Paideia XXI, Vol. 13, N°1, Lima, enero-junio 2023, pp. XX-XX.
https://doi.org/10.31381/paideiaxxi.v13i1.5696

ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

ANALYTICAL SUGGESTIONS FOR THE MANUFACTURING OF SMART SENSORS BASED IN AMORPHOUS NANOSTRUCTURES, UNDER THE ANDES MOUNTAINS CONDITIONS

SUGERENCIAS ANALÍTICAS PARA LA FABRICACIÓN DE SENSORES INTELIGENTES BASADOS EN NANOESRUCTURAS AMORFAS, ANTE LAS CONDICIONES DE LAS MONTAÑAS ANDINAS

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Titulillo: Manufacturing of smart sensors

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ABSTRACT

It is proposed in this abstract some suggestions for the manufacturing of advanced sensors (smart sensors) that are based in amorphous nanostructures in order to prepare intelligent sensors from which their transducers elaboration need specific requirements, such as in geometry and material of every sample. Moreover, it is quite important the correlation understanding between the necessities of the community or company that will operate with them. It means, the manufacturing of the transducers samples can be prepared by sputtering process, atomic load deposition and also by electrochemical reactions. Hence it is suggested to analyze the chemical components that are possible to find in the Andes mountains, also the strict compromise of the responsible residual collection of every production step and caring the environment conditions. Furthermore, it is proposed that designers could get understanding of the Andes mountains conditions, because many times it is not analyzed the geographic or climatic conditions, where there will be used the devices that require sensors for many applications such as in fishing tasks, agriculture tasks, mining tasks and public transport tasks. In this context, the advantages of the sensors based on nanostructures are supported by the robustness and short response time that give more time for active applications of the sensors as part of mechanic or mechatronic systems. This advantage helps for programming possibilities by a microcontroller in order to execute adaptive algorithms and enhancing the physical measurement tasks.

Keywords: Amorphous nanostructures - geographic/climatic Andes mountains conditions - smart sensors

RESUMEN

En esta propuesta se plantean algunas sugerencias para la fabricación de sensores inteligentes basados en nanoestructuras amorfas, para lo cual la elaboración de los transductores de los sensores debe tener en cuenta la correlación entre su geometría interna (en escala nanométrica) y el material que lo compone, además de los requerimientos de la empresa que los necesite y el espacio geográfico de la comunidad donde estos sean usados. Tal es así, que la fabricación de estos sensores requiere procesos complejos cual pulverización catódica, deposición atómica, e incluso deposición atómica mediante reacciones electro-químicas. Por lo tanto, se sugiere estudiar qué minerales y componentes químicos se pueden encontrar en los alrededores de las montañas Andinas, para así poderlos usar en la fabricación de los sensores, teniendo un estricto compromiso del cuidado ambiental con los residuos acabado los procesos de fabricación. Además, se plantea tomar en cuenta la comprensión de las características geográficas y climatológicas del lugar de fabricación, cual también el lugar donde se someterá a prueba y uso de los sensores diseñados, que generalmente para las actividades de la población Andina, puede darse en la minería, pesca, agricultura y transporte público. En este contexto, los sensores diseñados en base a nanoestructuras tienen la ventaja de un corto tiempo de respuesta y robustez frente a perturbaciones, lo cual es muy útil para tareas de sistemas mecánicos o mecatrónicos donde el carácter activo de los sensores mejore el performance de las tareas, también esta ventaja es un soporte desde el punto de vista de la programación del microcontrolador que le dé el carácter de inteligencia artificial al sensor elaborado, pues permite ejecutar algoritmos complejos y adaptativos para trabajar en mejor respuesta de la transducción.

Palabras clave: Condiciones geográficas/climáticas Andinas - nanoestructuras amorfas - Sensores inteligentes

INTRODUCTION

The elaboration of advanced sensors needs very specific conditions, such as in the cleaning transducers samples task, which is given by electropolishing (electrochemical cleaning). Also for the elaboration of every Ultra-Thin Alumina Membrane (UTAM) sample is needed anodization as well as to start the procedure of the base, over which there will be stored atoms as the dependence on their materials: titanium, gold, silver, carbon and by structures: nanotubes, nanowires, nanodots, etc. (Ljung, 1994; Lei *et al*., 2006; Calderón *et al*., 2019; Calderón *et al*., 2022).

