CHAPTER 6

CONCLUSIONS

This research has been successfully worked at the Plasma and Beam Physics Research Facility (PBP), Chiang Mai University. The 30-kV vertical bioengineering beam line (CMU3) has been used in the research. The research composes of: (1) the designing, construction, installation, and testing of the deceleration lens system, (2) measurement of ultra-low ion beam energy, and (3) bombardment of naked DNA by nitrogen and argon ion beam at ultra-low energy.

6.1 Designing, construction and installation of the deceleration lens

The retarding electrostatic field was the basics of the deceleration lens, which was designed and simulated by the SIMION program version 8.0. The deceleration lens consisted of 6 Al-made cylindrical electrodes, having the last one connected with a long tube for the exiting parallel beam. Teflon rod insulators were used for separating the electrodes (the dielectric breakdown: 60 MV/m). The deceleration lens was installed inside the beam line of CMU3 ion implanter, and could decelerate ion beam energy from an order of tens kV to 10-100 eV.

6.2 Measurements of ultra-low ion beam energy

Basic theory of a deflecting electrostatic field was used in the measurement of the ultra-low ion beam energy. An ion was bent in a quadratic path inside an electrostatic field with a bending distance depending on ion beam energy. In the experiment, the distance of the ion was determined by measuring ion beam current as a function of position. The electric plates for bending ion beam were installed under the deceleration lens and the copper rod was used for measurement of the ion beam current. This technique is easy and simple based on the basic physics theory and reduces cost for construction.

The experiments of measuring an ion energy had measured 4 situations. The ion energy from the theories and simulations are 230.0, 56.5, 39.0, and 32 eV, from the experiments are 258.0, 62.0, 41.0, and 28.5 eV, respectively. The ion beam energy error from theories are ±11.3%, ±11.3%, ±9.5%, and ±8.9%, from simulations are ±11.1%, ±10.6%, ±9.5%, and ±9.1%, from experiments are ±14%, ±13.6%, ±10.5%, and ±6.9%, respectively.

The ion energy error can occur many reasons following, the first cause is the position of ion beam not stable at different time since the limitation of the ion source, the second, the deceleration lens was aligned non-coaxial including the electrodes were not circular which it occurs the ellipticity astigmatism, the third cause is the limitation of the resolution copper's slide which the resolution copper's slide is 1 mm, and the last cause is the error of equipment including observer's error.

6.3 Bombardment of naked DNA using ultra-low energy ion beam

This research focused on the direct effect of ion beam on DNA. The naked DNA could be changed from supercoiled to relaxed forms and even to linear form. Nitrogen ion bombardment was found to be more effective in causing the DNA damage than argon ion bombardment, due to its active character and interaction field stronger than argon ion because diameter smaller than argon. The interaction depends on inverse of distance between ion with target (ion, atom, molecule) power integer number ($1/r^n$). The interactions are: charge-charge ($1/r$), charge-dipole ($1/r^2$), dipole-dipole ($1/r^3$), charge-induced dipole ($1/r^4$), dispersion ($1/r^6$), and repulsion interaction ($1/r^{12}$), then if small distance compare with large distance, it show that the interaction of the small distance stronger than the large distance. Naked DNA bombarded by heavy ion beams with energy as low as tens of eV could induce the damage in DNA structure such as single strand break, double strand break, and multiple strand break. Therefore, this result extended our knowledge on energy limit for DNA damage at only tens of eV, not at keV level as previously used.