

INNOVATION IN BIOMASS DIGESTION WITH THE PRODUCTION OF SEMICONDUCTOR NANOSENSORS FOR BIOELECTRONICS

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Highlights

- Did you know that contaminated mangroves can help clean the environment and even become technology?
- Facultative filamentous fungi are like the “invisible workers” that make the magic happen.
- Semiconductors are a material that makes it possible to make chips, like the “brain of cell phones and electronic devices”

Introduction

In the contemporary world, daily activities require greater communication to exchange information, which requires greater development in the electronics industry. Here, anaerobic digestion of environmental waste is used as a producer of raw materials: semiconductors in biotechnological advancement, obtained from the digestion of facultative fungi. The bioremediation process was carried out with filamentous fungi and castor oil in mangrove sediment contaminated with petroleum, in order to remove contaminants from the sediment, obtaining a crystallized and semiconductor protein product. As is known, filamentous fungi are recognized for their high capacity to produce lipase enzymes, and as they are extracellular they contribute to the recovery process. This received Patent Letter BR PI 1105934-6 on 09/08/2022, PROCESS OF OBTAINING BIOSENSOR AND ENZYMATIC BIOACTIVE BIOSENSOR, proving to be Electromagnetic, having Protein, Enzyme and Amide Compounds. Currently participating in the Centelha 2 Project, Fapesb-BA.

The microbial agents *Aspergillus tamari* and *Fusarium solani* fungi are deposited in the Tropical Cultures Collection, André Tosello Foundation, SP. The product was characterized in physical/chemical analyses and showed strong potential for application in the bioelectronics industry. Scanning Electron Microscopy (SEM) with Energy Dispersive Spectroscopy (EDS) composition was used to characterize the inorganic elements. Semiconductors are particles, miniaturized compounds that involve nanotechnology and can be produced on a large scale. Thus, it was analyzed with the NANOSIZER (nm) technique, whose particle size is measured by dynamic light scattering. It is a measure of the surface charge developed for spherical particles detected by the Zeta Potential.

There was research in organic chemistry with nitrogen analysis for protein, due to it being a microbial production and peptide bonds of mangroves with the breakdown of molecules of polycyclic aromatic compounds of hydrocarbons in the ecosystem. Differential Scanning Calorimetry (DSC) is an analytical technique to characterize the stability of a protein or other biomolecule in its native form. FTIR is an infrared spectroscopy analysis to indicate amide and molecular organic compounds in organic chemistry.

In this profile, the work proposes to characterize and validate for commercialization a semiconductor raw material, obtained through the anaerobic digestion of solid mangrove oil exudate with potential for application in the integrated electronic systems industry, it is an electromagnetic sensor for the microelectronics sector. A biotransformed environmental waste product, an enzymatic protein crystallized, obtained through the bioremediation process with facultative anaerobic fungi, with application in the bioelectronics and pharmaceuticals industry.

Material and Methods

The methodology of a microbial consortium PI 1105934-6 of 2022 of biofuel byproducts, associated with facultative anaerobic microorganisms, with initial anaerobic digestion in the decomposition of organic matter from mangrove oil exudate and castor oil. These were processed with their percentages duly quantified, the mixture was subjected to a temperature increase of up to 87°C, for 3 minutes of agitation. After resting, the sludge-type inoculum was seeded in Petri dishes and sealed to allow microbial replication. It was then replicated individually for 1,600 kg of pasty mass, in ten (10) glass plates, 40 x 40 cm with lid and sealed. Remaining for three (3) months for proliferation and biotransformation combined with anaerobic digestion, inside a prototype “Treatment Station”. Initially, the process occurs by hydrolysis, in



the solid phase, in which the organic matter is converted into soluble material and absorbed as a nutrient by the decomposing fungi. However, this hydrolysis stage is considered limiting in the anaerobic digestion of solid waste or effluents when they have a high concentration of solids (GUO et al., 2014). Next, the acetogenesis process phase occurs, with alcoholic fermentation to be metabolized, with the production of biogas. These volatiles, inorganic carbon, and microparticles are trapped in bioactive halite crystals. Following the biotransformation of the clayey substrate of the ecosystem, sulfidegenesis also occurs with the reduction of sulfides for microbial metabolism and contributing to the production of organic macromolecules, peptides from mangrove microorganisms.

The work was accepted in Notice No. 3/2022 – Fapesb/Secti Notice – Centelha II to enable the commercialization of nanosensor crystals, with strong semiconductor potential, being considered raw material for the Bioelectronics industries.

The results of Scanning Electron Microscopy (SEM) measurements with Energy Dispersive Spectroscopy (EDS) composition of Mangrove Crystals - CM samples of fungi are presented. In this panorama, the use of silicon stands out, aimed at application in electronics in the format of small miniaturized sheets categorized as chips (Xiang et al., 2021; Wang; Liu; Zhou, 2022). NANOSIZER analysis (nm) - The particle size distribution was measured by dynamic light scattering (DLS, Zetasizer Nano S, Malvern Instr., UK). 200mg of the solid material (lyophilized live fungi) were dispersed in 5mL of ultrapure water, then vortexed for 10 min and centrifuged for 10 min at 3000 rpm, and the supernatant was analyzed for size, PDI and PZ. However, for such application, the compound used as a molecular semiconductor must present two essential properties, which are: structural stability and electrical neutrality (Gao, 2021; Schweicher, 2020).

