Status of DIAC and Future Utilizations in Nuclear Research

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1. Status of DIAC

DIAC (Daejeon Ion Accelerator Complex) has been constructed with some components of TRIAC (Tokai Radioactive Accelerate Complex) [1] transferred from KEK (High Energy Accelerator Research Organization, Japan) as a new ion beam irradiation facility. At the end of last year, the installation, licensing and facility inspection are completed at KAERI (Korea Atomic Energy Research Institute), Daejeon and then it was open for users since early this year. DIAC consists of an 18-GHz ECR (Electron Cyclotron Resonance) ion source, a 25.96-MHz SC RFQ (Split-Coaxial Radio Frequency Quadrupole), and a 51.92-MHz IH DTL (Interdigital H-type Drift Tube Linac). All kinds of atoms can be accelerated up to 1 MeV per nucleon, and the accelerated beam is transported along a beam line that can control the size of the beam depending on the requirements of the users [2].

At present, 4-MeV helium beam and 40-MeV argon beam are available, beam current is several μA, and beam is being prepared to be used mainly for nuclear and fusion material irradiations. Fig. 1 shows the charge distribution of the argon beam from the ECR ion source.

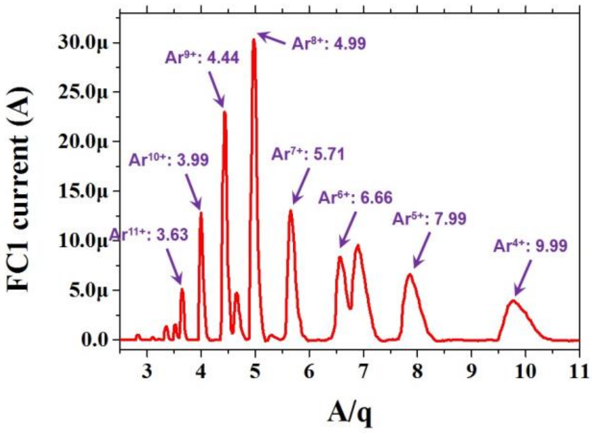

Fig. 1. Helium beam from ECR ion source.

2. Future Utilizations in Nuclear Research

Since DIAC is a linear accelerator, it can accelerate high currents of 1 mA or more, and accelerate heavy elements. Heavy elements accelerated to 1 MeV per nucleon become SHI (Swift Heavy Ion) beams whose electronic stopping is greater than the nuclear stopping. Utilizing these advantages, it will be possible to use it for nuclear research as follows.

2.1 High Current 4-MeV Helium Beam Irradiation

The helium created from deuterium-tritium fusion reactions or alpha decay of radioactive isotopes has the energy of approximately 4 MeV as shown in Fig. 2. Therefore, the 4-MeV helium beam obtained from DIAC can be used to simulate the phenomenon of alpha particle irradiation, such as fusion materials and spent fuel. In case of helium, it is possible to accelerate the beam of 1 mA or more by installing a small ECR ion source in place of the large ECR ion source in use. In this case, the beam power on the sample reaches 4 kW, and it is also possible to apply a high-thermal load on the irradiation samples by the beam simultaneously. The divertor and limiter in nuclear fusion machine can be an example.

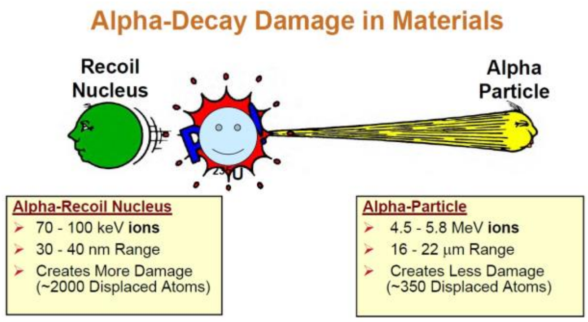

Fig. 2. Alpha-Decay [3].

2.2 1-MeV per Nucleon SHI Beam Irradiation

The fission fragments produced during the fission process have the same mass and energy as shown in the Fig. 3. Therefore, the SHI beam accelerated by DIAC has similar mass and energy, so it can simulate various phenomena occurring during nuclear fission in nuclear fuel. Fission products lose energy creating linear tracks of defects by electronic stopping or structural changes in materials. Fission tracks have nano-sized radii (~ 5 nm) and micro-sized lengths (~10 microns). In the case of xenon, which is a representative fission fragment, it can be extracted with the current ECR ion source because it is a gas. However, molybdenum requires a different method because it is a metal. In order to obtain a metal beam, there are various methods such as a high-temperature crucible. In DIAC, MIVOC (Metal Ions from Volatile Compounds) will be used to extract the metal ion beam. A beam current of about 10 μA is expected for metal ion beams.