The procedure described above is expensive, because of all the needed equipment, as for example, high vacuum chambers according to prepare the atomic load deposition, even though it can be possible to use electrochemical procedure to obtain the nanostructures. Hence, it must be analyzed the procedure for the responsible residual collections, as a result it must be analyzed the budget and the responsibility of the chemical residual collection in order to not damage the environment conditions, if it is decided to produce nanostructures in industrial level. In fact, it is suggested to keep good understanding of the sensors design requirements, because the dependence with the geographic/climate effects (Hwang, 2014; Chang *et al*., 2021; Zhang *et al*., 2022; Kees & Kasper, 2023).

Furthermore, in this research there are proposed some suggestions for the smart sensors design and the mathematical procedure for the algorithms to be executed by the microcontroller of the designed smart sensors. Especially, there are proposed some suggestions of the applications for the designed sensor, such as for example, there were given by the modular systems to be used for the enhancement of combustion motors, as a proposal in this research (Lobnik *et al*., 2010; Rahman *et al*., 2014; Sonker *et al*., 2022).

The main objective in this research is given by the suggested procedure for the smart sensors manufacturing, which also is based on the transducers that were designed by amorphous nanostructures. -There are consequently specific objectives, such as the transducers design as the dependence on the transduction properties. -Besides, it is as a specific objective the non-linear mathematical analysis for the adaptive algorithms design in order to give optimal measurements. There is another specific objective is given in explained suggestions for the applications of the designed sensors in tasks, such as in agriculture, mining, fishing and public transport for which it was interpreted some consequences to be used in the public transport applications of the Andes.

MATERIALS AND METHODS

For the advanced smart sensors that were designed it is proposed to use aluminum and consequently, it is possible to prepare different geometries on nanostructures that could be based on electropolishing, anodization and atomic load deposition (Lei *et al*., 2006).

After to have prepared the samples, it is proposed the transduction design as dependence on the physical variable to measure. As for example, the measurement of flow vibration surfaces, such as it is depicted by the figure 1, in which the electromagnetic transmitter sends a signal in Infrared (IR) wavelength according to take information of the target measurement, which is a vibration surface that achieve the estimation of the physical variables of the surface target by an analysis of the frequencies between the IR wave with the vibrating surface frequency. Therefore, the IR receiver has quite important task to get the transduction of the IR wave. The transduced physical variable can be voltage, electrical current or electrical resistance represented by the resultant measured physical variable.

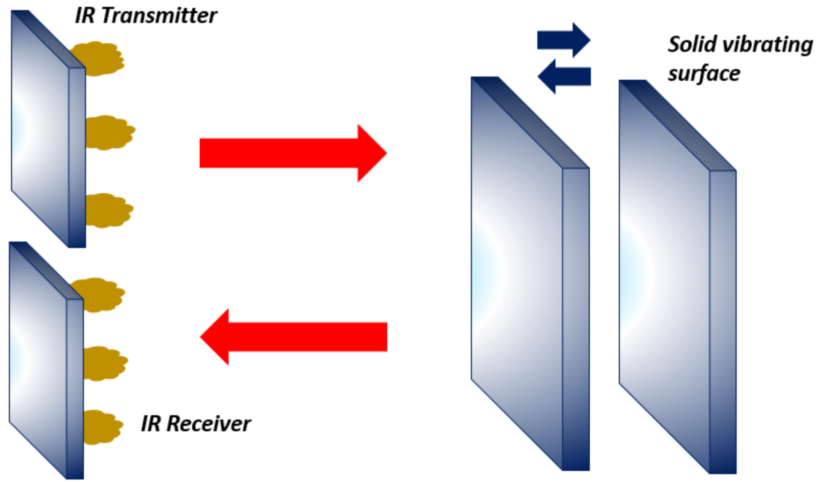

Figure 1. Proposed scheme of the IR receiver/transmitter from the designed smart sensor.

On the other hand, it is depicted the vibration transducer (by contact between the transducer sample with the target measurement that also can be gases), which has the scheme of an inverted pendulum that was based on nanoparticles that were fixed over nanotubes and finally, the transduced resultant physical variable can give information of the main target as gas temperature, gas pressure or air humidity. This depicted sensor is showed by the figure 2.

