Fabrication of ~ 450 μg/cm^2 Ni pressure window foil for HYRA

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Introduction

In gas-filled recoil separators [1], we need to separate the gas-filled magnetic region from beam line vacuum. One can use a thin foil or differential pumping.

The simplest is to use a thin foil. This foil can ideally be of any material, but should possess certain characteristics like strength to hold the pressure difference, ability to dissipate the heat produced by beam hitting, low Z and minimum thickness in order to minimize the beam energy loss in it.

Using thin carbon or nickel (Ni) foil for this purpose is a convention. In HYbrid Recoil mass Analyzer (HYRA) [2] at IUAC, we have been successfully using Ni foils of thickness ~ 1 - 1.5 mg/cm^2. These foils could survive several days with few pnA beam current. Fig 1 shows a schematic diagram of the experimental set-up.

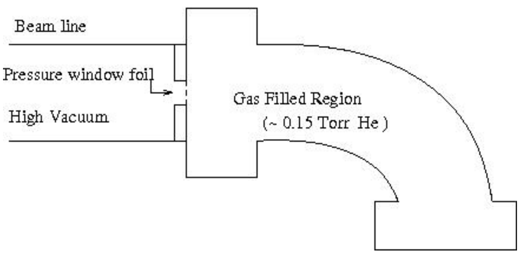

Fig.1 - Schematic diagram of the set-up.

Recently we tried to make thinner foils i.e. thickness below 1 mg/cm^2. Here we present the process of fabrication of thin Ni foils by rolling and the difficulties encountered.

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Rolling of Nickel foils

Ni is a silvery-white metal with a slight golden tinge. It belongs to the transition metals and is hard and ductile.
Ni foils to be rolled were placed between highly polished mirror finished folded stainless steel plates and rolled by means of a set of the shaped rollers in a conventional mill.

Ni foils were rolled from ~ 22 mg/cm^2 to below 1 mg/cm^2, the thinnest being ~ 450 μg/cm^2. As the thickness became less, small pin holes started appearing in the foil, and also a tendency to stick with the steel plate was developed in the foil.
Some precautions taken are-

Cleaning of stainless steel plate thoroughly with alcohol, so that it was not sticky, and dust free, reduced the chances for pin holes.

The pressure on the rollers was increased in small steps, so that foil didn't stick to plates, and a uniform thickness foil could be rolled.

When a foil stuck to the plates, we waited till the stress developed in the foil released, Then we tried to remove the foil from plates carefully using alcohol or acetone, if required.

Towards the lower thickness, when foil appeared to tear at the borders, those were trimmed immediately in order to stop the cracks from propagating further. Thus the effective area of foil normally went on decreasing as we went towards lower thickness.

In between the rolling, plates and foil itself were dipped in acetone to remove any dust particle. And below 1 mg/cm^2, most of the time we had to dip the stainless steel plate in acetone or alcohol to float the rolled foil.

Though all these precautions increases the survival chances of the foil considerably, yet rolling a foil of desired thickness is an art which takes time and patience.

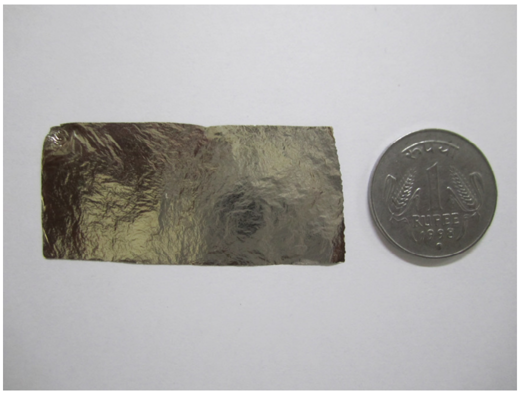

Fig 2- Ni foil of thickness ~ 680 µg/cm^2 (5.6 × 2.5 cm^2)

Pressure testing of foil

One foil of thickness ~ 450µg/cm^2 was pasted on an annular flange of 15 mm inner diameter and tested for pressure handling capability. Helium gas pressure on one side of the foil was maintained at 1.3 mbar and other side pressure was 1.7 × 10^{-5} mbar.

Though by careful rolling, the number of pin holes could be reduced, it was not possible to make such a thin foil free from pin holes.

As long as, the gas leakage through the pin holes does not hamper maintaining the desired pressure difference, the same can be accepted.

In an actual experiment we use the helium gas at a pressure lower than this (0.15 torr).

Result

A fresh lot of Ni foils was rolled to be used as pressure window foils for HYRA gas-filled operation. In the present lot of foils, maximum thickness was ~ 1 mg/cm^2 and minimum thickness achieved was ~ 450µg/cm^2. Thickness was estimated by dividing the weight of the foil by area.

The thinnest foil (~ 450µg/cm^2) could be successfully tested for pressure handling.

The table below shows the details of foils rolled in this lot. Foils with larger area can be cut and used for more than one flange.

Area	Thickness	Status
1.8 × 2.5 cm^2	~ 450 µg/cm^2	Pasted
2.5 × 2.0 cm^2	~ 540 µg/cm^2	Broken but can be used as a target
5.6 × 2.5 cm^2	~ 680 µg/cm^2	Intact
2.0 × 2.5 cm^2	~ 700 µg/cm^2	Pasted
2.1 × 2.7 cm^2	~ 810 µg/cm^2	Intact
5.0 × 3.0 cm^2	~ 1 mg /cm^2	Pasted (1 piece)

Acknowledgment

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References

[1] M. Leino, Nucl. Instr. and Meth. B 204, 129 (2003).

[2] N. Madhavan et al, PRAMANA-J. Phys. 75, 317 (2010).