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Carbon stripper foils held in place with carbon fibers

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Abstract

The Spallation Neutron Source (SNS) currently under construction at Oak Ridge National Laboratory, Oak Ridge, Tennessee, is planned to initially utilize carbon stripper foils having areal densities approximately 260 μg/cm^2. The projected design requires that each foil be supported by only one fixed edge. For stability of the foil, additional support is to be provided by carbon fibers. The feasibility of manufacturing and shipping such mounted carbon foils produced by arc evaporation was studied using two prototypes. Production of the foils is described. Fibers were chosen for satisfactory mechanical strength consistent with minimal interference with the SNS beam. Mounting of the fibers, and packaging of the assemblies for shipping are described. Ten completed assemblies were shipped to SNS for further testing. Preliminary evaluation of the survivability of the foils in the SNS foil changer is described.

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Keywords: Carbon stripper foils; Carbon fibers; Stripper foils

1. Introduction

The Spallation Neutron Source (SNS) [1] currently under construction at Oak Ridge National Laboratory, Oak Ridge, Tennessee, is planned to initially utilize carbon stripper foils with areal densities approximately 260 μg/cm^2. Some of the projected requirements for such foils have been described [2]. The SNS design requires that each foil be supported by one fixed edge. If necessary for its mechanical stability, additional support will be provided by carbon fibers. These and other specifications were summarized in an SNS internal document [3].

It was desirable to evaluate the feasibility of manufacturing and shipping such mounted carbon foils. This report summarizes the methods used to provide an initial lot of 10 mounted-foil assemblies for testing purposes.

Table 1 lists the original specifications of the foil, fibers, frame and adhesives for these assemblies; some specifications were modified in order to reduce cost of production and/or to increase mechanical stability. Fig. 1 shows a drawing of a complete assembly.

Two prototypes of this assembly were constructed and tested for feasibility. Then 10 final assemblies were completed and shipped to SNS for further testing, to include evaluation of the survivability of the foils in the SNS foil changer.

2. Previous work

Carbon foils mounted with free edges have been used in several applications, and some of these have involved support with carbon fibers. Foils having areal density of 60 μg/cm^2 and a single free edge about 50 mm in length are used at the IPNS at Los Alamos National Laboratory [7]. Carbon foils having areal density of 4 μg/cm^2 with a free edge 32 mm in length, and carbon filaments with areal density 4 μg/cm^2, length 22 mm and two unsupported edges were used by Lozowski and Hudson [8]. At the Michigan State University superconducting cyclotron, foils at 200 μg/cm^2 have been used both with single free edges, and with a free edge folded for strength over a thin wire guide [9]. Cyclotrons used for production of medical isotopes use stripper foils mounted with a single free edge [10]. Sugai et al. [11] tested foils fastened to a frame only on one edge,

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Table 1
Original specifications of mounted foil assembly (with final modifications by ACF-Metals in parentheses)

Foil	
Material	Amorphous carbon, annealed
Areal density	$260\,\mu g/cm^2 \pm 10\%$
Pinholes	Minimized
Layering	One or two layers (one layer)
Lateral dimensions	0.47 in. × 1.58 in. (12 ± 1 mm × 40 ± 1 mm)
Method of deposition	Vacuum arc
Edge formation	Mechanically cut to size
Fibers	
Material	Carbon
Diameter	4–6 μm (7 μm, Thornel T-300 [4])
Number of fibers	Not specified (4)
Pitch	⩾3 mm (5 mm)
Frame	
Material	Aluminum (alloy 1100 H14)
Purity	⩾99% (commercial purity)
Thickness	0.125 in. (3.18 mm)
Adhesives	
Carbon-to-frame	Epoxy, ultra-high vacuum compatible Tolerant to radiation $\leqslant 10^4$ rad/s Tolerant to total radiation $\leqslant 7\times10^6$ rad (Master Bond #EP33LV [5])
Conductive coupling	Graphite (Acheson DAG 154 [6])

