SHOP NOTES

These are "how to do it" papers. They should be written and illustrated so that the reader may easily follow whatever instruction or advice is being given.

Defining micron-scale platinum contacts on hydrogenated amorphous silicon

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(Received 8 June 1989; accepted 19 September 1989)

Various hydrogenated amorphous silicon (*a*-Si:H) devices, [for example, the Schottky diode[1] and the static induction transistor (SIT)[2–4]] require good platinum Schottky contacts made on *a*-Si:H. The definition of these (Pt) contacts on the millimeter scale on *a*-Si:H is easily made using a macroscopic metallic mask deposited onto the *a*-Si:H surface during Pt evaporation or sputtering. However, the utilization of *a*-Si:H for microelectronics is of increasing interest. The fabrication of patterns on the micron scale requires the use of conventional microelectronics techniques such as liftoff, and wet and dry etching. For that reason, we have performed a systematic study of the various ways of defining micron-scale Pt patterns on *a*-Si:H.

All tests have been made on 1500 Å thick Pt films sputtered on *a*-Si:H maintained at 250 °C, in a 20 mTorr Ar atmosphere with an incident power density of 1.65 W/cm^2. Table I summarizes the various processes investigated to define micron-scale Pt contacts on *a*-Si:H, along with the advantages and disadvantages of each process.

The liftoff technique[5] is usually a simple process that can be used to define micron-scale patterns. Chlorobenzene has been used to harden the top of the resist and to create an overhanging profile in the resist pattern. The main disadvantage of the liftoff approach for the case of Pt on *a*-Si:H, is that it leaves a residue of photoresist on the *a*-Si:H surface. An ultrasonic bath of acetone is required to remove most of this resist residue. We have used this technique with some success to define Pt lines having widths between 2 and 7 μm for the fabrication of a SIT.[4] However, this ultrasonic bath is violent and leads, in many cases, to severe pattern damage. We could also use a O_2 plasma etch to remove resist residues. However, the *a*-Si:H surface exposed to plasma seems to be deteriorated from an electrical point of view. Liftoff is therefore not recommended if one looks for a reproducible process.

The use of conventional wet etching with the solution $HCl:HNO_3:H_2O$ (7:1:8) at 70 °C[5] is suitable for a 700 Å thick Pt film, giving an etch rate of 500 Å/min. This solution cannot be used for a 1500 Å thick film, because the entire film always peels off the surface before the etch is completed. Several solutions of different proportions (3:1:4, 5:1:8) and at different temperatures (25, 50, and 80 °C) have been used but they all showed the same behavior after shorter immersion times. This phenomenon is probably due to the chemical solution infiltrating the Pt/*a*-Si:H interface from the sides of the sample causing a delamination of the Pt film. Peeling of the Pt film is not due to small dimensions of contacts since we have successfully defined Pt contacts of the same size on SiO_2 using this technique. This peeling seems to occur on the Pt/*a*-Si:H interface and results from poor adhesion between the Pt film and the *a*-Si:H substrate. Even a 2-h anneal at 275 °C did not improve the adhesion of the Pt film sufficiently to allow us enough time to etch successfully. Aqua regia solution ($HCl:HNO_3$, 3:1) cannot be used either, since the Pt film does not withstand the required 30-s immersion in HF prior to this etch.[5] The best wet-etching solution is $HCl:HNO_3:H_2O$ (7:1:8) at 70 °C, but it is recommended for Pt films thinner than ~700 Å.

Dry etching involves a plasma of a noble gas or of fluorine or chlorine based molecules. We do not suggest using Ar since we have found that the resist used (Microposit Photoresist S1400-23) when exposed to Ar bombardment cannot be removed even if left in a remover solution (Microposit Remover 1165) for several days. Following our previous work,[6] we used pure CF_4 at 20 mTorr pressure and an incident power density of 0.55 W/cm^2. This process gives an

TABLE I. Processes for defining micron-scale Pt contacts on *a*-Si:H.

Process	Advantages	Disadvantages
1. Liftoff	Simple	Residue of resists on the *a*-Si:H surface
2. Wet etching ($HCl:HNO_3:H_2O$)	Simple	Only suitable for films thinner than 700 Å
3. Dry etching (CF_4)	Simple; good definition	Significant undercut; not very selective; possible deterioration of the electronic properties of the *a*-Si:H surface
4. Combined dry etching followed by wet etching	Good definition; reproducible	Complicated process; requires a precise knowledge of both etching rates

 0734-211X/90/010109-02$01.00

etch rate of 50 Å/min for Pt, but an important undercut is observed. Moreover, it is a nonselective process that etches the *a*-Si:H as well, with an etch rate of ~80 Å/min. According to electrical measurements made on our fabricated SIT, it seems that exposition of the *a*-Si:H surface to the ionic bombardment deteriorates the electronic properties of the *a*-Si:H surface in such a way that the channels of the transistors could not be opened.[4,7] Therefore, dry etching is recommended only for specific applications where the electronic properties of the *a*-Si:H surface are not important.

To prevent any exposure of the *a*-Si:H surface to the plasma, we have to use an alternative technique. We have developed a combined process in which Pt is etched by plasma down to a thickness of ~700 Å, which is followed by a wet etch of $HCl:HNO_3:H_2O$ (7:1:8) at 70 °C (etch rate of 500 Å/min). The wet etching time must be <90 s in order to prevent any peeling of the Pt film. We have to control the temperature of the etching solution within a ± 3 °C range to obtain reproductibility in etching time and resolution of patterns within 10% (considering that dry etching is well controlled). This being so, we obtained six samples from three different runs that resulted in a uniform etch (75 s etching time and 2 μm resolution for all of them).

We could expect that aqueous solution has an effect on the electrical properties of the *a*-Si:H.[8] Nevertheless, we believe that this effect is less important than the one induced by ionic bombardment since SIT exposed to an aqueous process worked whereas those exposed to a plasma process did not.[4,7]

In conclusion, we suggest that while dry etching is acceptable in certain cases, only a combined process (plasma followed by wet etching) is suitable in applications like the SIT, where the electronic properties of the *a*-Si:H uncovered by etching Pt is important.

Acknowledgments: We would like to acknowledge the financial contribution of FCAR of Quebec, FDP of École Polytechnique de Montréal, and NSERC of Canada. The authors also thank S. Boivin of École Polytechnique for his technical assistance.

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