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Proceedings of RNB 2000 to be published in Nuclear Physics A

GANIL P 00 29

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Abstract

The diffusion properties of graphite targets with 1, 4 and 15 microns microstructure has been measured for He and Ar isotopes. An important enhancement of the diffusion efficiency for the smaller microstructure is observed. A releasing efficiency of the order of 100% was obtained for ^6He ($T_{1/2} = 806$ ms) at a temperature of 1600 K. The diffusion and production properties of He isotopes in a target of B_4C (Boron Carbide) have also been studied. Yields of 1.5 10^8 pps and 10^6 pps for ^6He and ^8He has been obtained.

The diffusion properties of carbon graphite and B_4C as well as the production yields of Ar and He isotopes have been measured at the SIRa/GANIL (Radioactive Ion Separator) - the test bench for SPIRAL [1]. The NANOGAN-III production system [2], consisting of a target container linked to an ECR (Electron Cyclotron Resonance) ion source by a cold transfer tube has been used. The releasing properties have been measured using the direct technique [3]. This technique is based on the faculty of the GANIL accelerators to produce a secondary radioactive beam by in-flight projectile fragmentation (using the

Preprint submitted to Elsevier Preprint *2 August 2000*

SISSI facility) and implant it in the ISOL target at SIRa. A first plastic scintillator placed just before the ISOL target allows us to evaluate the number of radioactive ions (NHE) implanted in the target. After diffusion, effusion, ionisation and selection, the remaining radioactive ions are detected at the end of the low energy line (NLE) of the separator. The overall efficiency can be written as:

$$\xi_{Total} = NLE/NHE = \xi_{SIRa} * \xi_{Diff-Eff} \qquad (1)$$

Where $\xi_{Diff-Eff}$ is the diffusion-effusion efficiency, which we want to deduce. The injection of a stable gas with the same chemical characteristics of the radioactive element close to the target through a calibrated leak allows us to have access to the time-independent efficiency of the SIRa separator, including the ionisation and the transport efficiencies, up to the detection station (ξ_{SIRa}).

In the first part of this contribution, we show the diffusion-effusion properties of a carbon target. The choice differs from the proton (or light ion) beam technique in that the projectile rather than the target is varied in order to produce the different radioactive species, thereby allowing us to use the most resilient and efficient production target for most cases. The target developed for SPIRAL consists in thin slices of carbon (0.5 mm) in a conical geometry [4]. We present the results of carbon targets with different grain microstructures, i.e. 1μm, 4μm and 15 μm of diameter. The diffusion-effusion efficiencies deduced from equation 1 for $^{35}Ar(1.78s)$ are shown as a function of the target temperature and the grain size in figure 1. The results show an important enhancement of the diffusion effusion efficiency for the 1 μm microstructure, when compared with the 4 μm and 15 μm. While 100% efficiency is reached at 2000 K temperature for the 1 μm carbon, only 30 % and 10 % has been measured for the 4 μm and 15 μm respectively. The continuous lines represent the theoretical calculations of the diffusion efficiency assuming as Arrhenius parameters: E_a = 2.38 eV and Log (D_0) = -3.6 $cm^2.s^{-1}$ (see equation 2) deduced fitting the experimental data of 4 μm and 15 μm.

$$\xi_{Diff} = 3\frac{(\sqrt{\pi_2\lambda/\mu_0}coth\sqrt{\pi^2\lambda/\mu_0} - 1)}{\pi^2\lambda/\mu_0}; \mu_0 = \frac{\pi^2 D}{\rho^2}; D = D_0 e^{\frac{-E_a}{kT}} \qquad (2)$$

Where λ is the radioactive decay probability, ρ is the grain size diameter and k the Boltzman constant.

