STATUS REPORT OF THE ISPRA CYCLOTRON LABORATORY (MACY)

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ABSTRACT

Several experiments at the Cyclotron Laboratory in Ispra are continuing on different research lines in the Thermonuclear Fusion Technology Programme, including:
- irradiation of metallic targets for post-irradiation measurements of mechanical properties;
- in-beam creep and fatigue crack growth experiments;
- radiation studies on low activation materials, such as vanadium and vanadium alloys.

In 1988 high specific activity radioisotopes for metallobiochemical, environmental and biomedical studies have been produced. In particular several medium lived radioisotopes have been chemically processed and used at the Radiochemistry Division such as: 48-V, 205/206-Bi, 201/101-Tl, 67-Ga, 91-Nb, 74-As and 52-Mn.

1. FACILITY DESCRIPTION

1.1 The Accelerator

The MC-40 cyclotron installed at the Ispra JRC Laboratory is a variable energy light ion machine. The fundamental techno-physical data are resumed in Tables I and II.

1.2 Experimental Facilities

The extraction of the beam is obtained through an electrostatic deflector. A steering magnet adjusts the horizontal position of the extracted beam at the center of the exit port. Extraction efficiencies measured at the target typically range from 50% to 80% and depend on the type of ions and on their energy. Other typical elements in the exit beam line are a quadrupole triplet, an adjustable collimator, a wobbling system, a viewer, a fast valve, a beam profile monitor and a movable Faraday cup.

The switching magnet has seven ports, and six beam lines are now equipped and routinely used. The specific irradiation equipment currently in use comprises:

- irradiation chambers for proton damage or helium implantation in material specimens, some with connected in-beam creep or fatigue crack growth apparatus;
- radioisotope production chambers, with automatic extraction of the irradiated targets;
- a proton nuclear activation station, permitting a simultaneous irradiation of 32 biological specimens.

TABLE I: Characteristics of the Ispra MC-40 Cyclotron

Pole diameter	115 cm
Magnet weight	60 tons
Main coils max curr.	850 A
Sectors	3
Hill gap	100 mm
Valley gap	180 mm
Max magnetic field	2.1 Tesla
Extraction radius	50 cm
Trim coils	8
Harmonic coils	4 sets
RF cavities	2; $\lambda/4$
Dees	2; 90°
Beam aperture	20 mm
RF range	12.5-27 MHz
Frequency stability	$1x10^{-4}$
Amplitude stability	$1x10^{-3}$
Max Dee peak volt.	44 KV
Ion source	P.I.G. type
Chimneys	2
Cathode lifetime	2 weeks (p,d) 50 hours (α)
Current stability	+ 1.5% (short time)

TABLE II: Beam characteristics

Particles	Energy (MeV)	Max extr. beam curr. (μA)	Energy spread $\Delta E/E$
Protons	10-38	65	0.005
Deuterons	5-19	65	0.01
Helium-4	10-38	30	0.01

The different targets can be cooled directly by jets of purified helium from a closed loop system, or indirectly by water-cooled support plates. Temperature control is normally obtained using infrared pyrometers.

2. UTILIZATION

The Ispra Cyclotron was acquired specifically as a facility for studies of radiation damage in fusion reactor materials, both as displacement damage and gas (hydrogen and helium) production damage. A large number of material tests in the scope of the European Fusion Technology Programme are presently under way. They include:

- basic studies on the kinetics of displacement damage;
- irradiation of AISI 316 and AMCR samples for post-irradiation measurements of mechanical properties;
- in-beam creep experiments on AISI 316 samples (see Figs. 1 and 2);

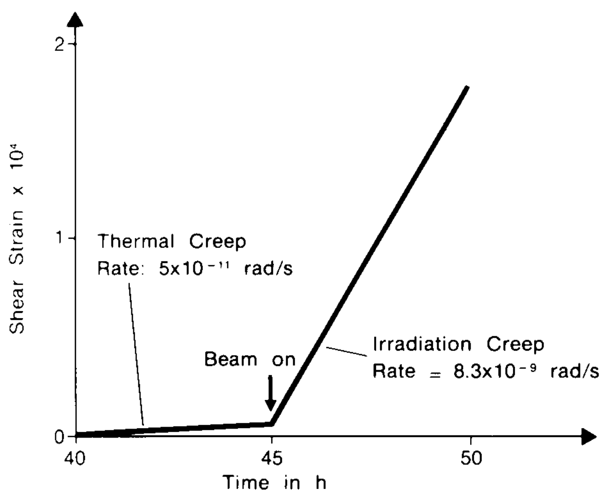

Fig. 1: The irradiation increases the creep deformation rate by about two orders of magnitude under the indicated conditions.