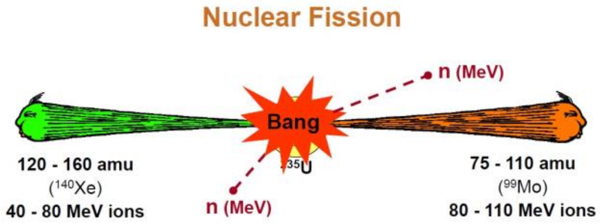

Fig. 3. Fission product in nuclear fission [3]

2.3 14-MeV Neutron Source

The neutron energy produced by the deuterium-tritium fusion reaction is 14 MeV. A D-T neutron generator can be used to simulate this neutron, but it is difficult to handle the radioactive tritium. To avoid this, deuterium-lithium reactions can be used to generate neutrons of similar energy. For example, IFMIF (International Fusion Materials Irradiation Facility) for testing fusion materials accelerates deuterium to 20 MeV and collides with liquid lithium to generate a large amount of fast neutrons. In this case, however, accelerated deuterium adheres to the main body of the accelerator to generate neutrons, which causes the main body of the accelerator to be contaminated with radiation. To avoid this, irradiating the accelerated lithium to deuterium adsorbed on the titanium can produce fast neutrons of similar energy. In this case, the ion source used can be supplied with a lithium ion beam of about 1 mA by using a thermionic type which is different from the ECR ion source currently in use. Fig. 4 shows the fast neutron energy spectrum of deuterium-lithium reactions calculated by Geant-4 computer code.

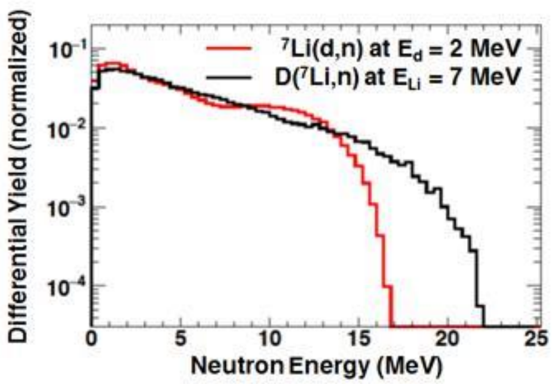

Fig. 4. Neutron energy spectrum (Geant4 code).

2.4 High Energy Heavy Ion Beam Analysis

Generally, ERDA (Elastic Recoil Detection Analysis) uses a helium beam of several MeV or a silicon beam of tens of MeV obtained from a tandem accelerator. However, when ERDA is performed by iodine or gold to 1 MeV per nucleon, it is possible to analyze almost all the elements at the same time, and since the reaction cross section is large, it can be analyzed with a small beam current. This has the advantage that the damage of the sample can be minimized. These features enable simultaneous analysis of various elements such as hydrogen, deuterium, heavy metals, etc. contained in nuclear materials. Fig. 5 is an example of analysis of argon implanted on uranium oxide fuel.

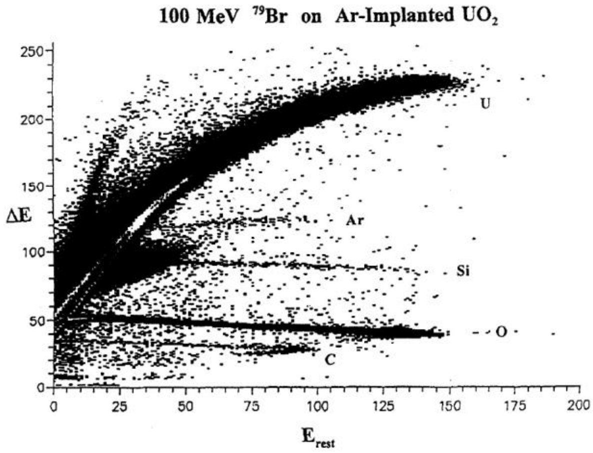

Fig. 5. High energy heavy ion ERDA [4].

3. Conclusions

Currently, DIAC provides users with about 1μA helium and argon beams for nuclear and fusion materials research. In the future, we will expand the utilizations to nuclear research such as high current helium beam, fast neutron source using lithium-deuterium reaction, SHI beam irradiation and high energy heavy ion beam analysis. For these utilizations, basic technologies such as small ECR ion source for helium beam, thermionic ion source for lithium beam, and particle detection technology for ERDA should be developed as well.

REFERENCES

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