products such as food, clothing, toys, tools and costume jewelery are mainly carried out in tianguis or informal street stalls which we give them the classification of micro businesses,

Objective. Evaluate the decision-making process in two market segments for a micro-business of chopped fruit using an organoleptic technique which is the foundation of neuromarketing.

Investigation

The research was carried out in the three primary schools that represent the usual micro-business market, Francisco Gonzalez Bocanegra, Emiliano Zapata and Adolfo López Mateos. This market was divided into two groups of children where the distinguishing factor is being accompanied by their mothers, the first group consists of 464 children who choose their purchase without being directly accompanied by their mothers and the second group of 105 the latter Accompanied, approximately fifty percent of the portions were sold, counting the decisions was made since the decision from this point becomes biased when leaving the market with limited decision-making options.

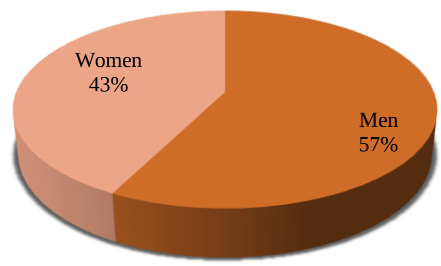
An urban marketing conference was convened, which was attended by 127 young people between 18 and 21 years old students of the technological university of Nezahualcoyotl, they were offered a tasting of the product.

Results

Children from 7 to 9 years old

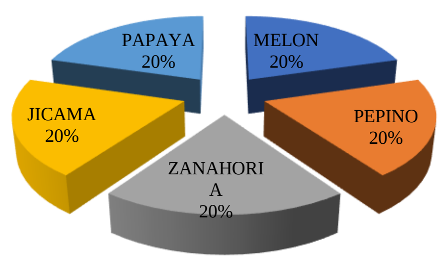
Men	Women	Total
37	68	105

SEX



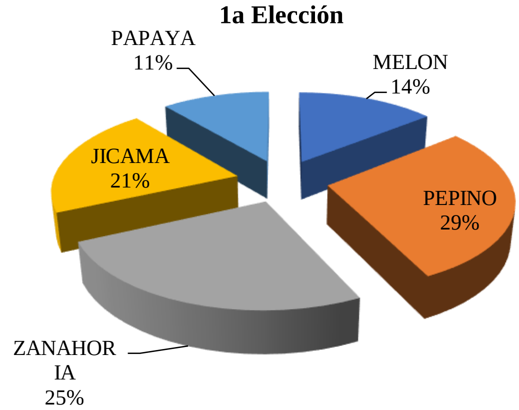
Fruit					
Melon	Cucumber	Carrot	Jicama	Papaya	Total
19	24	24	24	19	110

FRUIT

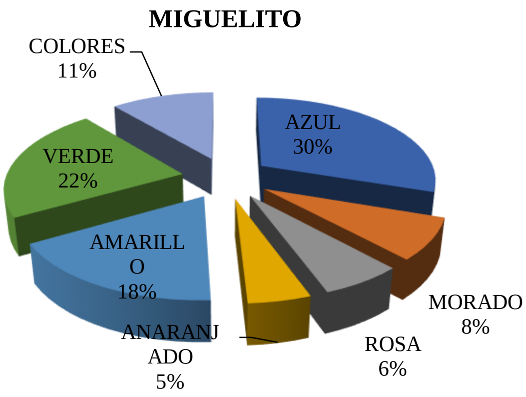


Fist Elección	
Melon	14
Pepino	19
Zanahoria	6
Jicama	4
Papaya	15
	58

1a Elección

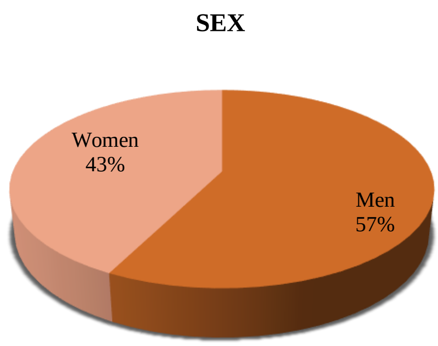


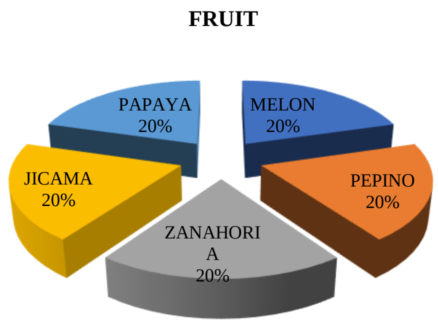
Bittersweet						
Blue	Purple	Pink	Orange	Yellow	Green	Colors
13	7	3	2	1	14	18



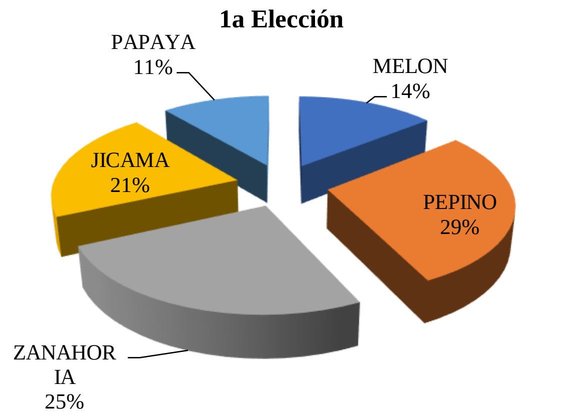
Niños de 7 a 11 años de edad sin compañía