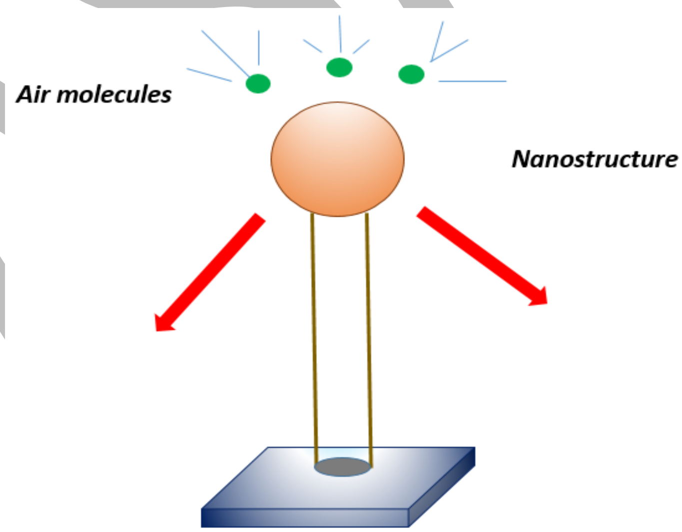

Figure 2. Proposed scheme of the vibrating transducer from the smart designed sensor.

Otherwise, the methodology to suggest the manufacturing of smart advanced sensors under the Andes mountains conditions is given by the recognizement of the geographic and climate conditions of the place, in which samples of the advanced sensors will be created the and also of the place, where they will be used.

Of course, a simple answer is given through the protocols of the laboratory, in which will be prepared the nanostructures samples. Nevertheless, it is assumed that the laboratory must to keep the conditions whereas it must be analyzed the residual reactions, according to not damage the environment conditions. It is necessary to know, what minerals can be possible to find in mining around the laboratory, because to be used in the material analysis of the transducer samples elaboration.

Furthermore, while it is known the requirement for which will be used the sensor, it is necessary to know if the adaptive algorithm detects the external parameters and no matter where to use the designed sensor that was based in the adaptive properties. Notwithstanding, the manufacturing of the advanced sensor can contribute to the development of the community by the engineering applications.

The next step of the proposed methodology is based on the understanding of the theory and practice for the advanced sensors design. Therefore, it is proposed to start the theoretical analysis by the Schrödinger equation as it is showed by the equation (1), in which "$\hbar$" is the Planck constant, "Ψ" is the wave function for the particle or molecule in the position "x" and time "t", and "m" is the mass. The equation (1) is a non-relativistic model of the Schrödinger equation (Wichmann, 1971).

$$i\hbar \frac{d}{dt}\Psi(x,t) = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\Psi(x,t) \qquad (1)$$

The equation (2) is another presentation of the non-relativistic Schrödinger equation that gives presentation of its wave behavior (Wichmann, 1971).

$$i\hbar \frac{d}{dt}\Psi(x,t) + \frac{\hbar^2}{2m}\nabla^2\Psi(x,t) = 0 \qquad (2)$$

One solution is obtained by the equation (3), in which "E" is the energy level of the particle (Wichmann, 1971).

$$\Psi(x,t) = \varphi(x)\exp(-\frac{itE}{\hbar}) \qquad (3)$$

As well as "$\varphi(x)$" is the amplitude that depends on "m", "$\hbar$", "E", and "V" that is the achieved potential when it is analyzed the voltage effect of the charged particle in the equation (2). This dependence can be found by the function "f" as the behavior of a particle or molecule in the Schrödinger equation. Therefore, the amplitude "$\varphi(x)$" is given by the equation (4).

$$\varphi(x) = f(m, V, \hbar, E) \tag{4}$$

Furthermore, the potential function is also in dependence on "m", "$\hbar$", and "E", by the function "g" that also can be found the behavior of a charged particle or molecule in the Schrödinger model of the equation (2). Hence, the potential is given by the equation (5).

$$V = g(m, \hbar, E) \tag{5}$$

As a consequence, the Schrödinger analysis that was described in paragraphs above can help to understand the wave-particle behavior of the interaction between the particles-molecules that are part of the target measurement system, such as the task to measure pressure, temperature, volume, flow of gases, liquids or solids, with the particles-molecules of the contact surface of the transducer sample. This interaction is quite important to research, in order to get good understanding of an optimal transduction for the physical variables measurement of the designed smart sensor, for which the Schrödinger equation gave support in order to prevent the nature of the particle as a wave or as a particle as part of the interaction. Hence the non-relativistic Schrödinger equation was based in not fast movement of the particles in interaction (not so proximal to the speed of light) is the theoretical model to get information of the transduction. Nevertheless, it must be analyzed cases of relativity, while it is working with non-contact physical variables measurement, because the interaction is based in the package of information that is obtained by the selected electromagnetic wave that gives the information of the physical variable under the transduction effect (Wichmann, 1971).

