Weak Presence of Women in Microelectronics: Analysis and Suggestions of the French Training Network to be More Attractive

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***Abstract*— The engineering sciences, and more particularly microelectronics, are a field where the presence of women is very low, although they should logically account for half of the staff. The electronics and microelectronics sectors are growing rapidly due to the development of the Internet and connected objects more generally known as the digital society. Industrialists in the field are lacking in skills and have a large number of job vacancies which are difficult to fill. These jobs cover almost all the professional facets that are entitled " Skilled manpower shortage". The arrival in this sector of a large number of female candidates could reduce this deficit and increase the sector's capacity for innovation through their difference of appreciation on many societal aspects. This paper discusses and analyses the presence of French young women in science studies from secondary school to doctorate level by linking this behavior to societal aspects. It then proposes approaches that are currently being carried out by the national academic network at the French level with the profession in the context of the implementation of an electronics sector by the government. These approaches aim to limit the loss of female candidates to other fields and to increase the attractiveness for young girls.**

Index Terms*— *Microelectronics, Electrical engineering, Low presence of women, French strategy.

I. Introduction

The engineering sciences, and more particularly microelectronics, are a field in which the presence of women is very low, although they should logically account for half of the staff, since women make up half of the human population. For nearly sixty years, electronics and microelectronics have been growing exponentially, according to a heuristic law, Moore's Law [1]. This has led to the development of increasingly complex circuits and systems that today fulfil the functions of connected objects and the Internet of Things (IoT). With this new societal evolution, the electronics and microelectronics sectors are increasingly growing and will have to face new challenges related to security [2], increasing complexity [3], multidisciplinary openness of applications [4], and energy consumption [5].

Faced with this influx of challenges and the growing need for research and development as well as production, industrialists in the field are lacking in skilled staffs and have a large number of jobs offers that are difficult to fill. These jobs cover almost all professional facets which include the different levels, from operators to doctors via technicians and engineers, and the different specialties including, the design and production of circuit components and systems covering the extended fields of frequency, power, information processing and signal transmission. The industry worldwide identifies occupations facing manpower shortages. The influx of female candidates in this electronics sector could reduce this deficit and increase the innovative capacity of the sector by their different appreciation of many societal aspects. It can be noted that this phenomenon is global and that any approach that would change it could potentially be applied anywhere in the world! It is therefore necessary, first to understand the origin of this desertion of women, second to correct the origins of this behavior, and third to find the arguments and the modifications that can make this field more attractive to them.

This article discusses and analyses the presence of young French women in scientific studies from secondary school to doctorate level, linking this behavior to societal aspects. It then proposes approaches that are currently being carried out at the French level with the profession in the context of the government's implementation of a national electronic sector. These approaches aim to limit the loss of female candidates to other fields and to increase the attractiveness for young girls.

II. Situation of the Microelectronics

A. High increase of the activities

The evolution of microelectronic technology is well known, and specialists in the field are completely aware that Moore's Law has now been overtaken by the implication of the third dimension in circuit integration and the introduction of heterogeneous assembly to increase the capacity of applications in all economic fields. Indeed, it is now possible to combine a large number of electronics-based functions as in the case of connected objects. These combine sensors and actuators, digital/analog and analog/digital conversion circuits, information storage and processing circuits, power supplies, transmit/receive circuits, etc... The number of these objects increases exponentially as does the number of sensors [6].

B. Huge multiplication of the hardware

It is currently predicted that by 2030 about 30 trillion sensors will be integrated in all applications of connected objects [7], these last reaching 110 billion. This growth is exponential, with a doubling every 4 years [8]. Under these conditions, the creation, transfer flow, storage and processing of data become gigantic since we are approaching the yottabyte (10^{24} bytes) on the planet, 1000 times more bytes than grains of sand on all the beaches of the world [9]!

C. Challenges facing the microelectronics industry

This growth has an immediate impact on the energy consumption associated with the Internet, connected objects, and the industrial revolution called "Industry 4.0" that has already begun [10]. Indeed, on average, one gigabyte transferred via the Internet induces an equivalent electricity

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consumption of 25 kWh [11]. Thus, the associated energy consumption is growing exponentially. It is multiplied by 2 every 4 years despite the efforts made by researchers and the profession. Without a radical change in the field of electronics and microelectronics, this growth in energy consumption will become an insurmountable obstacle, since in 2040 the internet could consume as much energy as all the energy consumed on the planet in 2020 in all its forms [12].

