MY FIRST EXPERIENCES WITH SYNCHROTRON RADIATION

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1. FIRST CONTACT WITH SYNCHROTRON RADIATION

My experience with the use of synchrotron radiation begun 33 years ago when, in January of 1975, I started my half-year fellowship sponsored by the Italian National Research Committee (CNR) in the Laboratori Nazionali di Frascati (LNF). Frascati the town famous for a nice view and excellent local vine is situated about 20 km south-east from Rome. LNF is hidden in the surrounding Frascati hills covered by the olive grows and vineyards in a very beautiful landscape typical for the Albanese mountains. My first main task in the Laboratory, carried out jointly with Emilio Burattini, was a preparation of the hydrogenated palladium thin films for the spectroscopic studies with the use of the synchrotron light radiation from the 1.1 GeV electron synchrotron as a source. The electron synchrotron (Electronsicrotrone) in Frascati constructed by the Italian National Committee of the Nuclear Energy (CNEN) started in 1958. At that time this synchrotron was the biggest electron synchrotron of the first generation in the world, applied only to the nuclear physics research. In 1967 this synchrotron has been adapted to the synchrotron radiation extraction and to the solid state physics purposes. For me, it brought also a real possibility to apply the synchrotron radiation to the optical spectroscopy analysis of palladium. A problem of absorption of huge quantities of hydrogen in Pd was known already in XIX century. However, a mechanism of this absorption and a form of hydrogen bonding in Pd has not been satisfactory explained up to the 70 years of XX century. In contradiction to the previous models of the hydrogen atoms or protons free diffusion through Pd sample, in 1971 Estman at al [1] suggested the existence of PdH compounds in the Pd/H system. Their statement was based on the photoelectron emission spectra analysis of the hydrogenated Pd samples. For the final confirmation of this revolutionary suggestion the use of other independent experimental method was necessary. The corroboration of this suggestion could be evidently supported by the spectroscopic analysis of the electronic transitions from $4p_{1/2}$ and $4p_{3/2}$ Pd core levels to the conduction band density of states for pure and hydrogenated Pd. We proposed the idea of this experiment and carried out it with the use of the unique vacuum spectrometer and electron synchrotron operating in the 30 –60 eV energy range. A several-year experience of my Italian colleagues with the use of synchrotron radiation gave a guaranty for the success of our project. Unfortunately, in course of our measurements in 1976 the electron synchrotron has been heavily damaged, then closed and in several months rapidly dismantled. This incident stopped our interest in the Pd problem and we did not return to it in our later research. From our preliminary studies of pure and hydrogenated Pd thin films remained only a publication concerning the electrical properties of the PdH thin films with which we tested a quality of samples applied to the optical measurements [2].

2. AN EXPERIENCE WITH THE ADONE STORAGE RING

Due to the damage of the electron synchrotron me and my Italian colleagues lost the unique possibility of application of the synchrotron radiation for the solid state physics. In result of his situation in Autumn of 1976 the Italian solid state physicists from the LNF and the Institute of Physics of Rome University “La Sapienza” begun very rapidly, under the auspices of professor Franco Bassani, the construction of the synchrotron radiation beam lines. At the same time, the ADONE storage ring situated in another place of the LNF has been adapted to the solid state physics purposes. ADONE storage ring which started to work in LNF in 1969 was at that time the first in the world 1.5 GeV storage ring dedicated only to the nuclear physics applications. In 1978, after two-year ADONE reconstruction and building the synchrotron radiation beam lines the PULS (Progetto Utilizzo Luce di Sincrotrone) laboratory started to work. It was used to perform experiments in the fields of atomic and molecular spectroscopy with the use of high vacuum optical spectroscopy line in 2-30 eV energy range (Mario Piacentini), material structure with the use of X-ray absorption spectroscopy (XAS) line in 2 – 6 keV energy range (Settimio Mobilio) and photo-emission line (Paolo Perfetti). In 1980 started Wiggler XAS line in the laboratory PWA (Progetto Wiggler Adone) directed by Emilio Burattini and Adolfo Savoya. Wiggler line operated in hard X-ray energy range from about 3 keV to about 30 keV with use Ge or Si monocrystals in the double crystalline monochromator. In course of the construction and commission of the experimental facilities I was present during my short visits in Frascati in several informal discussions of the Italian constructors and was also invited to the further collaboration. During one of the meetings Giorgio Margaritondo shown us his project of the trade mark of the PULS laboratory which has been accepted and later commonly used by the PULS laboratory. The first years of the work in the PULS and PWA laboratories were not easy. The synchrotron radiation beam time dedicated by nuclear physicists for

the solid state applications was for us not sufficient. The users from Italy and abroad obtained very short periods of the synchrotron radiation dedicated beam time. ADONE worked mainly for the nuclear physicists purposes, and was often applied by them in nuclear physics experiments far from the stable work conditions of the facility. It caused that ADONE was often destroyed, or at least the modifications affected instability of the electron current for a longer time. Sometimes we waited for a long time, even several days, for the successful and stable electron injections. For the above reasons the solid state experiments with the use of the synchrotron radiation proceeded slowly.

