Industrial applications of heavy ions beams at GANIL

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INDUSTRIAL APPLICATIONS OF HEAVY IONS BEAMS AT GANIL

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Abstract : After a year of research and development, BSI and GANIL started an industrial production of microporous membranes. The status of the technical and commercial problems is given.

With the collaboration of industrial firms, other applications are studied, like : non reflecting surfaces, ion implantation, surface treatment, radiation damage ...*

1. INTRODUCTION

During the last year an important effort has been done to determine the main parameters of microporous membranes obtained by ion irradiation and chemical etching, in the frame of an industrial contract signed with BIOSYSTEM INTERNATIONAL. At the beginning of this year the industrial production started for the microporous membranes. An other contract has been signed with MATRA to study electronic component damages induced by different heavy ions at variable energies. Various applications are actually under studies and industrial contacts are carried out.

2. REVIEW OF THE MAIN POSSIBLE INDUSTRIAL APPLICATIONS WITH HEAVY IONS AT GANIL

From the high charge state ion source (ECR) to the final energy at the end of the SSC2, all the energies from 0 to 100 MeV/a.m.u are available in three steps :

ECR source and DC injection. We use actually 20 kV and 100 kV in the future. The intensities, depending of the charge state, are variable from 2.10^{14} pps to 2.10^{13} pps. Industrial application can use the source test bench.

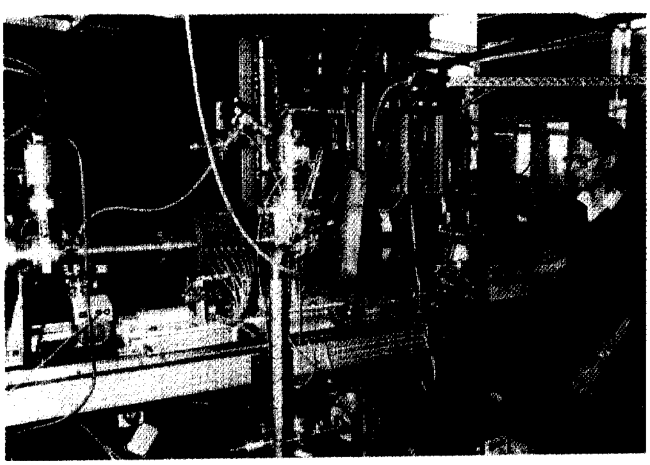

Fig. 1 ECR Test Bench

If an ECR source would be used with a 500 kV DC injector, energies as high as 10 MeV could be directly obtained with Xenon or heavier ions.

- The external beam of the injector cyclotron can't be used (lack of space). We use only the CO + SSC1 beam at energies around 7 MeV/a.m.u. and with intensities in the range of 10^{12} pps.

- CO + SSC1 + SSC2 are also used for industrial application at energies around 50 to 100 MeV/a.m.u. and intensities between 10^{12} to 10^{10} pps.

The possible industrial applications are shown in table 1.

MODE OF OPERATION	ECR SOURCE + DC ACCELERATION 20 kV (500 kV*)		Co + SSC1		Co + SSC1 + SSC2	
INTENSITIES pps	2.10^{14}	2.10^{13}	1.10^{13}	1.10^{12}	1.10^{11}	1.10^{14}
ENERGIES	100 keV	1 MeV	10 MeV	100 Mev	1 GeV	10 GeV
Membranes Litography Others			Ar,	Kr, Xe		
Ion Implantation	B, ρ,	As				
Friction Corrosion Hardness	N, Fe,	P, Ti				
Coloration Adhesion Reflectivity			Ar, Kr			
Electronic Damages			Ar, Fe,	Kr		

Table 1.

3. LATENT TRACKS : APPLICATION TO THE MICROPOROUS MEMBRANES PRODUCTION

3.1. Production of micropores in insulating material is well known and many laboratories produce microporous membranes with heavy ions accelerators [1,2]. One advantage of the GANIL's beam is the excess in energy which can be used to make the irradiation in air after a thin metallic window. In this case, the roller is easy to operate (Fig. 2).

