Zadeh's fuzzy sets theory in physical science

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Abstract

We consider the hierarchy of uncertainties in physical science from the point of view of Zadeh's fuzzy sets theory. The flicker noise that occurs in semiconductor devices still causes a great deal of controversy over the understanding of their origin. We can say that the reason for this is to applicate of many concepts of probability theory, such as for example conception "independence" to random phenomena without deep analyses.. Using electronic computing programs developed by the Zadeh's fuzzy sets we can say that in transistors in the appearance of flicker noise, the generation and recombination of charge carriers plays a large role.

Key words: external fluctuations, flicker noise, semiconductors, p-n junction, Zadeh's Fuzzy sets theory.

The founder of the fuzzy sets theory, professor L.A.Zadeh, have written in his review to the book entitled "Fuzzy Logic in Chemistry" that he was very astonished when he sew that this theory had found its application even in chemistry. After, he valued this beginning as necessary in development of sciences. Presently there made several steps for application of the fuzzy sets theory (FST) also in physics and in our opinion, it seems to be prospective.

The physical science studying the real world phenomena, often comes across uncertainties and therefore make the models of these phenomena that are only copy of the real nature. The types of these models connected with the evolution of physics. In its early development, physicists mainly used deterministic models. In that period Hartley^s formula was used to represent the uncertainty of the Nonspecifity type.In the next period of its development, physics, having started to consider uncertainties, included in its models probabilistic uncertainty measures of Strife^s type.The statistical physics is a product of that period.

Further, studying the micro-world, physics comes across a quantum uncertainty, Heisenberg principle, based on the probability measure. To consider the probabilistic uncertainty in that period the quantum mechanics created based on the Bayesian statistical approach.

In our view, the inclusion of the fuzzy uncertainty measure in our models will allow studying many physical phenomena at a higher level of uncertainties hierarchy. To this end the Fuzzy Sets Theory (FST), suggested by L. Zadeh [1], seems to be an adequate mathematical and philosophical technique. The previously mentioned based on the following.

A physical model, having been based on a number of assumptions, is approximate and is always characterized by some imprecision. This imprecision is resulted from the conflict between the complexity of the model and the required accuracy. Study of this imprecision, an adequate measure of which is the fuzzy measure, is a subject for FST.

Some physical laws are empirical and obtained as results of analyses of experimental data [2]. Those data are always supposed to be non-ambiguous, complete and not error-prone. Although, it is almost impossible to carry out the "pure" physical experiments that meet the mentioned features. Therefore, strict functional relations can hardly describe the real world's phenomena. Attempts to process such experiment data by statistical methods cannot always be successful due to the four hard assumptions in the statistical regression analysis. In this case, the FST can be useful technique to improve the adequacy of empirical laws of physics.

Structural analysis of various materials, for example alloys, by using the classical methods is often ineffective in its recognition ability. This inefficiency is associated with the imprecision and uncertainty of the spectrums, i.e. with overlapping of the lines in the spectrums. For this also, methods of FST can used for determining adequate structures.

There is also one important moment. In physics, the notion of entropy is very basic and it used in thermodynamics when analyzing chaotic processes. The entropy is the measure of chaos. Fuzziness in chaos, looks like entropy, can measured by an appropriate fuzzy measure.Fuzzy sets theory includes also such fuzzy categories as the possibility measure, Π, and necessity measure, N. They connected with each other as:

$\Pi(A) + \Pi(A^*) \geq 1$ (1)

Where A and A*−are two opposite fuzzy events.

As it well known, in the probability theory at studying random processes uses the probability measure, P, is used. However, when considering fuzzy processes, the possibility measure, Π, and necessity measure can be used, N, too.

The previously mentioned can summarized in the **Table** below.

Table 1. Summary of general problems of fuzzy physics

	Problems of physics	Supposed methods of solution in fuzzy logic
I	Uncertainty in physics	Possibility theory Fuzzy set theory Fuzzified evidence theory
II	Improvement(perfection) of t classical empirical physical laws	Fuzzy data analysis
III	Interpolation of theoretic regularities	Extension principle of Zadeh
IV	Structure research Structure recognition problems	Fuzzy partition Fuzzy clustering Fuzzy graph theory
V	Analysis of fluctuations and chaos	Fuzzy data analysis Fuzzy differential equations Fuzzy regression analysis Fuzzy computing

The fluctuations are a very interesting problem of physics. In FST the multivariate logic requires introduction of a new function measuring membership grade in the range [1-3] corresponding to an event. From this range, “zero” can be corresponded to an event that there are no fluctuations; and “1” can be corresponded to an event that the existing fluctuations are all of the same type (same value and same direction). However, real fluctuations generate unlimited number of fuzzy events and each element from this set can matched with a value from the range [1-5]. So, in our belief, if the fluctuations are of fuzzy nature, then some membership functions, μ, should be involved to study the appropriate processes as necessary.

