

Use of Stainless Steel Piezo Inkjet Printheads to Enable Jetting of Aggressive Etchants for Improved Solar PV Cell Processing

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Introduction

Solar photovoltaic cells are devices for converting solar radiation to electrical energy. Solar radiation impinges on the active layer of the solar cell (typically silicon) and excites nearby electrons sufficiently to create a current in an electronic circuit. The contact fingers typically located on the front and back plane allow an external electrical circuit to be coupled to the solar cell.

In traditional Silicon-wafer based solar cells the crystalline silicon substrate material typically makes up 50 – 75% of the cost of the cells. Because silicon does not absorb light very strongly, silicon wafer cells have to be very thick (around 180 – 200 μm). In order to reduce cost the trend is to move to thinner wafers. Because wafers are fragile, their intricate handling complicates processing all the way up to the panel product.

In solar cell manufacturing wet chemical processing has been adopted from more mature industries such as semiconductor and printed circuit board industries. Etching of features can offer desirable results – such as producing electric contact points to underlying doping layers of a junction or to isolate segments of a cell to enable series combination.

Photolithography is the traditional method for production of a negative or positive etch structure. It is a multi-step process comprising spin coating of the substrate surface with liquid photoresist; drying of the photoresist; exposure of the coated substrate surface; development; rinsing; etching of the structures through wet etching or dip processing; dry etching such as plasma etching in vacuum units or with reactive gases; removal of the photoresist by solvents; rinsing; drying.¹

Through this method features can be etched accurately with typical widths of 100 μm or greater. However, it is particularly disadvantageous that a large number of process steps are required with use of expensive capital equipment with considerable amounts of chemicals (photoresist, developer, etching agent, resist stripper) and rinsing water consumed. Contact of the fragile silicon material can potentially result in breakage and scrap.

In addition, a common feature of the fluid etching agent is the extremely corrosive nature. This can be problematic to the surrounding equipment, operating personnel and environment.²

A more efficient approach with considerable reductions in process steps, fluids, and capital equipment - and without silicon contact - is the use of a non-contact ink jet for precise etch positioning and etching control. Alkaline or acidic etchants can be used as the jetted etching fluid. Through this additive process etch line widths of <50 μm can be achieved.²

Ink Jet Etching Features

When processing photovoltaic cells the goal is to selectively deposit a processing etching agent directly onto a substrate surface to be processed in only locations where processing is required. This optimizes efficiency and eliminates waste. Ink jet is an alternative process to traditional photolithography methods to achieve digitally controlled etching in an effective manner, without contacting the fragile substrates and with reduced impact of hazardous etchants to equipment, operating personnel and environment.

A solar cell is typically comprised of a plurality of diffusion layers. A dielectric layer is formed over the diffusion region to prevent a metal contact finger of one polarity from electrically shorting to a diffusion region of another polarity.

An ink jetted etchant can be used to produce selective features in the cell layers. For example, undercut openings can be produced in dielectric layers and semiconductor structure. Since the different layers have different resistivities against etchants the etch process can be well controlled.¹ Refer to Table 1 for etchant examples.

Layer	KOH Alkaline	H ₂ SO ₄ Acid	NaOH Alkaline	H ₃ PO ₄ Acid
SnO ₂ or ITO	X			
ZnO		X		
A-Si	X		X	
Back electrode		X		X

Table 1. Acid and alkaline etchants for producing solar cell features.

In one described cell process a first etchant is applied to open the top dielectric or insulating surface layer. A localized laser can be used to heat the etching expediting the etching effect. A second etchant then etches the semiconductor material significantly more strongly than it etches the top surface layer. The second etchant will open a hole in the semiconductor material under the surface layer and will then etch sideways to undercut the surface layer. This undercut can be used for a contact to underlying doping layer of a junction. A subsequent metallization step can be used to contact the doped region at the bottom of the opening while isolating it from the upper oppositely doped layer by the formed void.

In another etching application related to amorphous silicon thin film solar module fabrication the silicon thickness is approximately 1.6 μm . Contact processes could damage the thin film. Small drops of caustic alkaline fluid are jetted in order to etch through the resin film / silicon layer to form electric contacts after a metallization process. ¹ (Figure 1.)