The dashed line is obtained by fittig the 1 μm data. The obtained values are: E_a =5.41 eV and Log (D_0) = 4.6 $cm^2.s^{-1}$. The behaviour of the 1 μm data is very different from the latter one. We could imagine several reasons for a such effect. A possible interpretation could be the inter-grain effusion, which is certainly different between all cases studied. First of all, the 1 μm

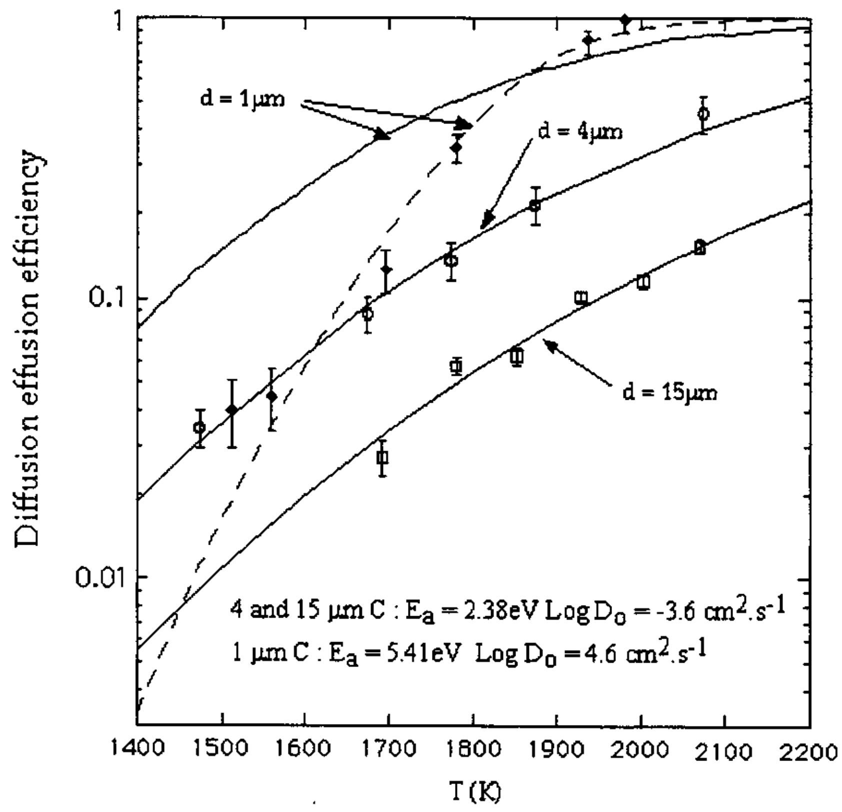

Fig. 1. Diffusion effusion efficiency as a function of the target temperature for ^{35}Ar

Table 1
Production yield obtained at the detection station of the SIRa separator normalised to 1pμA incident beam

Beam	Q	4 μm	1 μm	Beam	Q	4 μm	1 μm
$^{32}Ar(98ms)$	1+		9740	$^{34}Ar(844ms)$	1+		4.7 10^7
$^{32}Ar(98ms)$	7+	300	2700	$^{34}Ar(844ms)$	8+	7.9 10^6	2.2 10^7
$^{33}Ar(173ms)$	1+		5.8 10^5	$^{35}Ar(1.78s)$	1+		2.2 10^9
$^{33}Ar(173ms)$	8+	1.6 10^5	3.1 10^5	$^{35}Ar(1.78s)$	8+	3.0 10^8	5.4 10^8

carbon comes from POCO Graphite industry and the 4 μm and 15 μm carbon have been furnished by Carbone Lorraine. Secondly, the path between grains varies strongly with the grain size. Monte Carlo calculations are in progress in order to understand this behaviour. The production of neutron deficient Ar using the 1 μm and 4 μm microstructure targets with ^{36}Ar (95 A MeV) are reported on table 1. One observes an enhancement of a factor around 2 for the production of ^{35}Ar (1.78s) while a factor 10 is observed for ^{32}Ar (98 ms). This results confirms our preceeding efficiency measurements.

The diffusion-effusion efficiency of ^{6}He in the 1 μm microstructure target has been also measured as a function of the target temperature using a secondary SISSI beam. Two different geometries have been investigated: a - Sliced 0.5 mm target (as described above), b - A block of Carbon of 5 cm thick. The secondary beam energy has been chosen in order to implant the ^6He at a depth of 3 mm and 5 mm in the last (block) target. The obtained efficiencies are presented on figure 2. The first important observation is the fact that the ^6He diffusion-effusion efficiency reaches 100% at reasonably low temperatures, around 1600K. Secondly, one can observe an inter-grain "effusion" effect between the results at 3 mm and 5 mm depth. It is clear that a target design with slices has a better performance than a simple block. On the other hand - and for ^6He - the size of 0.5 mm is not a limiting parameter, since the efficiency obtained is already 100% at low temperature.

