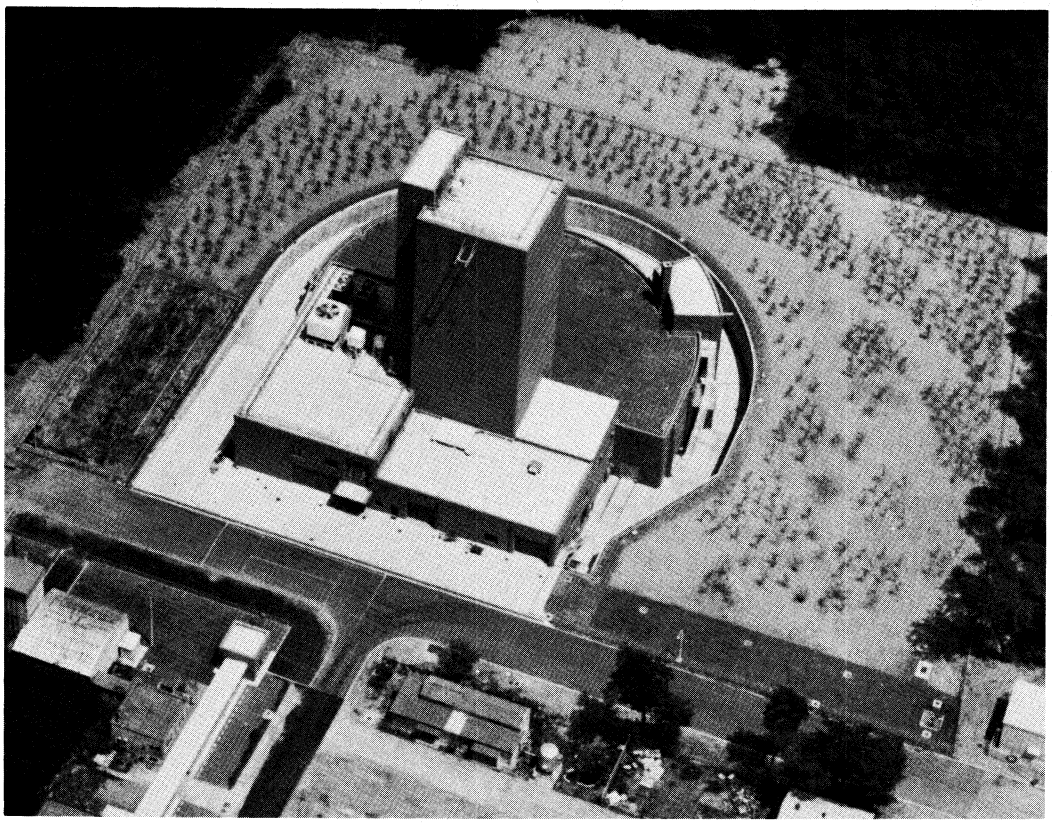
JAERI TANDEM

NEWSLETTER No. 9

December, 1982

Accelerators Section, Division of Physics
Tokai Establishment, Japan Atomic Energy Research Institute
Postal Area Number 319-11
Tokaimura, Nakagun, Ibaraki-ken, Japan
Tel. 02928-2-5439

Contents



JAERI Tandem Accelerator Building

Preface to the Last Issue of the "JAERI TANDEM"

Installation of the JAERI tandem accelerator has been completed at August 1982. Though there is some delay to the initial schedule, we are now in a position to start the studies of the heavy ion science for which we are longing. The accelerator has superior properties, and it is expected that a lot of valuable data are obtained in a wide area of the science.

The "JAERI TANDEM", which has been issued in order to inform the persons in and out of JAERI about the progress of installation, is also brought to a close with the present number. Hereafter, the annual report will be issued instead, printing the results of investigations for the heavy ion science, as well as those of development for the accelerator technology.