Men	Women	Total
216	248	464

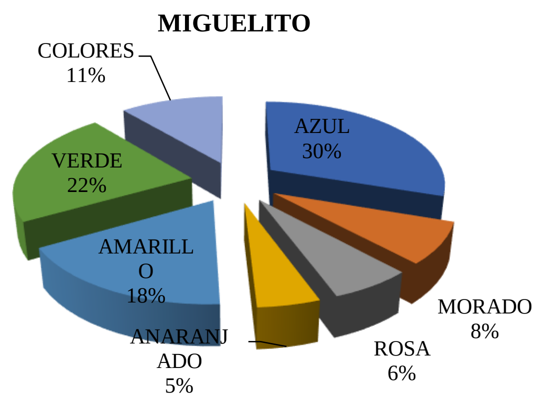




Fist Elección	
Melon	42
Pepino	62
Zanahoria	48
Jicama	53
Papaya	33
	238

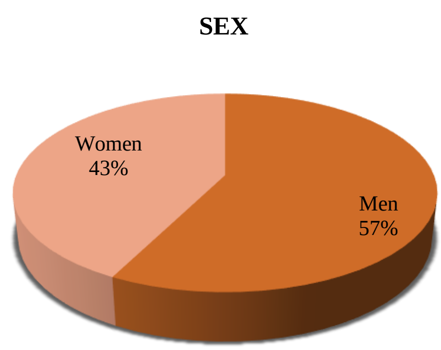


Bittersweet						
Blue	Purple	Pink	Orange	Yellow	Green	Colors
13	7	3	2	1	14	18

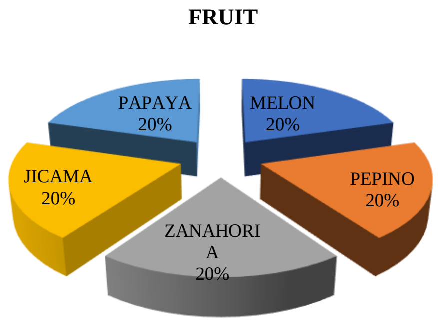


Jovenes de 18 a 21 años

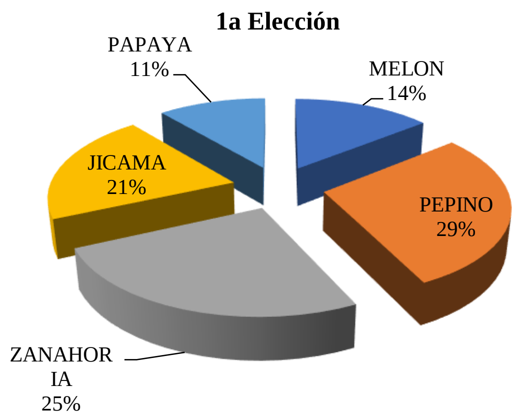
Men	Women	Total
73	54	127



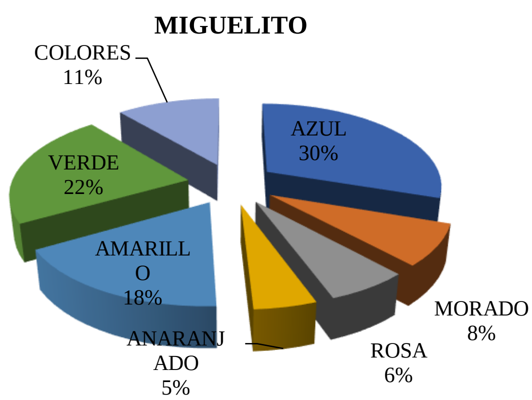
Fruit					
Melon	Cucumber	Carrot	Jicama	Papaya	Total
19	24	24	24	19	110



Fist Elección	
Melon	26
Pepino	25
Zanahoria	25
Jicama	25
Papaya	26
	127



Bittersweet						
Blue	Purple	Pink	Orange	Yellow	Green	Colors



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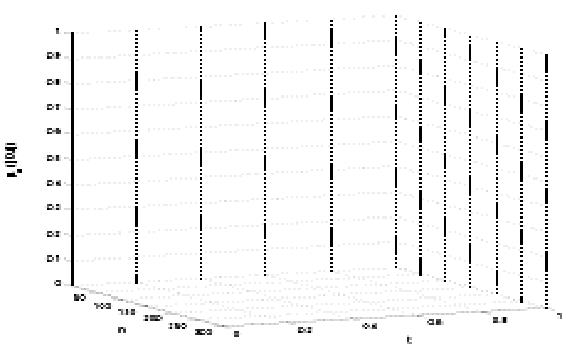

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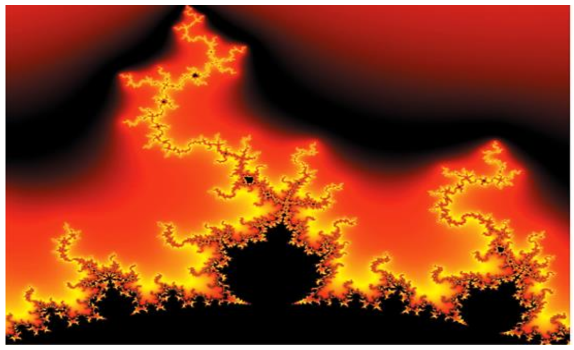

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