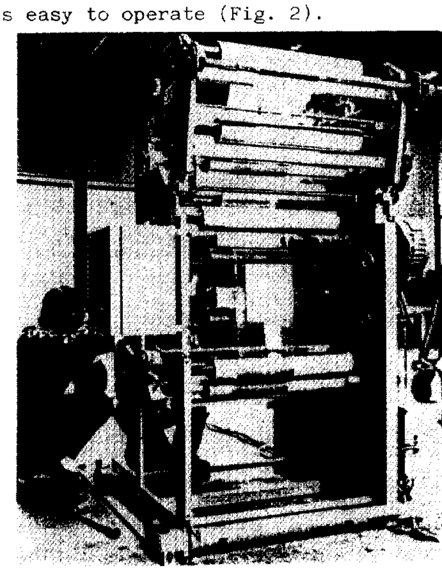

Fig. 2. Film roller

(*) Work supported by grants of ANVAR, DVAR, MRT, Regional Council.

In order to obtain large homogenous film width (500mm) the beam is swept with a saw-tooth modulated magnet at high speed.

To avoid the multihole problems the beam has to be vertically shaped (mainly constant), which is done by an other vertical modulation of the beam with a frequency greater than 2 kHz. The cylinder of the roller which support the film has a diameter adapted to the vertical size of the beam.

The speed of the film is adjusted to the following parameters :

- horizontal width of the irradiated film,
- beam intensity available,
- pore diameter and porosity which are required.

The distance between the film and the metallic window is adjusted for an energy determined by the film thickness and the efficiency of latent tracks production.

During the irradiation all the main parameters are controlled by a microprocessor. The roller is also, on its side, controlled by an other microprocessor and the speed can be adjusted to the beam intensity and the short beam interruptions can be detected and printed on the film.

3.2. <u>Theoretical studies on latent tracks for membranes production</u>

Goals for membrane production are the following :

- Good selectivity (Fig.3) for a maximum porosity
- Simplicity of the etching process and other treatment
- Low price.

The selectivity is the most important and difficult goal (taking into account the two others !)

For a given porosity, the selectivity is affected by two parameters :

- The statistic distribution of the "break through" time which depends on the atomic number of the ion and its energy. From this point of view it's clear that the heaviest ions are the best (krypton, xenon, ...). But as the GANIL's beam current decrease with the ion mass the most interesting compromise between price and quality is given by argon. With this ion additional treatments before the etching process are necessary to restore the membrane quality at the same level than the krypton.
- The perturbation of the statistics by the multihole phenomenon.

On the statistic distribution of the "break through" time theoretical calculations are carried out using the non-continuous damage model [3].

For the "multihole" problems calculations have shown that the statistic can be improved by using a variable angle of the incident ions during the irradiation [4] (Fig. 4).

As the visual aspect has an important psychological impact we have modelised the "multihole" effect [5]. Figure 5 shows a simulated microscopic picture with multiholes. On the right a computer view of the surface of a membrane ; 100 pores are drawn, 9 doblets and two neighbour triplets are found (black dots). On the left intrance and exit positions of the pores for a membrane 200 times thicker than the pore diameter. Irradiation angle : ±10°.

3.3. <u>Etching process</u>

Additional U.V. treatment, etching process have been studied using a conductancemeter which gives, during the etching, the evolution of membrane impedance (Fig. 6).

This impedance can be related to the effective pore diameter in a computer code which take into account a given statistic distribution of the "break through" time, the evolution of the radial etching speed and so on.