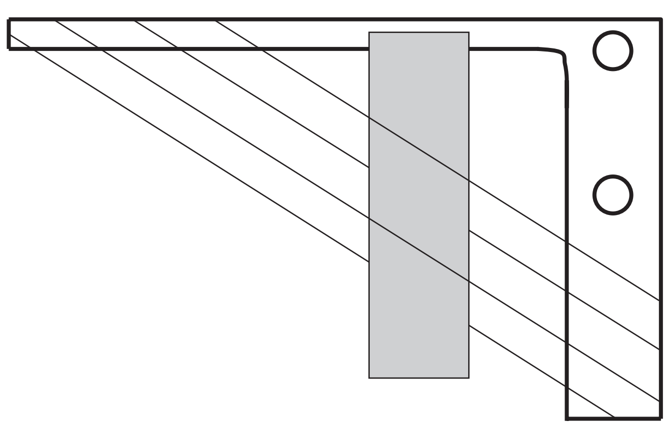

Fig. 1. Carbon foil holder (L-frame) showing nominal position and size of foil. The frame is about 76 mm wide and 51 mm high. The material is aluminum alloy 1100 (commercially pure), temper H14, nominal thickness 3.18 mm. Nominal positions of the fibers, alternately on top of and underneath the foil, are indicated. Mounting holes have diameter 4.22 mm. For ease in alignment of the fibers, small notches (not shown) were cut into the upper edges of the frame, to provide a center-to-center separation of 5 mm for adjacent fibers.

with stabilization of the foil using carbon fibers. Carbon foils having areal densities of $200\,\mu g/cm^2$ and supported entirely on carbon fibers (i.e., four free edges) were used at LAMPF [12]. That reference provided several useful hints for the present work. Previous work at the same facility used large triangular foils with areal density $625\,\mu g/cm^2$, also supported entirely on carbon fibers [13].

3. Experimental

3.1. Production of foils

Numerous methods are known for producing carbon foils [14]. For the present work, carbon foils were produced by multiple arc evaporations [15,16]. The foils were annealed in nitrogen at $220\pm10\,^{\circ}C$ for 1 h, then cut to size using a straightedge and a sharp razor blade. Such foils have turbostratic crystal structure [17,18], and are suspected to have microcracks at cut edges [19]; however, no indication of fractures extending into the foil was seen in this study. Foils were weighed to verify their areal densities, selected for minimal pinhole density, and stored until use.

3.2. Choice of fibers

For the purposes of providing maximum restraint on the mounted foils, and for ease in handling, the maximum allowable fiber diameter was desired. However, minimal loss of the SNS beam for particles passing through the support fibers required use of minimum fiber diameter. After trying several different fibers, those having diameters below 7 μm were deemed too frail to be useful for this application. The final choice was Thornel type T-300 [4] consisting of 1000 fibers in a straight (not woven) bundle, or tow. The fiber diameter was measured both by microscope and by laser scattering, and was found to be $6.95\pm0.6\,\mu m$.

Health hazards involved with the use of carbon fibers include "mild, temporary mechanical eye and skin irritation" [20]. No case of disease, which is caused by carbon fiber, has been reported, according to Ref. [21]. The precaution was taken to wear goggles and filter-based respirators while working with carbon fibers. The mask also helped to prevent damage to the foil–fiber assembly due to air currents caused by breathing.

3.3. Mounting procedure

A 30–50 cm hank, or length of the tow, was cut off of the spool of fiber and laid on a clean glass plate illuminated from below. A tiny bunch of fibers was pulled lengthwise out of the hank and laid onto the glass plate. The end of the bunch was then teased apart to display the individual fibers.

Pieces of Scotch Magic Mend tape (#810), 19 mm wide, were used to handle individual fibers. A piece of this tape about 5 mm long was folded crosswise to make a non-sticky end about 6 mm long, leaving a sticky end about 7 mm long. The sticky end was used to pick up the free end of a fiber from the glass plate. The sticky end was then folded over the end of the fiber to secure it, and then the tape could be used to pull the fiber free of its bunch. The tape was then laid on the glass plate, and another similar piece of tape was used to pick up the other end of the fiber. It was helpful to make the second piece of tape somewhat