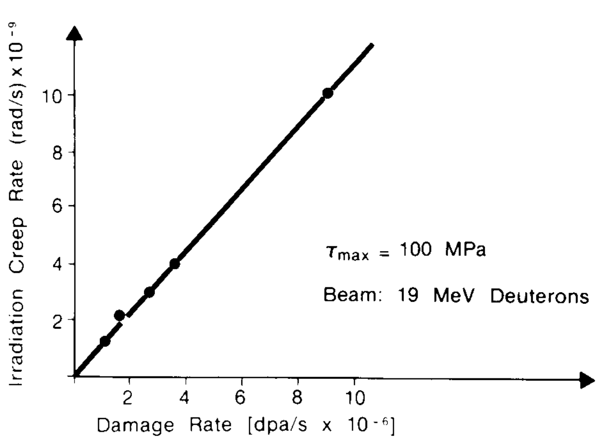

Fig. 2: Irradiation creep rate as a function of the damage rate for an AISI 316 20% c.w. specimen at 350°C and a max shear stress.

- fundamental radiation studies on SAP, vanadium and vanadium alloys, silicon monocrystals, iron, (pure) gold, copper, nickel, DENSIMET, ELBRODUR (Cu,Cr,Zr alloy), crystalline and amorphous SiO_2, boron carbide, ceramics and numerous other materials;
- simultaneous light ion irradiation and fatigue crack propagation on AISI 316 and AMCR steel samples (see Fig. 3);
- irradiation of copper and tungsten samples for post-irradiation examination of induced damage;
- helium implantation into vanadium and vanadium alloy samples for subsequent neutron irradiation in a fission reactor.

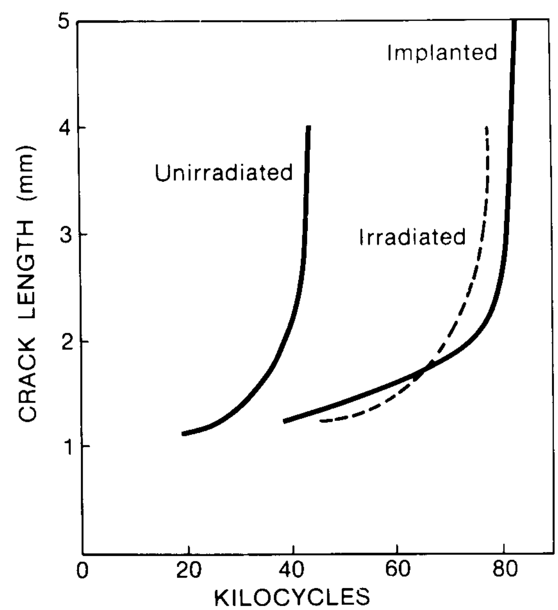

Fig. 3: Effect of proton irradiation and α-particle implantation on fatigue crack growth. In AISI type 316 stainless steel at 500°C, in comparison with unirradiated material.

Another field of Cyclotron activities concerns the production of isotopes, mainly used as tracers in biomedical research, by the Ispra Environment Institute and for other scientific/technical applications.

A last activity is beginning in the laboratory in the field of radioisotopes used in nuclear medicine. As a first step we have successfully tried a production station for 67-Ga, produced from a natural zinc target. In this case a maximum current of 54 μA was used. In a next future a production of other radioisotopes of medical interest is foreseen. Actually, a target holder for the production of 18-F is in preparation.

3. IMPROVEMENTS

The most important improvements at the Cyclotron Laboratory refer in particular to the beam diagnostics and to the targetry for radioisotope production.

3.1 Nipkov Disc

A Nipkov disc permitting the control of the beam spot homogeneity was mounted in front of the fatigue crack growth facility and is currently used. By means of this apparatus an absolute measurement of the beam density is obtained in 49 points (a 7x7 matrix for an area of 12x12 mm^2) permitting a sufficient spatial resolution, associated to a good precision. In these conditions the transfer of the information taken at the disc position to the target position is possible with small errors.

3.2 Calibration of the Beam Energy

An apparatus for the energy calibration of the cyclotron particles was mounted on the beam line N°1 and the first tests using a proton beam at different energies have been performed. This apparatus is based on the superposition of the energy peaks of the particles scattered by the different nuclei of the target (a thin mylar foil).

By measuring the scattering angles where this superposition is obtained, it is possible to determine the energy of the beam impinging on the target.

3.3 Liquid Target

A target of enriched water for 18-F production, for use in studies of active fluorine labelling of organic molecules and/or for use in PET installations, will be tested in the next months.

4. UTILIZATION

4.1 A continuation of radiation damage and the implantation on fusion materials is foreseen in the next years.

4.2 The main development which we foresee for the coming years is an increase of radioisotope production for medical, industrial and scientific purposes.

4.3 An extension of the proton nuclear activation method (PNA) in medicine and in industry will be pursued.

5. BIBLIOGRAPHY

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