Finally, we would like to express sincere thanks to all persons who have given us continued and hearty support for our project, and to NEC and HAKUTO Co. Ltd. for their efforts for a long period to construct the accelerator.

Head, Division of Physics
K. Harada

Tandem Installation Has Been Completed !

Completion of the Accelerator

Final installation works were carried out over the whole accelerator system in the period from January to early March, 1982. They included the improvement of the bending magnets, the external and interminal beam pulsing devices and the spark gaps of the accelerating tubes and the assembly of the enclosed corona tubes.

Acceptance tests started in the middle of March and all guaranteed performances in the terminal voltage range up to 18 MV were successfully demonstrated by June. The beam pulsing systems worked reliably and provided pulsed proton and iodine beams with widths of 0.5 to 1 ns and 2 to 3 ns (FWHM), respectively. Especially the interminal ion source and pulsing system produced beautiful intense proton pulses with very small intensity modulation at 18 MV. This is believed to be the world highest terminal voltage in performances of single ended electrostatic accelerators. Table 1 shows some examples of the ion beam performances.

The terminal can reach 18.5 MV without so intensive voltage conditioning, but not 20 MV. This is a problem left for future improvement. The accelerator is equipped with both open and enclosed corona point systems in parallel for potential distribution. In the voltage range below 13 MV the enclosed corona points are mainly used to maintain enough drain current with lower SF_6 gas pressure than that (about 5 kg/cm^{2}G) of the accelerator vessel. It is very convenient for a large voltage change, because the inside pressure of the enclosed corona tube is easily lowered in several minutes.

Termination of the Contract and Start of Scheduled Running for Experiments

Over the whole accelerator system, installation of all equipments was completed and all specifications except the terminal voltage were satisfied. Now the accelerator can run enough stably with various ions. On the other hand, installation of experimental equipments has been proceeding steadily and eleven apparatuses have gotten useable so far.

Considering the above situation, the contract of the accelerator was terminated in August 1982, and scheduled running of the accelerator for experiments started on September 1, 1982.

Table 1 Ion Beam Performance of the Tandem Accelerator

Ion (Continuous)	Terminal Voltage (MV)	Energy (MeV)	Current (pμA)	Pulse Width(FWHM) (ns)
H^+	18	36	5	
$^{12}C^{5+}$	14	84	0.2	
$^{16}O^{6+}$	16	112	0.35	
$^{28}Si^{8+}$	13	117	0.025	
$^{35}Cl^{9+}$	18	180	0.53	
$^{58}Ni^{10+}$	13	143	0.02	
$^{63}Cu^{10+}$	13	143	0.03	
$^{81}Br^{10+}$	13	143	0.012	
$^{127}I^{7+}$	18	144	0.54	
(pulse, 1 MHz)				
H^+	13	13	4000(peak)	0.6
	18	18	1100(peak)	0.9
I^{8+}	18	162	12(peak)	1.9

Present Status of Experimental Apparatus

A five year project started in 1978 to install heavy ion experimental equipments at the tandem accelerator site. At first it included 25 apparatuses and later was modified to include 21. To date, a heavy ion TOF spectrometer, instruments for β and γ spectroscopy, a heavy ion magnetic spectrometer (ENMA), a fast neutron TOF spectrometer, an on-line mass separator, instruments for beam foil and charge exchange studies, an electron spectrometer for chemical analysis, an irradiation creep facility, an irradiation chambers for material tests in wide temperature range and a calorimetry system for heavy-ion irradiation damage study have been completed and now are useable in experiments. Furthermore the budget for a Raman spectrometer for surface analysis and a microscopic analyzer for swelling was already approved and they are expected to be useable in 1983.

Electron Spectrometer for Chemical Analysis

To study following subjects related to chemical damages by heavy-ion irradiation, the instrument has been connected to the H1 beam-line in a heavy-ion target room.

(i) Effects of heavy irradiation on the chemical states of inorganic materials.
(ii) Chemical state and depth profile of implanted ions.
(iii) Preparation of new materials by multiple ion-implantation and their energy-level structure in the valence band.