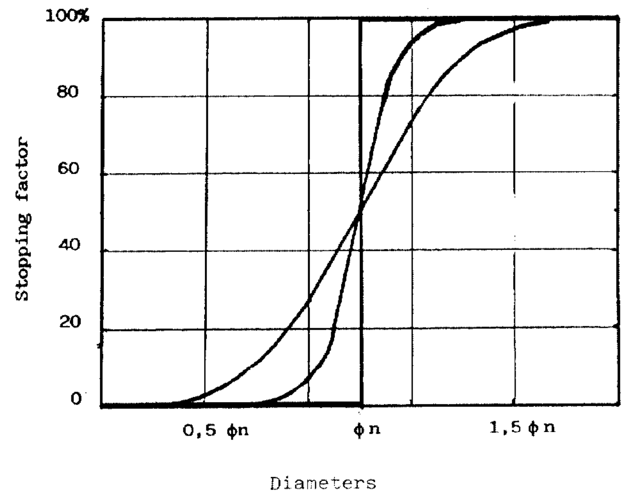

Fig. 3. Membrane Selectivity

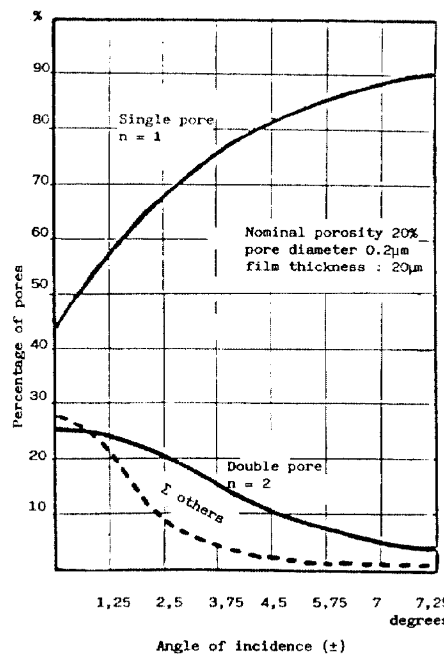

Fig. 4 : Multihole statistic vs maximum angle of incidence

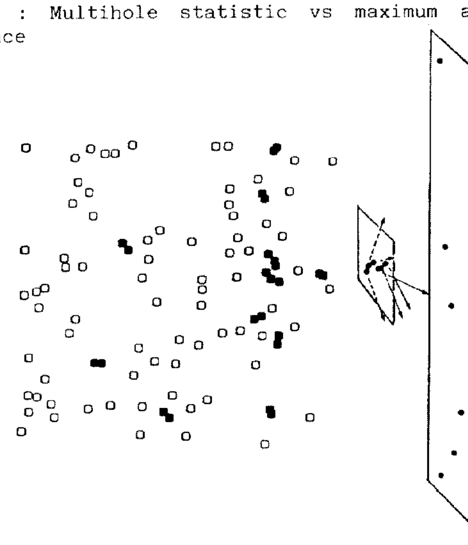

Fig. 5 : Computer simulation of microscopic etching

Qualitatively these measurements are important to show the improvements obtained by various treatments and related parameters (U.V. wavelength, temperature effects, additional etching, concentration ...).

Of course for each material such studies have to be done.

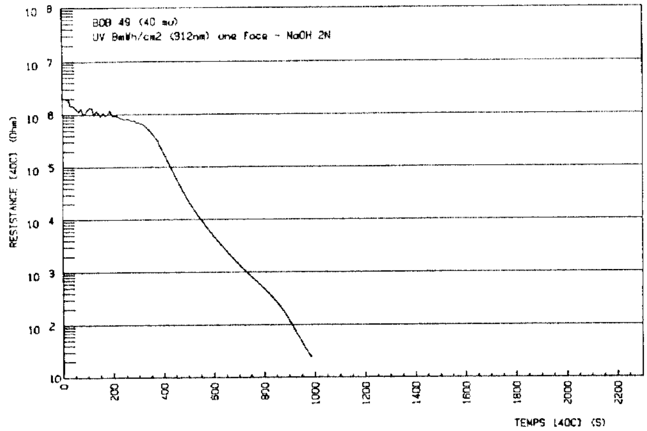

Fig. 6 : Evolution of the membrane impedance during etching

3.4. Membranes measurements and control

The first control which can be done on the membrane is the visual aspect using an electronic microscope.