Next, organic nitrogen analysis for proteins was performed, beginning the studies of the product's organic molecules. For DSC - Differential Scanning Calorimetry, 0.2g of the sample was weighed; a rate of 10°C/min was scanned; in atm of Nitrogen; this was heated from 25°C until reaching 600 °C; the data were treated with OriginLabOriginPro8.1.88.89 SR2 software. In FTIR - the spectroscopy analysis in the infrared region was performed using 3mg of the sample for 100 of KBr, in a Shimadzu IR-TRACE100 spectrophotometer, with scanning from 4000 to 400 cm⁻¹ and resolution 2 cm⁻¹. The CM sample was dried in a desiccator for 2h before measurement. The tablet was prepared in the proportion of 5 mg of the sample in 96 mg of KBr.

Results and Discussion

The entire substrate of the plates was biotransformed into a crystallized form after 3 months, becoming a raw material, a bioactive product with semiconductor potential. These were analyzed using physical/chemical techniques, namely: measurements in SEM microscopy of an elemental composition with the respective measurement conditions. The composition results indicate a composition of several components such as: Carbon, Oxygen, Silicon, Potassium, Calcium, Magnesium, Sulfur, Calcium and Sodium. All emissions are of type K. Here, the use of Silicon stands out, aimed at application in electronics in the format of small miniaturized sheets categorized as chips (Xiang et al., 2021).

NANOSIZER measurements (nm), the analysis of the average hydrodynamic diameter of the nanoparticles dispersed in the solutions showed an average size of 61.44 nm, satisfying the requirements that the particles are in the nanometric scale even with dispersion (Morais, 2021). Regarding the polydispersity index, values such as: PDI < 0.1, 0.1 - 0.4 and > 0.4 represent highly dispersed, moderately dispersed and colloidal solutions, respectively (ZAIB et al., 2020). Thus, the PDI obtained can be explained by the fact that it is a cylindrical structure, which may have interfered with the dispersion through the length of the tube, which can vary from 1 to 25µm, which will be better evaluated with microscopy analysis. Furthermore, despite a PDI that expresses heterogeneity in the dispersion of the nanostructures, the graph shows a monomodal sample with a narrow size distribution. For the Zeta Potential value (FIGURE 1a), this expresses the propensity for agglomeration, however, the average value around 19 mV presents good stability (SALOPEK et al., 1992; CLOGSTON; PATRI, 2011), (FIGURE 2). These results indicate that the dispersion is composed of nanometric nanostructures (carbon nanotube) with good stability. For DSC - Differential Scanning Calorimetry, exothermic events are observed that characterize the crystallinity of the carbon nanotube (ZHU, P.; CHEN, J.; WU). This is the combustion stage of the carbon nanotubes. The endothermic peaks, identified in red, are characteristic of the melting point temperature range of the material (FIGURE 1b). They represent the loss of mass of amorphous carbon product of the synthesis route.

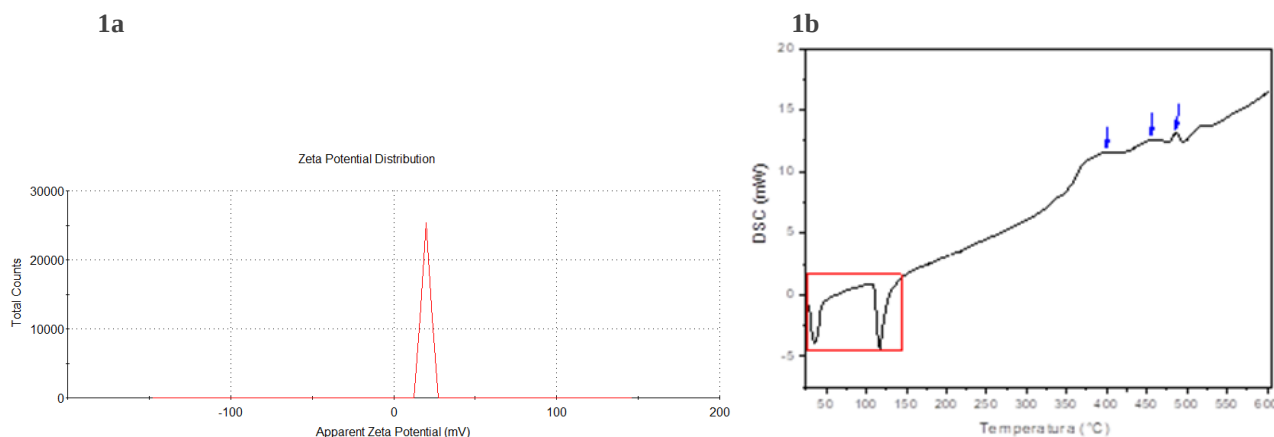


Figure 1a. Analysis of the Zeta potential of the sample. **Figure 1b.** DSC shows crystallinity, temperature range carbon nanotube.