Whereas the main task of the designed smart sensor is the measurement of the target object physical variables by short response time and high robustness, which is achieved because of the amorphous nanostructures as part of the designed transducer sample. Consequently, it is possible to use a microcontroller to execute advanced and adaptive algorithms to give optimal measured data due to the short response time of the measurement that can give time to execute the adaptive algorithms for the optimal measurement.

In this research, it was used a polynomial analysis in order to get a mathematical model for the analysis and interpretation of the data that was achieved from the experiments (measurements), which is based on

"Modulating Functions" owing to get the correlation among the measurement information with a theoretical model to get an optimal estimation of physical variables complementing the main measurement. The modulating function model is given by the equation (6), in which "$y(t)$" is the output variable as an array or a matrix of output variables, "$u(t)$" is the input variable as an array or a matrix of input variables, the derivatives can be generalized to order "n", because to find the appropriated polynomial model and as a consequence of every coefficient "a" and "b" that by the auxiliary variable "i" can fix matrixes of parameters for the "a" and "b" respectively (Pearson, 1995).

$$\frac{d^n}{dt^n}y(t) + \sum_{i=1}^{n} a_i \frac{d^{n-i}}{dt^n}y(t) = \sum_{i=1}^{n} b_i \frac{d^{n-i}}{dt^n}u(t) + e(t) \qquad (6)$$

Therefore, the error model in order to achieve the parameters of the mathematical model is obtained by introducing a modulated function "$\Phi(t)$" in the main model, as for example, in a second order model that is proposed by the equation (7), as well as the error in the proposed analysis is obtained by the integration in the domain from 0 to a time parameter "T" (Pearson, 1995).

$$\int_0^T \Phi(t)\,[\frac{d^2}{dt^2}y(t) + a_1\frac{d}{dt}y(t) + a_2 y(t) - b_1 u(t)]dt = e(t) \qquad (7)$$

According to keep the error model, there are proposed the following equations (8) and (9) as the part of equation above (Pearson, 1995).

$$I = \int_0^T \Phi(t)\frac{d^2}{dt^2}y(t) \qquad (8)$$

$$II = \int_0^T \Phi(t)\,a_1\frac{d}{dt}y(t)dt \qquad (9)$$

By integral analysis solutions, the equations (8) and (9) are reduced to the following equations (10) and (11) (Pearson, 1995).

$$I = \big(\Phi(T)dy(T) - \Phi(0)dy(0)\big) - \big(d\Phi(T)y(T) - d\Phi(0)y(0)\big) + \int_0^T \Phi(t)\frac{d^2}{dt^2}y(t) \qquad (10)$$

$$II = a_1\big(\Phi(T)y(T) - \Phi(0)y(0)\big) - a_1 \int_0^T y(t)\frac{d}{dt}\Phi(t)\,dt \qquad (11)$$

For which the Boundary Condition (BC) is given by the equation (12) that is obtained from the equations (10) and (11) described above (Pearson, 1995).

$$BC = a_1\big(\Phi(T)y(T) - \Phi(0)y(0)\big) - \big(d\Phi(T)y(T) - d\Phi(0)y(0)\big) + \big(\Phi(T)dy(T) - \Phi(0)dy(0)\big) \qquad (12)$$

Therefore, reorganizing the equation (7), it is achieved the equation (13) (Pearson, 1995).

$$I + II + \int_0^T \Phi(t)\,[a_2y(t) - b_1u(t)]dt = e(t) \qquad (13)$$

For which, replacing the equations (10), (11) and (12) in the equation (13), it is obtained the equation (14) (Pearson, 1995).

$$\int_0^T y(t)\frac{d^2}{dt^2}\Phi(t)dt - a_1\int_0^T y(t)\frac{d}{dt}\Phi(t)\,dt + a_2\int_0^T \Phi(t)\,y(t)dt$$
$$-b_1\int_0^T \Phi(t)\,u(t)dt + BC = e(t) \qquad (14)$$

Whereas, if the BC gets null value, as an assumption for the final solution of the equation (14), it can be proposed the following equation (15) that gives information of the identified parameter of the main measured system with the solved correlation between the modulated function with the response variable according to get an error equation (Pearson, 1995).

$$\gamma_0 - a_1\gamma_1 + a_2\gamma_2 - b_1\gamma_3 = e(t) \qquad (15)$$

By other side, also it is possible to find the parameters by the matrix "θ", which is proposed in the equation (16), because of costing function analysis (Wang, 2009).

