Scanning Hall Probe Fabrication

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Abstract:

Scanning Hall probes can be used to measure and image magnetic fields in a non-invasive manner. Magnetic field imaging is a very useful way to study the properties of superconducting materials. Improvements to the Hall probe design have been made to decrease the size and shorten the processing time of the probes. In this work, the new design was implemented and the Hall probe recipe was altered to optimize the fabrication process.

Background:

Scanning Hall probes utilize the Hall effect to make magnetic field measurements. Consequently, Scanning Hall probe microscopy is a very useful approach to studying superconducting materials. High temperature superconductivity has been a major technological advancement of recent history, yet there is still much to be learned about the fundamental physics behind the superconducting phenomenon. Using Hall probes to study the magnetic properties of superconducting materials can help to elucidate the physical mechanisms behind superconductivity.

Smaller Hall probes are desirable for improved magnetic field measurements. The Hall probe design has been enhanced to create 100 nm probes. The Hall probe design has also been changed so more of the probe can be defined optically. E-beam lithography is a slow and tedious process, using optical photolithography to define larger features of the probes can greatly decrease the processing time. Other changes to the probe design include the addition of an extra lead to enable gate defined probes, and more alignment marks.

Process:

The first step in Hall probe fabrication is the chip preparation. The probe mask design requires a chip that is approximately 7 mm x 9 mm, which must be cleaved from a gallium arsenide wafer. The chip then must be cleaned with a three solvent clean of acetone, methanol, and isopropyl alcohol. To improve the cleanliness of the chip, we added a hydrofluoric acid dip, which removed an additional 25%-35% of the particles on the chip. The chip is then baked and coated with HMDS to promote adhesion.

The next step is to coat the chip with Shipley's 3612 photoresist. Spinning on the resist at 3500 rpm's for 35s creates a 1.6 μm layer of resist. The spin coating is followed by a 60 second bake at 90°C. The next step is to define the Hall probe design using photolithography. A Karl Suss aligner was used to expose the chip. Before exposing the probe design, it is helpful to expose the edges of the chip to remove the edge bead created during the spin coating. Any additional edge bead must be removed with acetone and a clean room wipe.

Frequently the chuck range of the aligner and the size of the chip made it difficult to align the probe design on the chip. One way of getting around this problem was to mount the chip on a piece of silicon. In the future, the mask design will be changed to accommodate this problem.

After exposure, the piece is developed for 35s in LDD-26W developer. After another HF dip and oxygen plasma clean, the chip is ready for the deposition of the metal contacts. The metal deposition is done in an evaporator and consists of nickel, germanium, and gold layers. After deposition the unwanted metal is lifted off in acetone. Generally an ultrasonic bath is needed to aid the liftoff. The first attempt at liftoff produced less than desirable results, consequently, we began using an undercutting technique to improve the liftoff results.

Before spinning on the photoresist, we coated the chip with LOL 2000. The LOL 2000 was spun on at 3000 rmp's for 60s and then baked at 170°C for 5 minutes. It was found that the bake time for the LOL 2000 is very sensitive. Baking for 7-8 minutes seemed to cause problems with the development of the resist. Figure 1 shows the results of an incomplete development of the resist on a non-scan probe pattern.

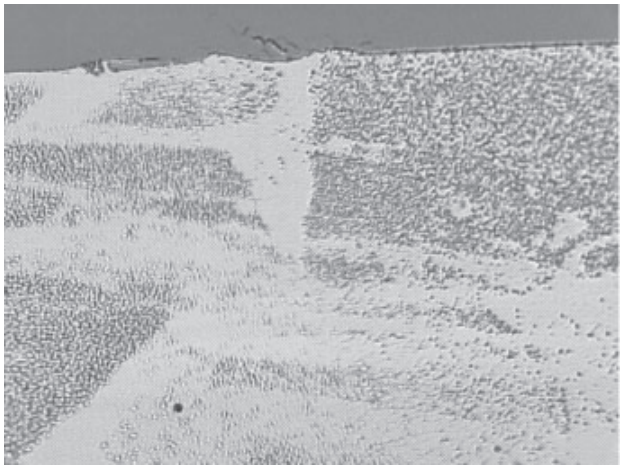

Figure 1: Residue left after incomplete development of resist.

After the bake, the chip is then coated with Shipley's 3612 photoresist. After liftoff, the piece is annealed in the Rapid Thermal Annealer. Annealing creates an electrical connection between the ohmic contacts and the 2-dimensional electron gas below the surface of the chip. The ohmic contacts must now be electrically isolated from one another. This is done using a deep mesa wet etch.

The mesa etch is defined using optical photolithography as before. Test samples were etched using both sulfuric acid and citric acid to help determine the ideal etching solution. The citric acid had an average etch rate of 2.6 nm/s, making it preferable for the mesa etch. The 100 nm active area of the probe must be defined using e-beam lithography. Unfortunately the e-beam machine was down and we were unable to complete the probes before the end of the program.

Results/Conclusions:

The Hall probe fabrication process was optimized by incorporating optical photolithography into the design where it was possible to do so. This saved considerable time and effort, which would otherwise be spent in the e-beam processing. The metal liftoff was improved by spinning a layer of LOL 2000 beneath the photoresist. This led to more a complete liftoff of the metal. The etch rates of sulphuric and citric acid were tested to determine the best choice for the wet mesa etch. The citric acid was determined to be the most ideal with an etch rate of 2.6 nm/s. The above improvements to the Hall probe recipe were used to fabricate chips with scanning Hall probes, non-scanning test probes, and Hall bars.

Future Work:

The active areas of the probes still need to be written using e-beam lithography. This will be done when the machine is up and running. After completion, the probes will then be ready for characterization and testing.

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