Heavy ion is characterized by its energy deposition of tremendously large amount on the surface layer. The irradiated surface becomes sensitive to chemical reaction because chemically unstable species are produced in the thin layer. Furthermore, changes in the

elemental composition is caused by the chemical reaction of implanted ion with the constituent atoms of the target material. To study such chemical damages, "in-situ" observation under the ultra-high vacuum is essential. A block diagram of experimental system is shown in Fig. 1. Sample is introduced from an inlet chamber, then is transferred to an irradiation chamber. Immediately after the irradiation at around -100 °C under the vacuum of 10^{-8}-10^{-9} Torr, the sample is brought to an analyzer chamber of 10^{-11} Torr. The information about chemical damages are obtained from X-ray photoelectron, Auger electron and secondary-ion mass spectroscopies. The instrument is equipped with several functions for sample treatment as listed in the lower part of Fig. 1. Main part of the spectrometer is shown in Fig. 2.

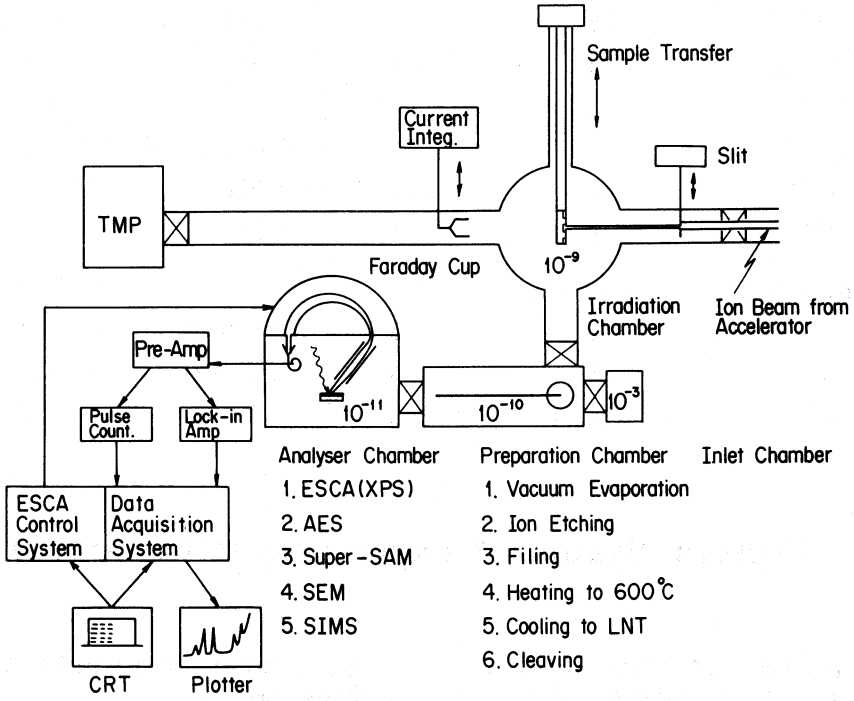


Fig. 1 Block diagram of an "in-situ" electron spectrometer for chemical analysis.

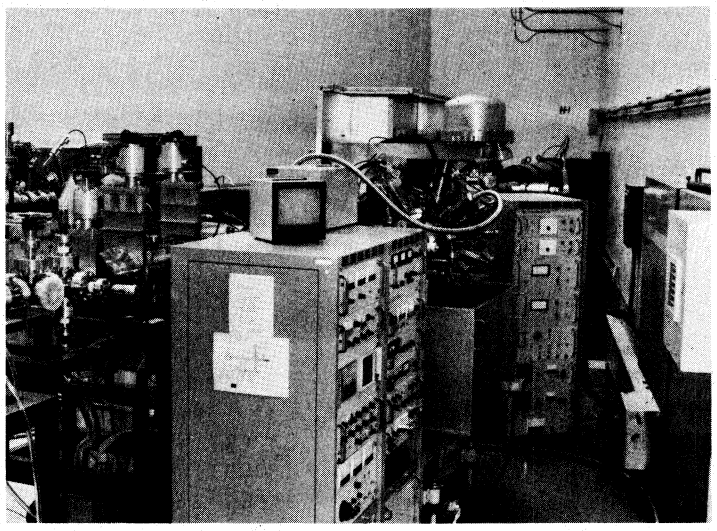


Fig. 2 Main part of the electron spectrometer for chemical analysis.

