A FACILITY FOR ELECTRON BEAM PROCESSING WITH A 10-MeV MICROTRON

D. Catana, I. Panaitescu, S. Axinescu, R. Minea, Institute of Atomic Physics
P.O.Box MG-6, Bucharest R-76900 ROMANIA

1.INTRODUCTION

Use of accelerated electron beams in radiation processing is a modern and widely applied method to induce new and desirable proprieties (physical, chemical, biological) in materials, such as: polymerization, sterilization, conservation, pasteurization,etc. Compared to isotopic gamma-radiation sources, electron beam generators have several advantages, including among others:

1. Easier and better control of the absorbed dose distribution;
2. Electrical control of the irradiation parameters;
3. No decay of the irradiating power;
4. No radioactive substances and waste, better safety;
5. Higher dose rates.

The use of the microtron for electron beam processing is a rather new subject. Because this type of electron accelerator is still a newcomer in this application, no other such facility was reported so far. Work in this field of interest was performed in Bucharest since 1977 when the 17-orbit microtron [1] was commissioned. At the time, Romania was among the first countries in Europe to operate a high-current microtron.

The microtron has some advantages for applications in electron beam processing. First of all, it is in principle simpler than a linear accelerator [1],[3] mainly for using only one resonant cavity instead of relatively more complicated to manufacture accelerating structure of a linac. This could be important especially for the case of a smaller, developing country [2] when one has to choose the most suitable type of electron accelerator in the 10 - 20 MeV energy range.

The energy spread of the electrons is proportional to $1/N^2$, where N is the number of orbits, so it is much better than in the linac case. This is another advantage in the design of deflecting and scanning magnets for electron beam processing, as well as in controlling dose distributions.

2. MAIN PARAMETERS OF THE MICROTRON

- Number of orbits	17
- Electron energy	10 MeV
- Pulse beam power	500 kW
- Repetition frequency	400 Hz
- Duty ratio	10^{-3}
- Average beam current	45 μA
- Pulse length	2.5 μs
- Working pressure	10^{-6} torr
- Polar piece diameter	800 mm
- Last orbit diameter	615 mm
- Gap	100 mm
- Electromagnet weight	2 t
- Resonant frequency	2800 MHz (λ = 10.7 cm)
- Pulse power of the magnetron	2 MW
- Average power of the magnetron	2 kW

3. BEAM TRANSPORT LINE

Though the microtron is in operation since 1977, applica-tions in radiation processing require some additional work to improve the beam quality and to transport it in the appropriate direction. There were developed facilities to perform:

a) additional focusing using quadrupoles;

b) 90° deflection magnet to bend the beam to the final vertical direction;

c) scanning of the electron beam in a vertical plane.

The vertical orientation of the electron beam is needed to achieve the electron beam processing of probes with various sizes including liquids and powders, and to allow the use of a conveyer for convenient transport. The beam scanning is compulsory in electron beam processing in order to obtain a homogenous absorbed dose in the material to be irradiated.

In the following, we shall describe every component of the beam transport line.

A. The extractor - is a simple tubular iron magnetic shield introduced in the accelerating chamber which directs the electron beam from the last orbit outside the accelerator. Since the distance between successive orbits is about λ/π [3], electron extraction puts no major problems. The only complication is the perturbation of the magnetic field homogeneity due to the iron tube, but this is avoided by adding two compensation rods. Using this method [3], high extraction efficiency, of about 90 %, can be obtained.

B. Focusing quadrupole lenses - a pair of quadrupoles located after the extraction tube focuses the beam outside the microtron.

C. Deflecting magnet

The 10-MeV electrons are deflected with 90° and directed vertically downwards. The radius is 0.25 m, with B = 0.13 T in a gap with a height of 60 mm. The DC power exciting the coils is aproximately 1 kW. The coils are made from copper with rectangular cross-section, 13 x 5 mm^2 and have 100 turns.

D. Scanning magnet

In order to simplify the supply circuits, we decided to feed the coil of the scanning magnet with a sinusoidal waveform having the frequency much lower than the repetition frequency of the electron pulses (400 Hz). The choice of 50 Hz is natural. The main problem is to obtain a homogeneity of the dose absorbed in the irradiated object of better than 10%, a value generally accepted for radiation processing.

Computations showed that for a sinusoidal supply, the non-uniformities of the absorbed dose, are up to 30%. To improve this, it is necessary to add a third-armonic component (frequency 150 Hz) with an amplitude of 1%

The parameters of the scanning magnet are:

- $B_{max} = 0.15$ T;
- Polar piece surface: 120 x 120 mm^2;
- Coil: 2 x 2,000 turns, copper Ø 1 mm.

The electrical supply circuit is a series resonant circuit tuned on 50 Hz. The capacitor is 2.4 μF and the maximum coil voltage is about 2,500 V. To obtain the third-armonic component, a saturating inductance is put in series with the scanning magnet coil. By regulating the DC nemagnetization current, one can obtain different values for the third-armonic component and, hence, the adjustement of the uniformity of the absorbed dose distribution.