The field of electronics and microelectronics must therefore modify all approaches concerning physical objects, knowing that Computer Science domain must also make efforts by adapting software architectures to minimize processing operations. An estimate which appears realistic consists in dividing by a factor of 10 the consumption of all the objects. Industry must therefore organize innovation and increase its production capacity. In this case, the associated human resources would be the most affected and this seems to be the most important challenge.

D. The present recruitment limitations

Recent French data given by the microelectronics industrial union [13] in the frame of the new Electronic sector strategy, highlights the human resource problem. Figure 1 shows the number of recruitment projects since 2013 by the French microelectronics sector. The recruitment target has been significantly growing since 2015.

At the same time, the difficulties to recruit employees having the skills adapted to the mission whatever the level kept increasing. It is estimate that nowadays 70% of the projects are not satisfied.

In fact, the number of employees in the sector should be almost doubled. It is expected that until 2022, 220,000 new jobs in information technology will be offered [14].

Fig. 1. Recruitment shortage in the electronics sector in France. The percentage of difficulties has been increasing since 2015. In other words, the demand /offer is decreasing each year since 2015.

The first approach is to be more attractive to new graduate students who are mostly men.

The second approach would therefore consist in increasing the contribution of the female since there is an enormous margin for progress before equivalence between women and men employed in this field is achieved.

III. ORIGIN OF THE SHORTAGE IN MICROELECTRONICS FIELD

In order to better understand the situation, we must first analyze the evolution of studies from secondary to higher education in France. The first problem that has arisen for more

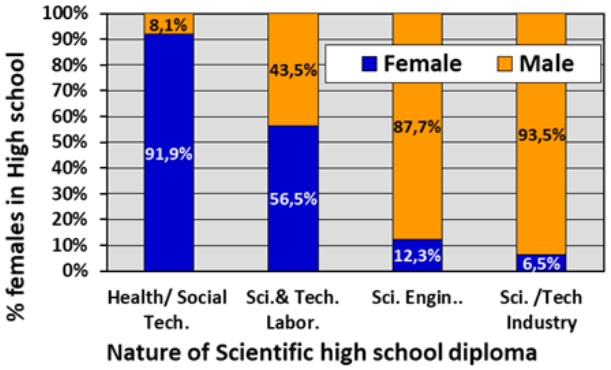

Fig. 2. Choice of optional courses by female at the end of the secondary school (High school senior class). Source: Ministry of Education.

than 20 years now is the choice of options for a scientific high school diploma. Figure 2 shows the very low level of attractiveness by scientific studies in engineering sciences and in industrial sciences and technologies for girls in comparison with health and social technologies and science and technologies of laboratories. Women account for less than 7% of candidates in industrial science and technology.

But the worst happens right after, at the entrance of university studies just after the last year of secondary school (Scientific Terminal “Sci Term”). Figure 3 shows the drastic decline of the student population towards engineering and the decreasing proportion of women within this population that becomes very low, too.

To sum up, throughout the eight years of study, the decrease in the number of women follows a "Moore's pseudo law" with a decrease of 2 every two years! Indeed, the absolute values are decreasing exponentially from High school entrance (secondary school or “Second”), last year of high school (Scientific Terminal or “Sci. Ter.”) to general engineering diploma (Engin.) entrance and masters in Information Technologies (ITC) or microelectronics engineer’s (Micro.) levels.

Figure 4 shows the percentages of women and men, for the different levels presented in Figure 3. The percentage of women in microelectronics is close to 14% for a total population coming very low!

These data in microelectronics come from the national network, the GIP-CNFM (National Coordination for Training in Microelectronics and Nanotechnologies) which

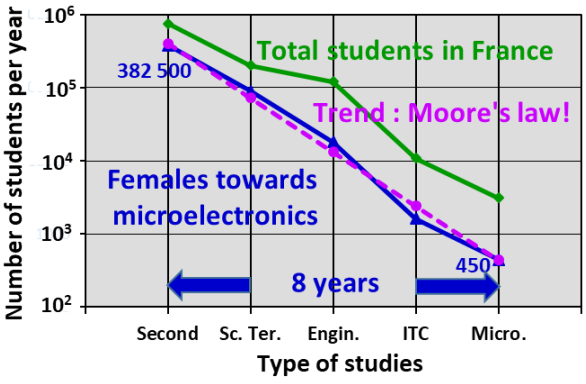

Fig. 3. From secondary school (Second) to Information technologies (ITC) and Microelectronics engineering diploma (Micro.) via scientific classes (Sc. Ter.), and engineering studies (Engin.), the number of females in France is exponentially decreasing, similarly to the Moore’s law.

organizes all the practical training activities at the national level, as already presented in the previous papers [15-16]. For the academic year 2017-2018, in the frame of a partial survey of the platform users, 450 female students out of the 3100 graduates have benefited from the technological platforms of the network, which corresponds to 14.3%, only. Just an interesting comment on PhD (or doctoral) studies in the field. In this case, more than 70% of the students in our field are of foreign origin and very often from developing countries. In this case, the proportion of women is almost twice as high. In this situation, it is quite realistic to consider that obtaining a PhD for a girl is a means of access to social advancement and in some cases of acquiring a certain degree of independence.