2.1. EXAFS analysis for $Cd_{1-x}Mn_xTe$

As I remember, I obtained the first dedicated beam time from ADONE in 1979 to realize a project concerning EXAFS studies of the local disorder in $Cd_{1-x}Mn_xTe$ ternary compounds. As it is well known, at that time the unique and the best high quality $Cd_{1-x}Mn_xTe$ monocrystals in the world were produced by Professor Witold Giriat at the Institute of Physics of the Polish Accademy of Sciences in Warsaw. $Cd_{1-x}Mn_xTe$ ternary compounds were intensively studied for their very interesting electrical, magnetic and optical properties. Also me and my group from the General Physics Department of the Jagellonian University started the studies of the electronic structure of $Cd_{1-x}Mn_xTe$ with the use of the fundamental reflectivity of light. The smearing of the distinct fundamental reflectivity structure with increase of the Mn content suggested some form of the local disorder inside the monocrystalline structure [3]. It was very strange because the diffraction analysis for this monocrystals showed an excellent crystalline order. We expected the EXAFS analysis to be able to give us a correct answer. Anyone who remembers the political situation in Poland at the end of 70th will understand well that organization of the periodic visits abroad from the communistic country was not simple. My close contact with the Italian colleagues and their understanding of our political situation resulted in the direct collaboration agreement between the Institutes of Physics of the Jagellonian University and the Rome University La Sapienza. This agreement allowed me and my Polish collaborators to start and to continue the suggested by us program in the PULS laboratory. Our collaborating group consisted from the Polish side of Marek Czyżyk, Marek Podgórny, Marta Zimnal-Starnawska and me and from the Italian side of Francesco Antonangeli, Adalberto Balzarotti, Nunzio Motta and Mario Piacentini. Our relatively rare visits in Frascati and very limited runs of the synchrotron radiation dedicated beam time caused a slow progress of our measurements. Often breaks of the ADONE created a nervous atmosphere when we waited for the start of storage ring. We were also not free from the events of misfortune. I remember well one our spring visits in Frascati (probably in June 1981) when Adalberto and me waited without result for several days for the synchrotron radiation beam. Finally, on Sunday which was the last day of our dedicated time, ADONE started fortunately to work in the morning. Unfortunately, our happiness was very short, at noon a spring storm arrived and a lightning blew into the LNF power station. A very short jump of the voltage in the net was sufficient to switch off the electron beam in ADONE storage for the next 24 hours. In this moment it occurred clearly for us that we had just lost our last chance of the measurements for at least next half a year. The complete experimental EXAFS results for Cd and Te L and Mn K edges were finally ready in 1982 and were presented during the International Conference on EXAFS and Near Edge Structures held in Frascati [4]. We considered our results and the research supposition as unique, but also found out during this Conference that J.C. Mikkelson and J.B. Boyce presented a very similar communication with their excellent EXAFS experimental results for ternary $Ga_{1-x}In_xSb$. This news had some dramatic aftertaste because we understood that we should very quickly publish our results with a full theoretical explanation. Mikkelson and Boyce published their EXAFS experimental results for $Ga_{1-x}In_xSb$ earlier than us, however with not correct theoretical explanation [5]. As I remember, our correct statistical model for $Cd_{1-x}Mn_xTe$ describing EXAFS experimental results arose during very hard discussions with Adalberto Balzarotti during his visit in Cracow. Our approach [6,7] cited later in the literature as a "rigid cation model" explained correctly also the Mikkelson and Boyce experimental results for $Ga_{1-x}In_xSb$ and measured later by us EXAFS results for CdZnTe and ZnMnS. Very intensive EXAFS studies in the period of 1980 - 86 for several semiconducting ternary compounds crystallizing in the zinc blende structure were very fruitful. We published more than 15 articles and conference communications cited often by other authors. This group of our publications were granted the Awards of the Minister of the Polish Ministry of the High Education and of the Secretary of the Polish Academy of Sciences.