$$e^2 = (y - x\theta)^T(y - x\theta) \qquad (16)$$

Hence, e^2 is the costing function "J" that is given by the equation (17) (Wang, 2009).

$$J = (y - x\theta)^T(y - x\theta) \qquad (17)$$

The equation (18) is an expansion of the equation (17) (Wang, 2009).

$$J = y^T y - 2x^T\theta^T y + x^T\theta^T x\theta \qquad (18)$$

For the context $\frac{d}{d\theta}J$ equal to zero, it is possible to obtain the parameters "θ" of the polynomial model, which is given by the equation (19) (Wang, 2009).

$$\theta = (x^T x)^{-1} x^T y \qquad (19)$$

However, the Least Mean Square (LMS) analysis helps to get an adaptive filtering for every input signal, as well as some estimations for expected physical variables in the measurement process. In the figure 3 it is depicted the curve "*C*", which can be given from data experiment, the straights "*L1*" and "*L2*" proportionate information of the relation between the costing function with the weight matrix by a recursive criterium (Calderón *et al*., 2019, 2022).

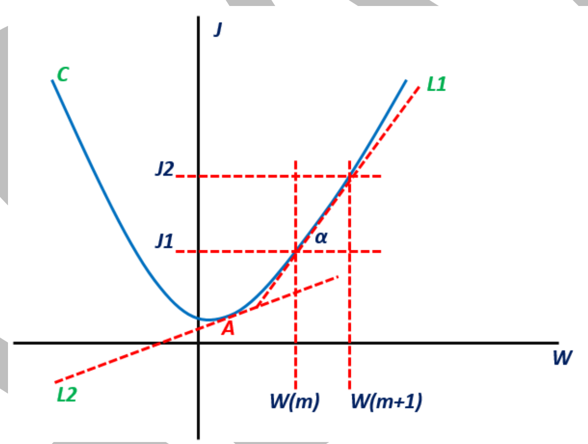

Figure 3. Geometric representation of the adaptive algorithm by LMS analysis.

From the figure above, it is obtained the tangent of the angle "α", in dependence of the costing functions "*J*" for the positions 1 and 2, as well as in dependence on the weights "*W*" for the positions "*m*" and "*m+1*", which is proposed by the equation (20) (Calderón *et al*., 2019, 2022).

$$\tan(\alpha) = \frac{J_2 - J_1}{W_m - W_{m+1}} \qquad (20)$$

From the previous equation, the difference of the both costing functions values is given by the error square "e^2", which is proposed in the following equation (21) (Calderón *et al*., 2019, 2022).

$$W_m - W_{m+1} = \frac{e^2}{\tan(\alpha)} \tag{21}$$

On the other hand, the previous equation can be reduced to the point "*A*" analysis by derivative of the error square depending the weight "*W*" and the adjusted coefficient "σ", which is proposed on the following equation (22). (Calderón *et al*., 2019, 2022).

$$W_n = W_{n+1} + \sigma \frac{d}{dW} e^2 \tag{22}$$

Hence, looking for a reduction of the equation (22) to an infinitive point of the curve "*C*" (figure 3), such as it is given in the point "*A*" by a derivative strategy it is obtained the equation (23) (Calderón *et al*., 2019, 2022).

$$W_n = W_{n+1} + \sigma \frac{d}{de} e^2 \frac{de}{dW} \tag{23}$$

In the equation (24) it is continued the derivative analysis, but it is replaced the error "*e*" by the difference among the desired signal "*D*" with the estimated signal "*XW*" that has the dependence on the internal variable "*X*" with the weight matrix "*W*" (Calderón *et al*., 2019, 2022).

$$W_n = W_{n+1} + \sigma 2e \frac{d(D - XW)}{dW} \tag{24}$$

Finally, it is possible to achieve the recursive equation known as LMS algorithm by the equation (25), in which the adjusted coefficient "μ" is a function of the previous coefficient "σ" (Calderón *et al*., 2019, 2022).

$$W_n = W_{n+1} - \mu e X \tag{25}$$

Moreover, the adapted response by LMS is given by the equation (26) (Calderón *et al*. 2019, 2022).

$$Y_e = X W_n \tag{26}$$

Indeed, the manufacturing of smart sensors based in nanostructures needs a good understanding of the requirements of the target sensor to elaborate, such as for example to know, what physical variable will measure the designed sensor or what material and geometry to use in the sample transducers of the designed sensor. Also to know, whether the laboratory is localized near a mining according to provide some minerals that can be useful for the transducer composition to elaborate. As well as to know the geographic and climate conditions of the place, where is localized the laboratory, because of to know what external disturbances could be possible to appear during the measurements and where to store the residuals components that were achieved during the sensors elaboration in order to care the environment condition by caring the residual components evacuation after the reactions of the sensors manufacturing, that means the result of all the elaboration process of smart sensors that were based in nanostructures.