FTIR - Infrared Spectroscopy Analysis on glass plates (FIGURE 2a)- As a result, the band at 3413 cm^{-1} appears, characteristic of the axial deformation of the N–H bond present in the imide functional group. It is noted that when digestion is applied to waste treatment, the low removal of nitrogen and phosphorus nutrients after digestion becomes an advantage due to the high concentration of these, which allows its use as fertilizer (CHERNICHARO, 2007; JABŁOŃSKI et al., 2015). An experimental study of continuous mesophilic anaerobic digestion of manure was also carried out. The bands at 2926 cm^{-1} and 2851 cm^{-1} correspond to the deformation of the C–H bonds in aliphatic groups. The band at 1640 cm^{-1} is attributed to the characteristic stretching of the C=O bond of amides. In this context, it is observed that a reducing agent such as cysteine needs to document its anaerobic conditions, to eliminate small amounts of oxygen that may be introduced unnoticed (Brook, 2011a; Nagy et al., 2018). The band located at 1462 cm^{-1} is related to the stretching of the C=C bond in aromatic rings. There is also a band at 1036 cm^{-1} related to the Si-O stretching (FIGURE 2b).

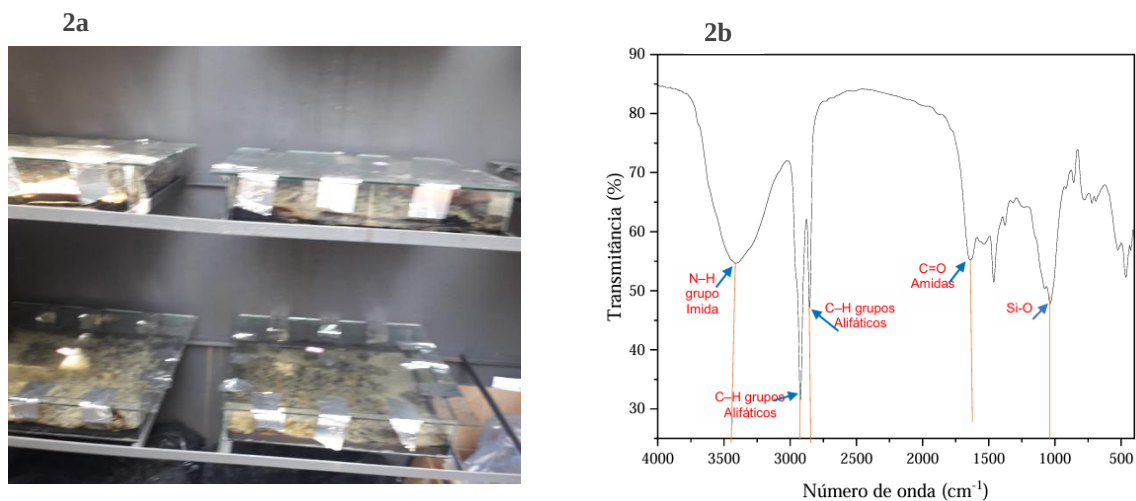


Figure 2a. Image of glass plates with microbial consortium. **Figure 2b.** FTIR vibrational spectrum of sample in KBr tablet.

With the initial Nitrogen and protein test with a sterilized sample, the result $\sum 5.98$ described in Table 1, of the Standard Deviation, is shown below.

Table 1. Standard Deviation of the Nitrogen and protein test $\sum 5.98$.

CM Sample	Nitrogen (%)	Factor (X)	$\sum$	Standard Deviation
0,09	0,93	5,81	5,98	0,17
0,11	0,95	5,96		
0,10	0,99	6,16		



Conclusion

After rigorous characterization of the product obtained through facultative anaerobic digestion of solid mangrove exudate from spilled oil, it is possible to point out that through the microbial metabolism of the environmental sediment and the formulation with fungi it is possible to synthesize nanosensor compounds for raw material with semiconductor potential for application in the integrated electronic systems industry, electromagnetic systems in the microelectronics and health sectors.

The validation for commercialization of the product awakens in the industrial environment the study of anaerobic digestion in a simple, low-cost way, encouraging microbial biotransformation work with environmental waste that ceases to be harmful and reaches a cutting-edge technological space, revolutionizing science in environmental cleaning, reducing CO₂, reducing the greenhouse effect, providing greater sustainability and health to the planet.

It is concluded that anaerobic digestion becomes an indispensable process in Biotechnology because it offers innovative solutions for environmental recovery and restoration of ecosystems, becoming a biotransformed environmental waste. It is concluded that a crystallized enzymatic protein was obtained through the bioremediation process with facultative anaerobic fungi. It contains an amide chemical compound, obtained from the crystallization reaction of volatile contaminants, when subjected to the bioremediation process. This process results in the microbial production of peptide bonds from mangroves and the breakdown of molecules of polycyclic aromatic compounds from hydrocarbons in the ecosystem with application in the bioelectronic and pharmaceutical industries.

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