2.2. Fundamental Reflectivity and XANES studies

As the time passed, the interest of the nuclear physicists in ADONE was smaller, thus the optical and x-ray absorption spectroscopy measurements in PULS and the acess to PWA laboratories becme easier and they worked without greater surprises. Our main interest in the band structure analysis directed us to the studies of the fundamental reflectivity of many semiconducting compounds in the vacuum ultraviolet energy range. To this investigations we used the vacuum ultraviolet optical line with the Hilger & Watts monochromator, presented in Fig.1. The first article on the fundamental reflectivity in the vacuum ultraviolet up to 30 eV for ZnTe, CdTe and HgTe commonly with Mario Piacentini , Nicola Zema and Francesco Antonangeli was published in 1986 [8]. Parallel to the optical investigations of the valence and conduction bands structure we studied the conduction band structure with the use of XANES analysis also for binary and ternary semiconducting compounds from II–VI group. We presented the first results of this activity together with Emilio Burattini and Giusppe Dalba during the International Conference on

the Physics of Semiconductors in Warsaw in 1988 and next year during the 2nd European Conference on the Progress in X-ray Synchrotron Radiation Research in Rome [9]. Since then Emilio Burattini and Mario Piacentini have very closely and effectively collaborated with us. At the Rome Conference in 1989 a group of several European physicists erected the European Synchrotron Radiation Society (ESRS). I was also in this group and, as the founder member of the ESRS, I stood the first representative of Poland in this Society. One a half year later, in February 1991 the late Professor Julian Auleytner and me organized in Cracow the First Symposium of the Synchrotron Radiation Users. During this Symposium the Polish Synchrotron Radiation Society was erected, officially registered in May 1991. I am not certain but I believe that PSRS was the earliest registered national synchrotron radiation society in Europe.

3. **Final Remarks**

My experience with synchrotron radiation is still alive and maintains up today and, what is not strange, is mainly connected with Italy. Me and my colleagues worked in Italy up to the time of closing of ADONE in 1993 and later when we started to use the ELETTRA storage ring in Trieste. We returned again to Frascati when there started the infrared and X-ray absorption of the synchrotron radiation lines installed in the DAFNE storage ring. My long and close contact with Italy has two sides: a scientific and personal. In Italy I found a very convenient technical conditions to my scientific activity and very inspiring Italian collaborators, and what is for me even more important, I found there some true friends. These friends allowed me and my family to fell in love in the beautiful Italy and to feel well in Italy as in our second patrimony. I am very grateful to them for that.

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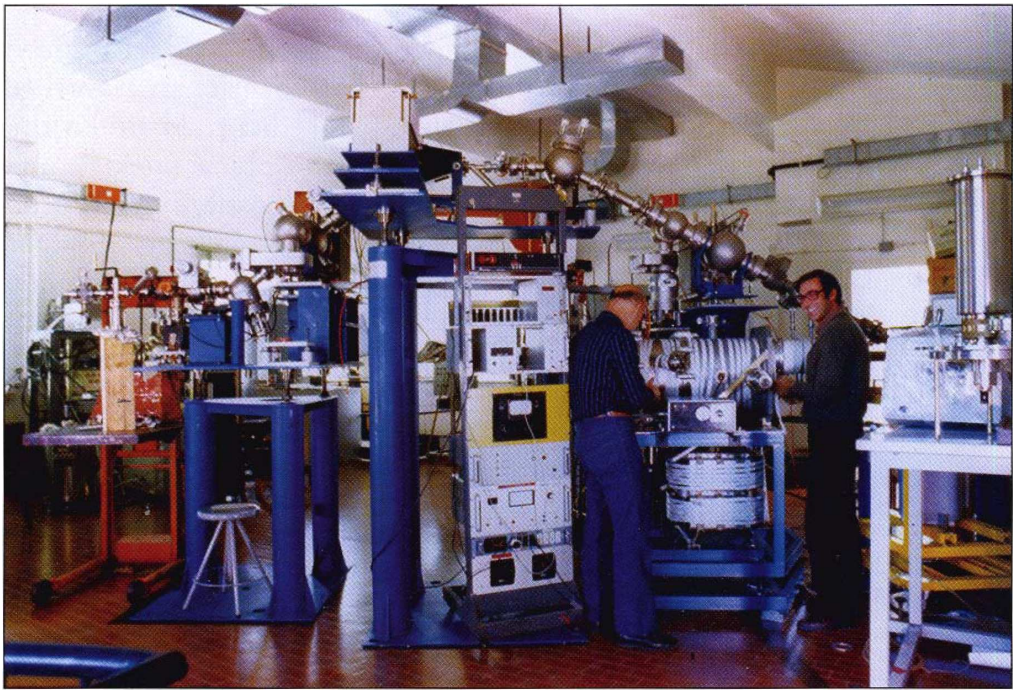

Figure 1. Adolfo Savoya and the author of this article (turned back) at the PULS optical line in the year 1980.