The paragraph above is depicted by the two blue arrows in the entrance and exit of the back square in the figure 4. Otherwise, the two red arrows at the entrance and exit of the blue box inside the back square represent the measured data and the adaptive/filtered/estimated data that were achieved by the designed smart sensor. Inside the blue box is depicted the procedure that made by the microcontroller according to process the information from the transducers that are in interaction with the target to measure its physical variables (contact measurement). Either, another option to measure is given through the non-contact with the target to measure because of there is an electromagnetic wave to get the information of the physical variables to measure from the target. For both contexts that are described above, it is executed an adaptive algorithm that was based in modulating functions for the polynomial analysis of the transduced data and previous filtered by LMS, taking reference a theoretical model of the physical variable to look for. Moreover, the algorithm has in reference the Schrödinger analysis in order to take care the transduction effect by the interaction between the target to make measurements as the dependence on the particles interaction in nanoscale, such as the wave-particle behavior in atomic scale around. Therefore, the measured data as a consequence of the designed smart sensor can execute complicated algorithms, because of the short response time and high robustness from the designed transducers that were based in amorphous nanostructures. (Calderón *et al*., 2019, 2022).

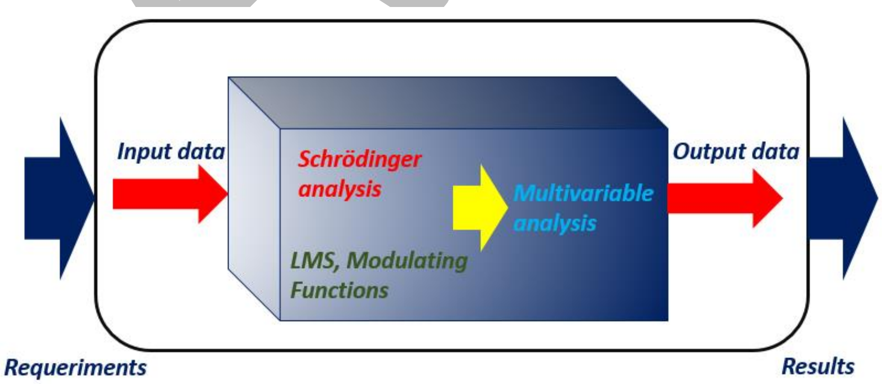

Figure 4. Scheme representation of the proposed methodology for the smart sensors manufacturing.

Ethical aspects: This research has not ethical conflicts in the proposed article, it was cited every bibliographic reference for every described analysis.

RESULTS AND DISCUSSION

The result analysis of the proposed research is based in the simulation and experimental analysis results as a consequence of the previous mathematical analysis explained in chapters above. For the simulation analysis, it was simulated a second order system in order to explain an ideal signal to follow by the adaptive models, even though this model gives a theoretical criterion of the referential signal for the adaptive measurements. Therefore, the adaptive model can keep in reference an ideal model (supported by theoretical analysis) even though many times it is not so simple to find a theoretical model according to keep it as a reference. Hence, in this context it is necessary to keep as a reference a filtered input signal, while it is known an estimation of the added external noise (Lei *et al*. 2006).

Otherwise, it is necessary to know that the parameters of the designed transducer can be the correlation between the system in its nanoscale (as the dependence on its geometry and materials) with the external macro system that is given by the transducer in fact. In summary, this process is executed by the algorithm of the microcontroller of the designed sensor that is represented by the flowchart of the figure 5.