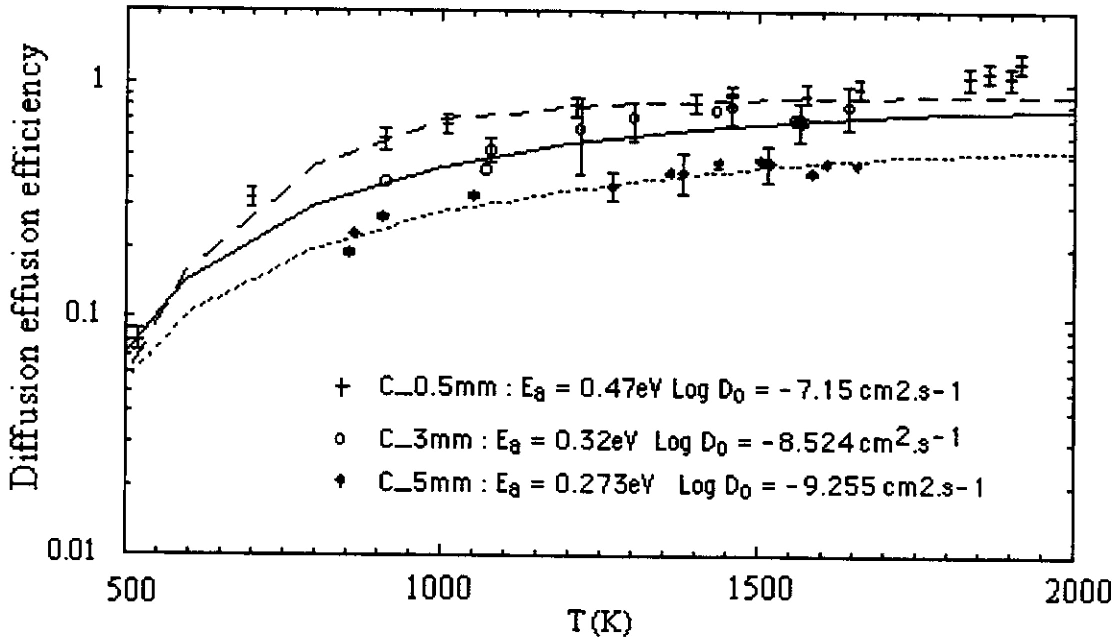

Fig. 2. Diffusion effusion efficiency as a function of the target temperature for ^6He.

Due to a better in-target production yield of $^{6,8}He$ in a lighter target - like Boron - we studied the releasing characteristics of a B_4C (Boron Carbide) target. A preliminary experiment has been performed using a 4mm block of B_4C with 10 μm microstructure. The best result obtained so far was an efficiency of 40 % at 1700K for releasing ^6He atoms. This preliminary result is very encouraging, since it is clear that a thinner microstructure and smaller slices could enhance this value. In spite of this result, Boron Carbide is not the best material concerning on-line production systems: weak resistance against thermal chocks and difficulty to machine. The production yields of $^{6,8}He$ in a mixed target has been measured with a ^{13}C at 75 A MeV production beam: B_4C - for target fragmentation products - followed by a C (1 μm block) stopper - for projectile fragmentation residues. We obtained 1.5 10^8 pps and 10^6 for ^6He and ^8He respectively, normalised to 1pμA incident beam.

In the near future, we will test a new double target, following the same geometry, but with slices. The first part can be of C (1 μm) - in a first step - or of B_4C if one improve the reliability of a such material.

References

[1] M. Lieuvin et al., *14th Int. Conf. Cyc. Applic.* Cape Town, S. Africa (1995) 651.

[2] L. Maunoury et al., *18th Int. Work. ECR Ion Sources* Texas USA (1997).

[3] N. Lecesne et al., *Nucl. Instr. Meth. Phys. Res.* **B126** (1997) 141 and references therein.

[4] R. Lichtenthäler et al., *Nucl. Instr. Meth. Phys. Res.* **B140** (1998) 415.