THE USE OF GRAPHENE AS STRIPPER FOILS IN SIEMENS ECLIPSE CYCLOTRONS

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Abstract

This paper presents the results of an experimental study for the use of graphene foils as an extractor (stripper) foil in the 11-MeV Siemens Eclipse Cyclotron. The main advantage of graphene foils compared with carbon is very high thermal conductivity. The graphene also has significant mechanical strength for atomically thin carbon layers. The life time of these foils is more than 16,000 μA*Hour. The graphene foils showed a significant increase in the transmission factor (the ratio of the beam current on the stripper foil to the current on the target), which was approximately 90%. The technology in fabricating these graphene foils is shown. The pros and cons of using the graphene material as a stripper foil in cyclotrons are analysed.

Eclipse Cyclotron for the production of medical isotopes

The Siemens Eclipse Cyclotron (pictured below) is an 11 MeV, negative ion, single particle accelerator designed for clinical and commercial production and distribution of isotopes for Positron Emission Tomography (PET) imaging.

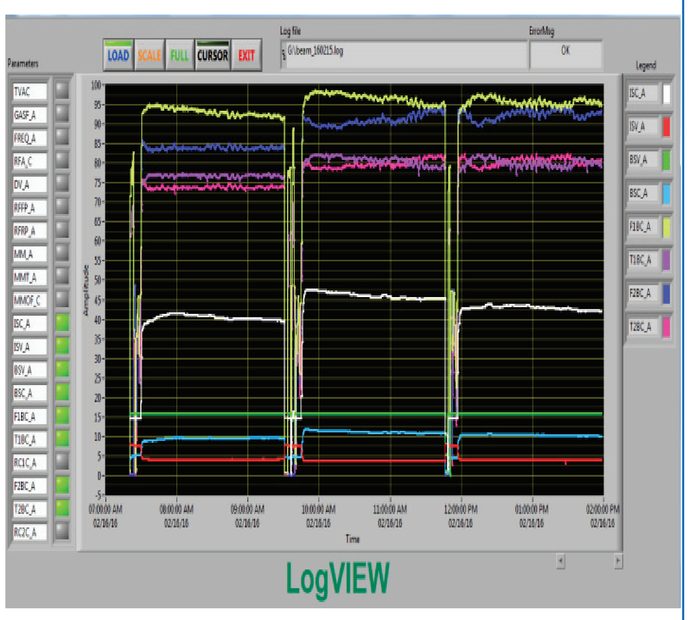
Graphene foil

The technology for the fabrication of graphene foils is described in more detail in paper:. *I. Pavlovsky, R.L. Fink. J. Vac. Sci. Technol. B 30(3), May/Jun 2012 . The* foil fabrication method is based on the controlled reduction of graphene oxide by hydrazine with addition of ammonia in an aqueous dispersion. The dispersion of graphene oxide with loading of 0.5% wt. in water was obtained from Angstron Materials. The dispersion was reduced for 4 hours at 95°C and then cooled down to room temperature. The thickness of graphene foils was controlled by using a calculated volume of graphene dispersion knowing the loading of graphene.

Experimental data

The main experimental result of testing of cyclotron with graphene stripper foils is high transmission factor and decreasing of ion source current. The good experimental correlation is decreasing of thickness with high thermal conductivity and ion source current allows to works on the relative low current ion source, that increase the life time of ion source.

Cyclotron	Proton beam current, mA	Transmission factor for regular and graphene stripper foils, %	Ion source current for cyclotron with regular and graphene stripper foils, mA
Cyclotron #1	2x55	86/75;92/78	230/192
Cyclotron #2	2x25	80/81; 88/89	120/90
Cyclotron #3	2x60 2x75	75/88;89/90 70/72;87/92	340/250 500/300
Cyclotron #4	2x60 2x80	73/82;82/90 70/85; 82/93	320/220 600/450



Log file shows the traces for main parameters of cyclotron

Life Time of Graphene Foils

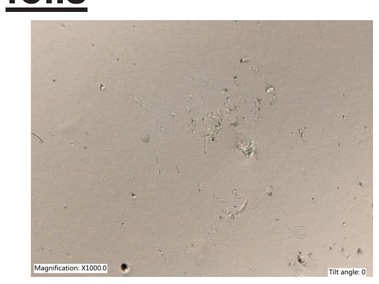
The lifetime of stripper foils is determined by 2 main mechanisms: radiation defects and sublimation. The experiments with graphene foils on the Eclipse cyclotron showed the radiation defects and sublimation have place.. The lifetime of graphene foils determined by losses of the transmission factor and the mechanical destruction.

The picture of broken graphene foils after 16,000μa*Hour

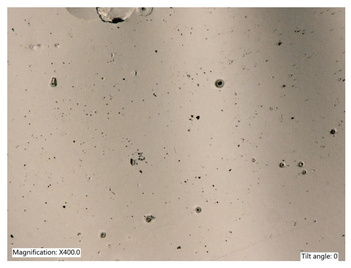
The comparison of stripper foils

Type of stripper foils	Pros	Cons
Carbon foil	1. Low cost.	1.Lifetime. 2. Thermal conductivity. 3. Ablation of foil.
DLC	1. Lifetime. 2. Small thickness.	1. High Cost. 2. Technology of fabrication methods.
Polycrystalline graphite foil	1. Low cost.	1. Lifetime. 2. Thermal conductivity. 3. Ablation of foil.
Graphene Foils	1.High thermo-conductivity. 2. Small thickness. 3. Lifetime.	1. Technology of fabrication. 2. Small number of suppliers.

The pictures from Laser microscope for graphene and regular carbon stripper foils

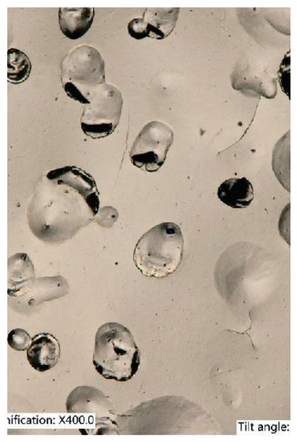


Surface of graphene -No beam



Surface of regular carbon foil -No beam

Surface of graphene foil after 10,000 μA*Hour



Surface of carbon regular foil after 100μA*Hour

Conclusions

In conclusion we can say that graphene stripper foils have a future that will require additional testing on different types of accelerators with stripper foils. The main advantage of the graphene stripper foils is their unique properties, such as a high thermal conductivity and high mechanical strength compared to the standard carbon and graphite type foils.

Acknowledgements

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