Reactive Plasma Etching for GEM foil fabrication

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Introduction:

Large area, Micro Pattern Gas Detectors (MPGDs), such as Gas Electron Multipliers (GEMs) having an active area in the range of 100 cm^2 to 5000 cm^2 are becoming quite robust with evolving techniques as they can simultaneously provide tracking and triggering in high energy physics experiments. GEMs are becoming quite popular, because of the use of eco-friendly and non-flammable gases such as Argon and CO_2. The GEM foils consists of 5 μm of Cu clad on both the sides of 50 μm polymide (PMMA/kapton) (5/50/5). At present these foils are developed in South Korea without having any adhesive between the Cu and polymide. There are various techniques involved in making uniform punch through holes (70 μm diameter at a pitch of 140 μm in a repetitive equilateral triangle geometry) in the Cu clad polymide foils, such as chemical etching [1], reactive plasma etching and laser etching. In this paper, we report our efforts in the direction of developing a set up for reactive ion etching for copper and polymide with the help of a local industry.

Present process of GEM foils making involves Photolithography and Chemical/ Electrochemical etching of copper and polymide layers. Uniformity and reproducibility of etching are governed by the rate of a chemical reaction and is a function of ratio of activities (concentration) of reactants to products, temperature and mass transport parameters. Activity, at the reaction surface is a function of diffusivity of reactant species (inward) and products species (outward) through the boundary layer i.e. the stagnant layer sticking to the reaction surface. The flow of reactants and products across boundary layer is controlled by the thickness of boundary layer. When the reactants and products are in liquid state, the reaction rates are highly sensitive to temperature and concentration of reacting species. In case of liquids, the boundary layer is a few microns thick and the thickness increases along the geometry such as depth of the hole. The supply of the reacting species to the reaction surface becomes lesser as the holes become deeper resulting in conical wedges. Due to the above reasons wet chemical processes have performance limitations such as poor differential etch rate, low anisotropy of etching, heavy undercutting, and poor resolution of geometry. These limitations affect the quality and yield during production of GEM based detectors.

As an alternative technique reactive ion etching (dry etching), process is being developed using Sulphur Hexafluoride + Oxygen plasma (SF_6 + O_2 plasma). A Vacuum system with CCP plasma at 13.56 MHz is built to create a range of process conditions. The variables are pressure, substrate temperature, power density, DC bias and the gas ratio. The parameters under investigation are differential etch rates on photo-resist, Copper and PMMA. The vertical etch profile is also studied. Optical / Scanning Electron Microscopy (SEM) is employed to measure dimensions of features. As is shown in Fig.1., one obtains a large aspect ratio (depth to width : L/a) of 100 μm : 15 μm, for silicon in the same set up that has been developed for GEMs,

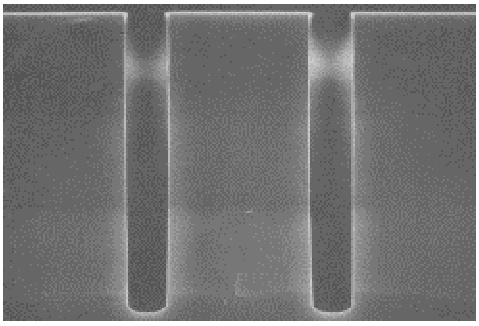

Fig. 1 : Large aspect ratio (depth to width, L/a) of 100 µm to 15 µm in case of silicon

The foil used in this set of experiment has 5 µm copper clad on both sides of 50 µm thick polymide foil (PMMA/Kapton 5/50/5). The vacuum system used for conducting plasma etching experiments consists of a sealed chamber, 450 mm internal diameter and two electrically isolated round electrodes of 200 mm diameter as shown in Fig.2. Upper electrode has fine holes distributed over its bottom surface to serve as shower head for gas mixture flow. Electrodes are placed at a distance of 10 to 30 mm, parallel to each other. Samples of 25 mm x 25 mm is cut from these foils and used for etching experiments. The sample is placed on bottom electrode. After pumping vacuum chamber to 30 mTorr pressure, gas mixture is added through shower head electrode, pressure is maintained at 0.7 to 3.0 Torr while ratio and flow rate are controlled by Mass Flow Controllers (MFCs). A 600 Watt capacity RF generator is used to power one electrode and other is connected to ground. Plasma is created by manual matching of circuit impedance. Etching cycle is set up with a timer typically 10 to 30 min. The plasma is observed through a viewing port for colour (pinkish glow) and intensity (Fig.2). Typical Etching process values are : Process Pressure : 1.10 Torr, RF Power Density : 2.03 Watt/cm^2, Substrate Temp : 25^{O}C (Start), 35^{O}C (End), Etch Time :10.0 min.

For Copper Film Etching :

a) SF$_6$: 22.5 SCCM (90%)
b) O$_2$: 2.5 SCCM (10%)
c) Achieved etch rate : 0.1 micron /min

The copper etched is shown in Fig.3.

For Polyamide Film Etching

a) SF$_6$: 5 SCCM (20%)
b) O$_2$: 20 SCCM (80%)
c) Achieved etch rate : 0.5 micron/min

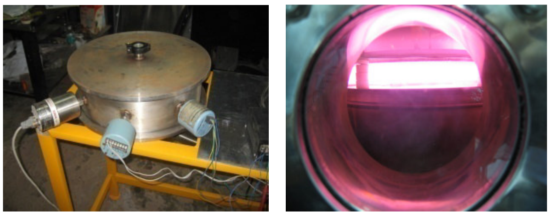

Fig. 2 : Plasma etching set up (left) & SF$_6$ + O$_2$ RF plasma at 13.56 MHz, through a view port with a pinkish glow (right)

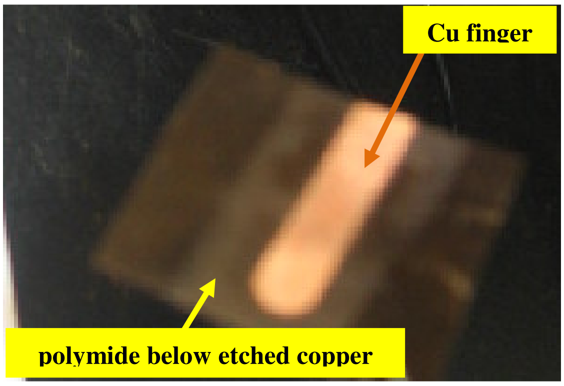

Fig. 3 : Copper etched around the Cu finger, exposing the polymide (PMMA/kapton)

Conclusions :

The reactive ion etching has shown good control on vertical profile of etched copper. The results also indicate a good differential etch rate between components of the foil by controlling the gas concentrations. It is further planned to have a layout over a 10 cm x 10 cm square, with rows of 65 µm holes at a pitch of 130 µm, which would be presented at the time of symposium.

References :

[1] https://twiki.cern.ch/twiki/pub/MPGD/CmsGEMCollaboration/GEM_technical_proposal.pdf