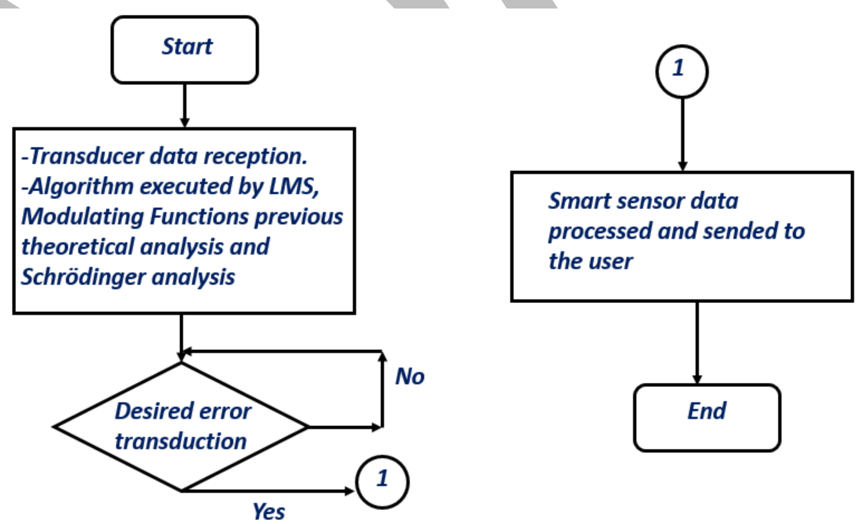

Figure 5. Flowchart of the algorithm designed for the microcontroller of the smart sensor.

There are quite important characteristics (geometrical and material) that recognized the designed transducer as part of the designed sensor (De Berredo-Peixoto *et al*., 2010). The transduction task is given by the interaction effect between the target to measure its physical variables, such as for example to measure the temperature, pressure, vibration, distance as the dependence of the object to measure with the designed sensor, also the target measurement can be a solid, a fluid or a gas. Moreover, there is a medium between the objective measurement with the designed sensor. The transduction effect can be given by contact even though it cannot be totally in contact among the transducer with the target measurement, because of for example, there are some particles or molecules of different composition of the target measurement with the transducer, between the surface of high temperature with a fixed thermocouple. Otherwise, for non-contact measurement, it can be achieved the measurement through the electromagnetic wave that could get interaction between the target measurement, the medium and the transducer. Perhaps, in future the quantum coherence in sensors could make that the time delays would be obtained between the interaction of the target measurement with the transducer could tend to be instantaneous and could not depend of the separation distance (García *et al*., 2021). As a consequence, whether the transducer can be defined by the material, the geometry and structure it can help for the optimal measurement due to more appropriated energy transmission as an effect of the transducer. The proposed sensors of the described work in this article are designed for contact measurement or wireless measurement. Moreover, it is described by Schrödinger equation the relationship between the electrons and atoms between the target measurement with the transducer structure. It is necessary to analyze that the short response time and the robustness in the physical variable measurement over the target has correlation with the material and geometry/structure of the transducer, but the traditional transducers have not this effect. However, in this research is proposed this task and importance for the measurement of physical variables, hence, while it is achieved short response time and robustness during the measurement then it is possible to use the short response time according to give sophisticated function over the transducer, as for example, the artificial intelligence as it is known by the smart sensor (Wichmann, 1971; Calderón *et al.,* 2019, 2022).

In the figure 6, there are subfigures A, B, and C that are showed regarding the nanostructures designed for the transducer samples of the smart sensor. The subfigure A shows a sample that is based on nanostructures of ferric particles that were stored over amorphous nanoholes of Anodic Aluminum Oxide (AAO). The subfigure B shows blocks of structures that were based on nanoparticles of Calcium Carbonate. The subfigure C shows nanoparticles of sodium that were stored over amorphous nanoholes that were based on AAO. For every nanostructure showed in the subfigures above, the overage size is around 1000 nm, hence, it was possible to show them by an optic microscope (Lei *et al*., 2006).

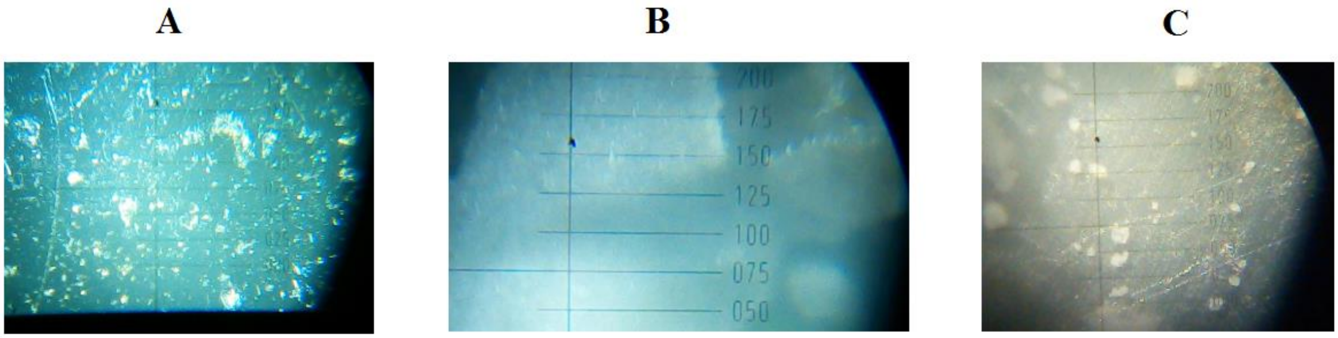

Figure 6. Designed nanostructures over samples that are based on AAO amorphous nanoholes.