Preliminary Review of Experimental Results

Damage Profile in Nickel Bombarded with High Energy Ion

Heavy-ion bombardment are capable of generating damage levels only in a few hours that are equivalent to years of reactor exposure, and have been a useful tool for the simulation study of swelling behavior in neutron irradiation environment. In this study, the damage-structure of pure nickel was observed with a transmission electron microscope as a function of depth from the specimen surface after 130 MeV Cl-ion bombardment of 1.4×10^{15} ions/$m^2\cdot s$ in flux by using the tandem accelerator at JAERI to the fluence of 4.1×10^{19} ions/m^2 at ambient temperature. The damage rate and level at the peak in this bombardment are 3.8×10^{-4} dpa/s and 11 dpa, respectively, according to the calculation by using the extended E-DEP-1 computer code. The damage peak appears at 12.1 μm in depth from the incident surface, and the injected Cl-ion is distributed in the depth ranged from 11.6 to 12.8 μm with a peak concentration of 4300 appm at 12.2 μm in depth.

A cross sectional microstructure in the bombarded nickel is shown in Fig. 3. The incident ions traveled from left to right in the micrograph. The bombarded surface is indicated in the figure. In heavily damaged region from 13 to 16 μm in depth, high density of both cavities and dislocation loops were observed. The depth dependence of swelling as a result of cavity formation in the damaged region is given in Fig. 4. Swelling peak appears at a depth of 14 μm, which is 16% deeper than the peak in the calculated damage profile.

This study shows that the more improvement in the accurate measurement of irradiation temperature and ion-flux from experimental side, and re-evolution and the accurate measurement of electronic stopping power in high ion-energy from the theoretical or calculation experimental side are both necessary to do futher simulation study of ion-irradiation.

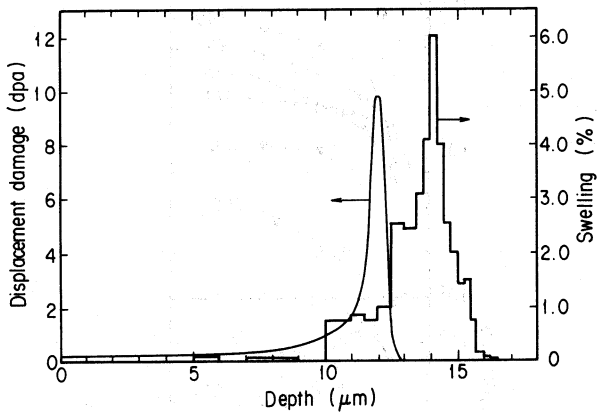


Fig. 4 Depth dependent swelling in pure nickel bombarded with 130 MeV Cl ions to a peak dose of 11 dpa.