Some indications can be obtained on the mean pore diameter and the porosity (Fig. 7).

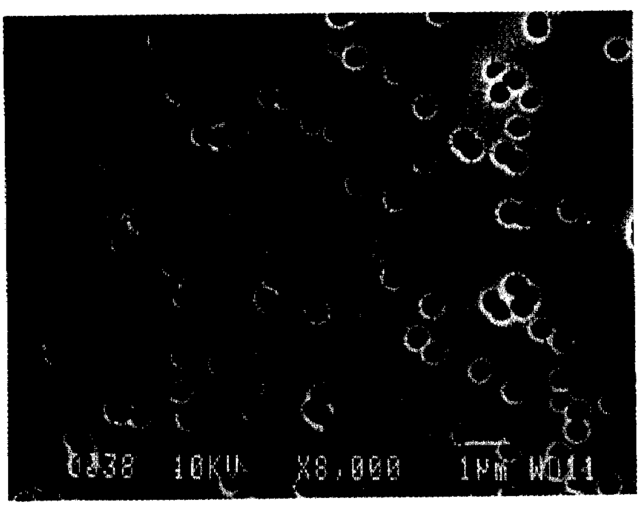

Fig. 7 : Microscope picture of 0.4 μm holes porosity 23% film thickness 40 μm

Then, other control and measurements have been done with :

- Nitrogen permeameter with a thermoporometer for pores diameters between 0.004 to 0.25 μm ,
- mercury porosimeter [6] ,
- specific surface [6] ,
- flow rate,
- bubble point [7].

These measurements give a lot of informations on the pore spectrum, on the shape of the pores (cylindrical, conical) as a function ot the etching parameters and U.V. treatment.

3.5. Status of the industrial membrane production

GANIL is producing for BSI in 1988 more than 200 hours of beam including beam adjustment in the dedicated beam line G4.

Membranes with holes diameter between 0.05 μm to 1 μm can be produced with porosities from few per cent to 30%.

On the other hand BSI has built, close to the GANIL, a pilot plant factory which will be operational for film treatment and production of filters during this year.

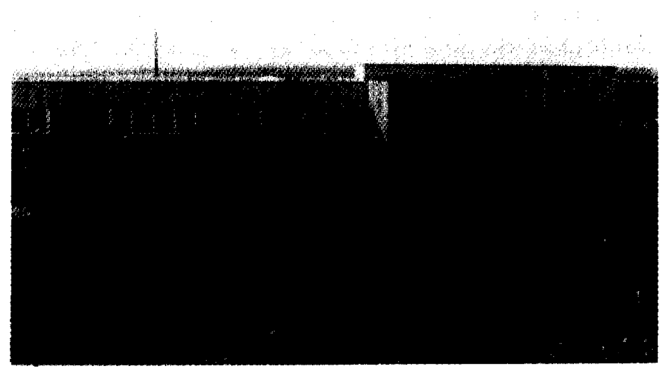

Fig. 8. Pilot plant factory at Caen

4. ELECTRONIC COMPONENTS TEST IN A RADIATIVE ENVIRONMENT

A contract has been signed between MATRA and GANIL for a research and development program on electronic components test under heavy ions flux, comparable to the projectile and flux space.

Electronic components are irradiated in air with various ions (from xenon to carbon) at different energies to cover a complete range of LET. Beam energy and ion flux is continuously monitored by equipments which received the same quantity of beam as the electronic componants.

The number of defects are measured during the irradiation.

After this research and development phase, which needs about 100 hours of beam including the beam adjustments, an industrial phase of irradiation might start.

5. OTHER APPLICATIONS

Among a large variety of industrial applications we are actually working on : non- reflecting glasses, cristal coloration and other applications derived from latent tracks. Due to the GANIL's shut down at the end of this year (for increasing the Heavy Ion Energies "O.A.E) this program will be reduced until June 1989.

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