IV. Challenge of the French National Network

Several problems and challenges must be treated knowing that for several points the solution does not lie at the level of Higher Education but is rather at the societal and policy levels. We successively analyze the level of salary and the difference of male and female in average, then the attractivity at the level of secondary schools. Concerning the electronic sector, a number of issues are being addressed through a strong partnership with industry and more especially with managers of companies of the field.. This partnership is enhanced since the President of the CNFM academic network is President of the industry union (ACSIEL Alliance Electronique) [13] and director of STMicrolectronics Paris.

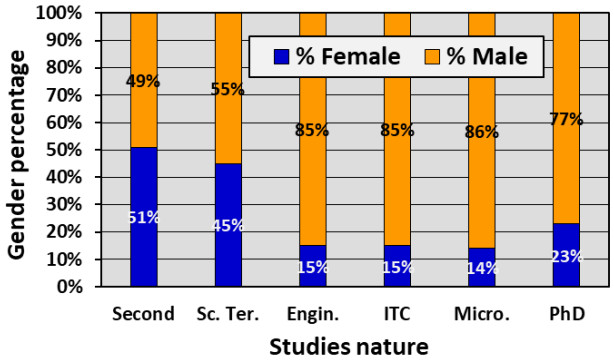

Fig. 4. Depending of the level of studies in microelectronics, the percentage of females is varying in France. In engineering and in microelectronics, this percentage is close to 14%.

A. Salary level of engineers and technicians in the electronics industry

In average, for all activity domains, in France, the difference of salary between men and women for the same activity and the same responsibility is significant [17], as shown table I. For a senior leadership job, the average net monthly wage is 26% higher for a man than for a woman.

TABLE I. Difference of Salaries between Men and Women for the Same Professional Activities.

Net Monthly Salaries by Gender in Euro			
Category	***Men***	***Women***	***% men vs women***
Senior leaderships	4377	3477	25,9%
Engineers	2396	2055	16,6%
Technicians	1681	1549	8,5%
Operators	1731	1441	20,1%

In microelectronics, the companies are making some effort to minimize this difference, but the international market is highly competitive, and this trend is coming slowly. This difference of salary can be also an explanation to the fact that the female students consider preferentially a liberal profession or self-employment rather than a salaried employment, as frequently reported.

B. Attractiveness at the level of secondary school

Specific activities in the frame of IDEFI-FINMINA project included a part of attractiveness of schoolers (students of high school) to pursue higher education studies in the field. Since 2012, each year many scientific classes of High Schools spend one day on the platforms of the national network [18-19]. In 2018-2019, about 4,000 schoolers experienced the microelectronics technologies in the twelve national interuniversity centers of the network. Figure 5 shows the increase of the awareness of schoolers in the network.

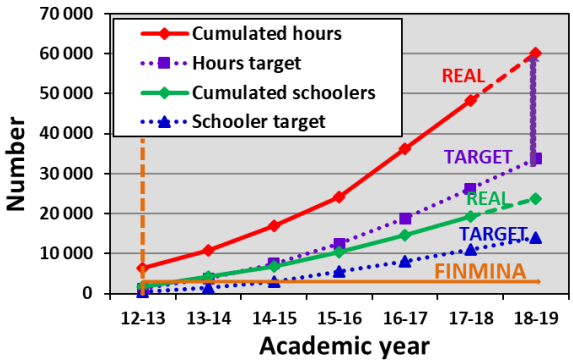

Fig. 5. Awareness of secondary schoolers who benefit from practical training on technological platforms. Thanks to a national program, the cumulated number of schoolers reached 24,000 all along the 8 years.