There were made experiments according to evaluate the performance of the designed sensors, some applications were given for the measurement of the combustion motor surface vibration, according to give this information to the user and it could be possible to get understanding of the behavior of the motor, whether it needs reparation either it could need an analysis of the right selection of the used fuel for the combustion.

Therefore, in the figure 7 it is showed the expected vibration curve in voltage equivalent (blue color curve), over which it is showed the experimental curve of the amplitude vibration of the surface combustion motor vibration in voltage equivalent (red color curve) achieved by a piezoelectric sensor, as well as it is showed the archived measurements by the designed smart sensor in voltage equivalent (green color curve).

In the figure 7 there are two graphs and the first one shows the amplitude vibration that was analyzed lines above. Furthermore, the second graph shows the error of the measurement, in which the blue color curve is the result of the comparison between the theoretical curve with the data that was given by the designed smart sensor, the green color curve is the result of the comparison between the theoretical curve with the curve data proportionated by a piezoelectric sensor.

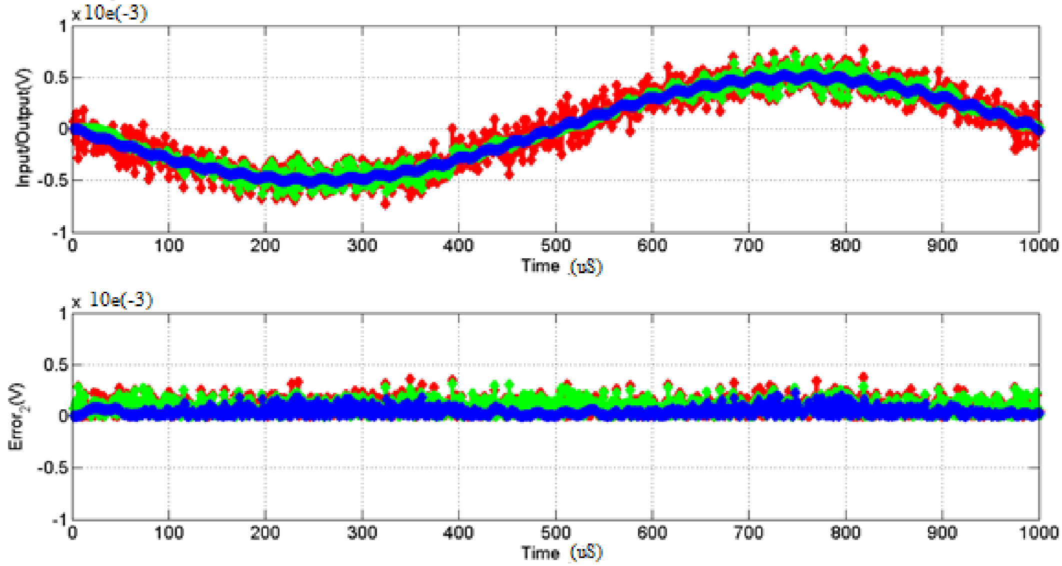

Figure 7. Experimental data analysis for the designed smart sensor.

In fact, it was analyzed in this research some proposals to elaborate smart sensors, moreover, some suggestions that the manufacturing sensors can be made in the Andes mountains of Peru, owing to keep correlation with the mining production, but always caring for the environment conditions.

Furthermore, in this research there were suggested some topics to get an optimal design for the measurement of the designed transducers, which are supported by the short response time and high robustness of the transducer samples that were based in amorphous nanostructures, as well as it was showed some applications of the designed smart sensors over combustion motors that are quite used in public transport of Perú.

ACKNOWLEDGMENT

It is expressed deep warm gratefulness to Aleksandra Ulianova de Calderón due to her support according to understand the importance of the necessity that the engineering can be quite important solution to connect the researchers of the country with its development technology, but always with respect of the own ancestral knowledge of all ethnic communities. It is expressed special thankful to Carlos Luis Calderón Soria, because of his support during the experiments and his permission to make experiments with the Nissan Frontier 2003, in which the performance of the designed smart sensor was evaluated.

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Received March 15, 2023.
Accepted May 11, 2023.