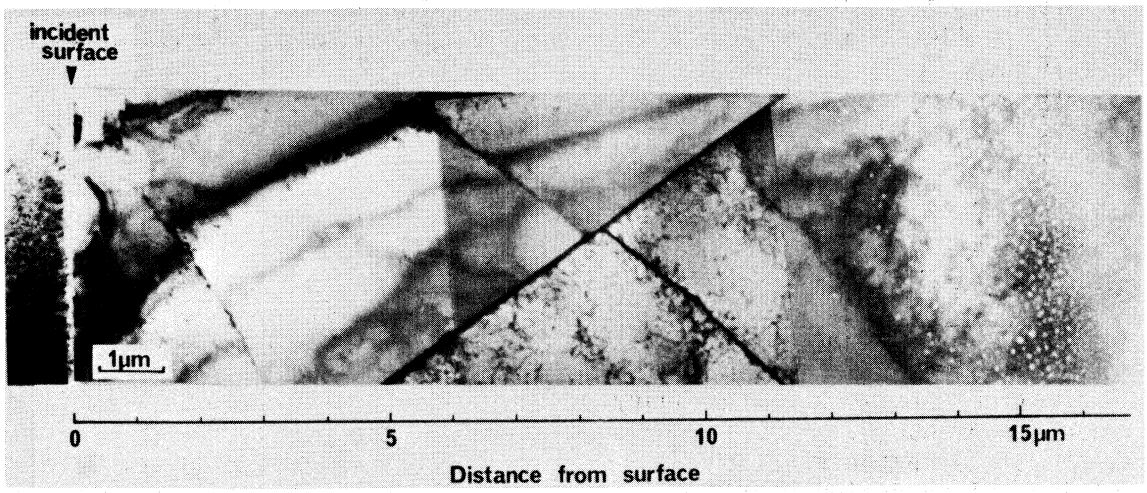


Fig. 3 Cross sectional microstructure of pure nickel bombarded with 130 MeV Cl ions to a peak dose of 11 dpa.

An Experiment of Irradiated ^{197}Au with ^{16}O Ions

Formation cross sections and recoil ranges of residual nuclei have been measured in the reaction of ^{197}Au with ^{16}O. The Au targets of 2 mg/cm^2 thick and Al catcher foils were bombarded for 0.5-2 hours with ^{16}O beams from the tandem accelerator operated at the terminal voltage of 14 MV. The incident energies to the Au targets were adjusted to 84, 89, 92, 98, 105 and 110 MeV in the lab. system using Al foils of 4-12 mg/cm^2 in thickness. After the irradiation, the activities of the heavy reaction products were determined by direct gamma-ray measurement of Au target and Al catcher foil, respectively, or by the measurements of radiochemically separated samples and mass-separated samples with ISOL. The recoil ranges of the heavy products were deduced from the ratio of their activities between in the target and in the catcher.

The cumulative cross sections of the mass number from 196 to 210 at various projectile energies are shown in Fig. 5. From these excitation functions, at least three types of reactions were found to exist in this system; complete fusion reaction, incomplete fusion reaction, and transfer reaction with deep inelastic collision or quasi-elastic collision. The recoil range of the product as a function of the incident energy of the projectile can also be explained by these reactions (Fig. 6). Experiments of Au with O are intended to continue concerning light particle production and fission.

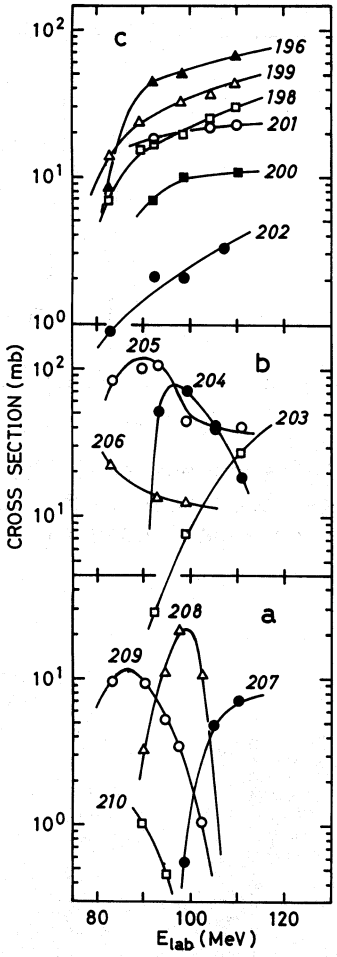


Fig. 5 Excitation functions of the heavy reaction products:
a) complete fusion reactions,
b) incomplete fusion reactions,
c) transfer reactions.