It should note although that it is not purposeful to use the FST where the statistical theory well suite the researched process. Nevertheless, it is obvious that the real world processes cannot often be appropriately researched using only statistical methods. The thermal fluctuations can calculated by using Nyqvist formula; experimental results of the concentration of charges can be forecast by the statistical theory; but the case of the flicker noise (fluctuations with the spectrum 1/f where f is the frequency) is very complicated and can hardly be explained by some existing theory. It note that the flicker noise in semiconductors is the result of conductivity modulation by some chaotic processes. Therefore, the of FST is more purposeful to

such problems and the possibility distribution function is more suitable than the probability distribution function. Here and in other cases, the measure of possibility in FST can be analog of the measure of probability.
Thus, we think that the application of FST in physics has good prospects, and now only first steps made. Our first works [4-6] were devoted to consideration of the physical processes taking place in the field of semiconductor and metal contact. This border is connection of two different crystal lattices, and the processes taking place here can be subject of FST study. That work considered the voltage-current characteristics of p-n junction in fuzzy environment. The p-n junction is the contact of two semiconductors –one with positive (hole)-p, and the other with negative (electron)-n, conductivity. It is know that in the field of p-n transition some distribution in the concentrations of current, potential etc. takes place; and this distribution may be fuzzy. In our belief, the application of FST in order to consider these points should be very useful. To this point the distribution of currency carries in the field of p-n junction is considered below with application of fuzzy sets theory. In the deep n-field the surplus fuzzy concentration of holes will be:

$$\Delta P(x) = [\Delta P_n^{1\alpha}, \Delta P_n^{2\alpha}]_{x=0} \quad e^{-\frac{x}{L_p}} - \left(e^{-\frac{x}{L_p}} - e^{\frac{x}{L_p}}\right)\left[-\beta_b \sqrt{-\ln\alpha}, \beta_b \sqrt{-\ln\alpha}\right] \quad (2)$$

$$\Delta P(x) = \bigcup_\alpha \Delta\tilde{P}^\alpha(x) \quad (14).$$

It can be shown that for Ge diodes the uniform concentration of holes is $P_n = 5.7 * 10^9$ cm^{-3}. Then by using the suggested method, we can calculate the fuzzy surplus concentration of holes dependent on X and voltage U. For example, in figures 1 and 2 the dependencies of fuzzy surplus concentration of holes on X are shown for the values of voltage u1=0.2V and u2=0.4V, respectively.

These figures 1 and 2 show us that it is true to consider the reason of flicker noise in the big concentration of charge near p-n junction.

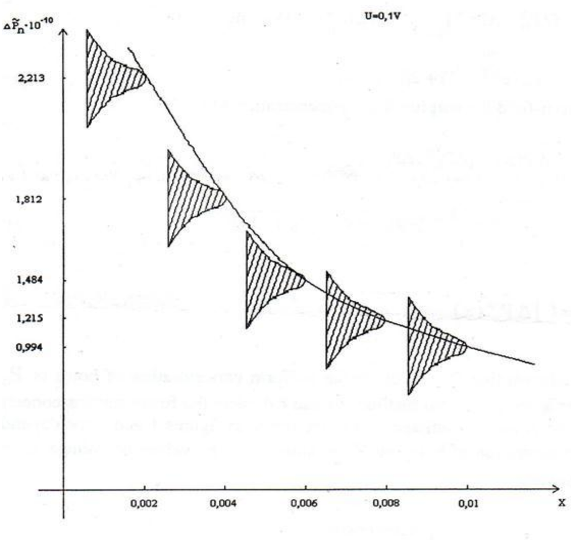

FIGURE 1

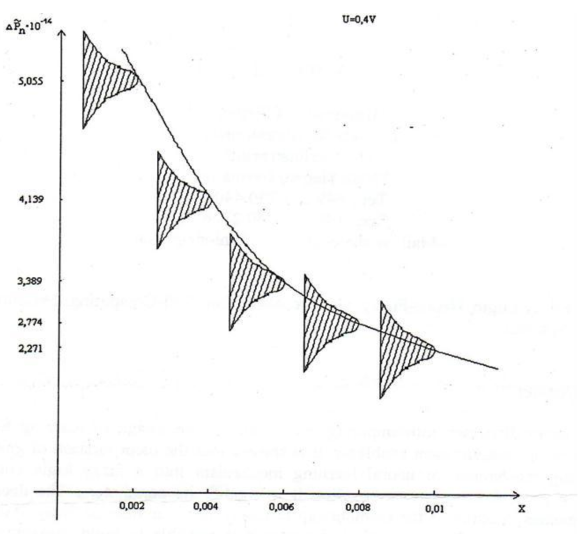

FIGURE 2

Conclusion
The task, which we have decided in this proposal, is only first small one from many like to it tasks. It is only our first try, but even it has proved us power and advisability to use Theory of Fuzzy Sets of our famous azerbaijanian scientist Lutfi Aleskerzadeh (Lotfi Zadeh) in many various problems of science. We proud of him.

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