After this very appreciated practical one-day training, a debriefing is organized during which they have to answer a questionnaire. Our experience has shown that, on average, girls in the scientific sections are almost unanimous in directing their higher education towards medicine or paramedical activities. In this situation, one way of raising their awareness is to show them how electronics, microelectronics and connected objects can contribute to improving the quality and efficiency of medical practice. For example, it is possible to present them a platform developed in Rennes (TherA-Image [20]), which is dedicated to full surgical assistance and which avoids many complications and minimizes or even eliminates invasive surgery. This is an argument to underline that even in the field of engineering, a significant contribution to the medical world can be of prime importance.

C. Opening the microelectronics practice to multidisciplinary approach

The second approach consists in attracting them to several training courses aimed at developing activities in the field of microelectronics which will be useful for future communicating objects applied to other fields and more particularly to health.

In the framework of the IDEFI-FINMINA project [19, 21] devoted to innovation, many innovative platforms have been created over the last eight years. Thus, for instance, dedicated platforms involving BioMEMS (Micro-Electrical-Mechanical-Systems applied to biological analyses) have been set up to provide practice and know-how to students enrolled in

biology departments. As this multidisciplinary approach has proved its value, several formations have introduced this practice into their degree programs [22]. As a result, despite a decrease in practice activities by many academic institutions over the past decade, the number of students trained on the network platforms has been steadily increasing, as shown in Figure 6.

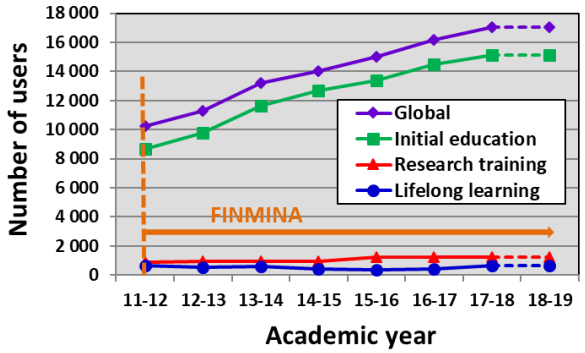

Fig. 6. Increase of the population of students thanks to a multidisciplinary approach. Among this population, a higher number of female students are counted.

The main growth is due to initial training, i.e. students preparing a bachelor's, master's or engineering degree. The activity of doctoral students is governed by the research laboratories and fluctuations are low, on average. Broadening the spectrum of activities towards fields of application has an impact on the presence of girls.

Indeed, if we analyze a sample of students having benefited from practice on innovative platforms, the most interesting result is that the number of female students has increased. Figure 7 shows the variation that corresponds in this case to an in-crease of 44%. However, the absolute percentage of female students is far from the target of 50%!

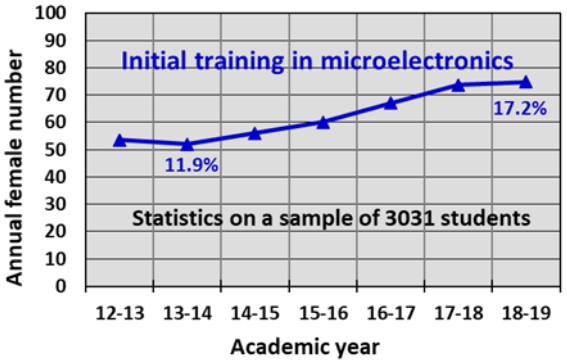

Fig. 7. Relative increase in the number of women in a sample of engineering students over the past five academic years. The relative increase is 44%. However, with only 17.2% of women, there is a significant margin of progress to be made if the 50% target is to be achieved.

V. Conclusion

We have been able to show the real situation of the low proportion of women in scientific training and more particularly in engineering sciences applied to electronics and microelectronics.

The origins of this deficit are multiple and this is why it will be necessary to act on several parameters, some of which are socio-economic and therefore difficult to control at the level of training institutions. Moreover, it is clear that the media (advertising, television series, films, etc.) do not encourage girls to engage in this type of professional activity and that they probably have a large part of the responsibility for this behavior of a large part of the population. The impact of a gender balance could be high because, after much reflection with companies, it has been found that a gender balance in an R&D team brings much more diversity and innovation to the company, as the views are often complementary for many electronics applications. The high-tech world believes that a new wealth is thus accessible. Thus, the close partnership between the national university training network and the microelectronics industries makes it possible to refine analyses and launch well-targeted operations.

Raising young people's awareness, through practical experiments on technological platforms, the implementation of innovative practical activities, the extension to multidisciplinary approaches, communication actions during events such as industrial fairs, open days, technical days, contribute to this objective. However, it is still difficult to know the real long-term effects, since many years elapse between the time young people benefit from awareness activities in secondary schools and the time they engage in an established activity in a company or research center in the field.

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