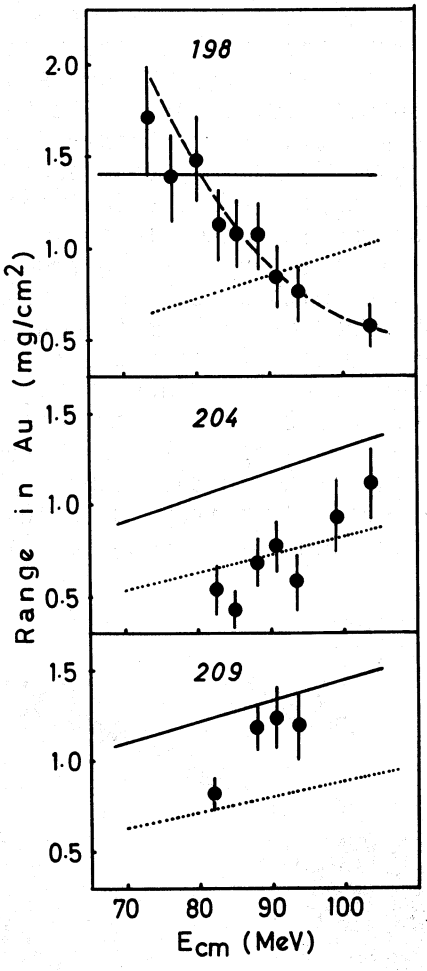
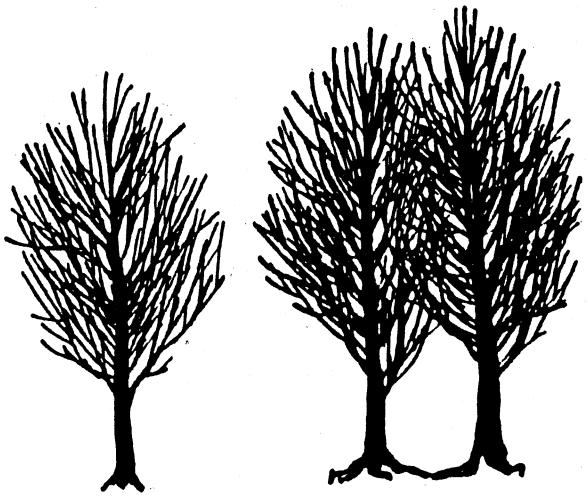


Fig. 6 The experimental recoil ranges of the products with the calculations assuming complete fusion (full line), incomplete fusion (dotted line), and quasi-elastic collision (broken line).

Publications Related to JAERI Tandem

- Nucl.Inst.Meth.188(1981)63:
  T.Matsuzaki, H.Taketani, M.Ishii and M.Ohshima
  A Compton Polarimeter with a Pair of High-Purity Ge Diodes
- Nucl.Inst.Meth.190(1981)515:
  H.Ikezoe, Y.Tomita, N.Shikazono and T.Murakami
  Magnetic Quadrupole Spectrometer for Time-of-Flight Measurements
- Nucl.Inst.Meth.196(1982)117:
  M.Ishii, M.Ohshima, T.Matsuzaki and H.Taketani
  A Compton Polarimeter Composed of Four Planer Diodes of High-Purity Germanium
- Nucl.Inst.Meth.196(1982)215:
  H.Ikezoe, Y.Tomita, N.Shikazono and T.Murakami
  Particle Identification for Heavy Ions in a Time-of-Flight Spectrometer
- Nucl.Inst.Meth.197(1982)267:
  S.Takeuchi and S.Kanazawa
  Carbon Deposition Apparatus to Produce Long-Lived Stripper Foils for the JAERI 20 MV Tandem Accelerator



Contributors to this Newsletter are:
K.Harada, M.Maruyama, T.Sasaki,
M.Tanaka, S.Baba.