After scanning, the beam is directed to the probes through an output window made from aluminium foil with thickness of 0.5 mm.

E. Vacuum system

The whole beam transport system is separated by a valve in two parts, each pumped by an ionic pump and a mechanical pump for starting. The separation is made by a valve, located near the deflecting magnet. Vacuum gauges are located in both parts in order to measure the pressure.

4. CONCLUSIONS

This work leads to the possibility of using the microtron beam in research on electron beam processing. The beam is directed downwards in a vertical direction which allows to irradiate liquid or powder probes and some large size objects with a height of up to 40 - 50 cm. The scanned beam cross-section at the output window is 0.02 x 0.4 m^2. The beam average power is 0.5 kW at an electron energy of 10 MeV.

REFERENCES

[1] Catana D., Axinescu S., Minea R., Romanian Journal of Physics, 37, No.8, 839-842, 1993.

[2] Catana D., Axinescu S., Minea R., "The 17 - orbit microtron from the Institute of Atomic Physics - Bucharest, Research work performed from 1977 up to the present", Indo - Soviet Meeting on Microtrons, Centre for Advanced Technology CAT - Indore, India, January 24, 1992.

[3] Kapitza S.P., Melekhin V. N., Mikrotron, Izdatelstvo Nauka, Moskva, 1969

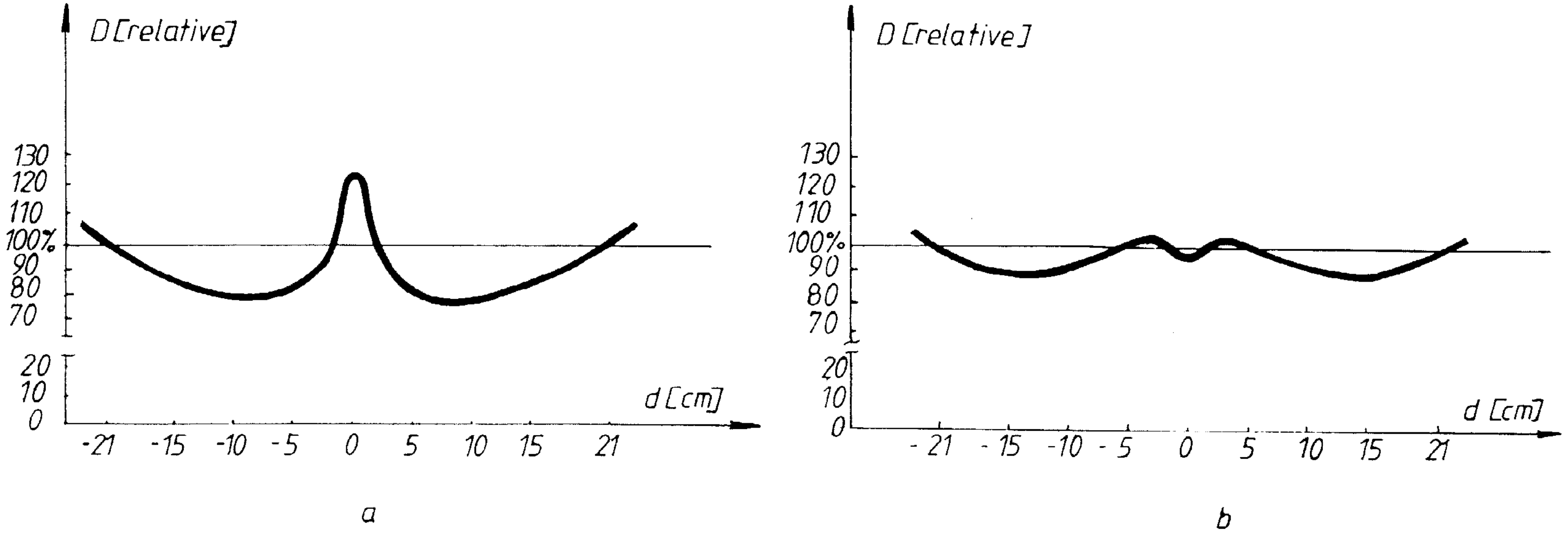
from the amplitude of the fundamental (frequency 50 Hz). In this case, the non-uniformities of the absorbed dose are no more than 10%. The results of this computations are shown in fig.1, where the absorbed dose is expressed in relative units.

FIGURE CAPTIONS

Fig. 1 - Absorbed dose distribution

a) scanning magnet coils fed with a 50-Hz sinusoidal waveform;

b) scanning magnet coils fed with a 50-Hz sinusoidal waveform and with a third-armonic component (amplitude - 1% from the 50-Hz fundamental amplitude).



a

b

Fig. 1 ABSORBED DOSE DISTRIBUTION

a) scanning magnet coils fed with a 50-Hz sinusoidal waveform

b) scanning magnet coils fed with a 50Hz sinusoidal waveform and with a third-armonic component(amplitude – 1% from the 50-Hz fundamental amplitude)