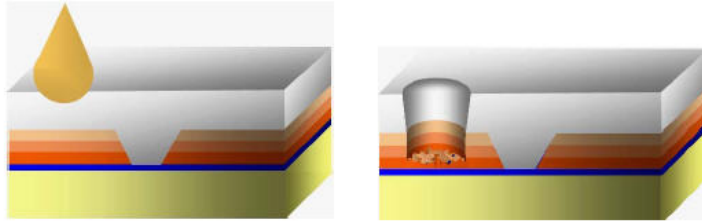


Figure 1. Acid or Alkaline Etching to Resist Layer

In a third etching application the back electrode is pattern etched with narrow stripes. This produces multiple, individual micro cells which are then interconnected in series to increase efficiency and power output. ³

Controlling Feature Resolution

These etching processes may be enhanced further by constraining the drops of the etching agent providing increased positioning control over the deposition process. This can be achieved for example by applying a hydrophobic coating to the surface prior to depositing the etchant causing the deposited droplets to form tight drops which do not spread out. The hydrophobic coating may then be removed or in some cases remain as part of the structure. ²

Another method to control drop spread is to adjust the viscosity of the processing agent through an additive or thickener.

Another drop control approach is to use a laser in concert with the ink jet to locally heat regions of the substrate being processed in order to subsequently evaporate the jetted etchant to reduce the dot size while simultaneously heating the etchant to increase the etch rate. The result is production of a hole smaller in diameter than the original dot. ⁴

Using these techniques produces lines and grooves by printing of the etchant in abutting or slightly overlapping dots without the etchant dispersing significantly from the deposited location.

Jetting Performance with Trident Piezo Ink Jet

Jetting an etchant requires an ink jet printhead that is sufficiently inert in its construction. Trident's "256Jet-S™" Piezo Printhead is stainless steel with a stainless steel diaphragm isolating the piezo elements from the fluid path. The nozzle plate is made of inert stainless steel. The combination of stainless steel components in the fluid path enable jetting of both alkaline or acid etchants from 2-14 PH while maintaining a long printhead life with good return on printhead investment.

The 256Jet-S™ Piezo Printhead contains 256 individually controlled nozzles along a 100 mm width (Fig.2). The nozzles can be arranged in rows and columns to form an array with dots created on the substrate based upon the pitch of the ink jet printhead nozzles. One or more passes of the printhead over the silicon wafer can result in patterns being printed.

The 256Jet-S™ Piezo Printhead can be heated up to 70°C to enable jetting of increased viscosity fluids for both formulation flexibility and reduced drop spread.

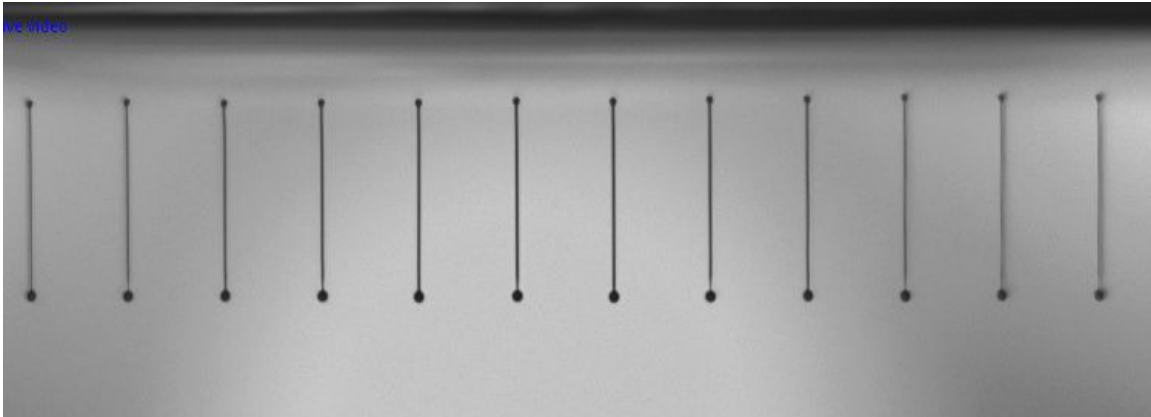


Figure 2. A dozen nozzles of Trident's 256Jet-S ink jet printhead jetting simultaneously

A KOH solution (14 pH) demonstrated no corrosion or impact on printhead materials or performance.¹ A Phosphoric Acid solution (2.5 pH) produced 10 kHz capability (Fig.3).

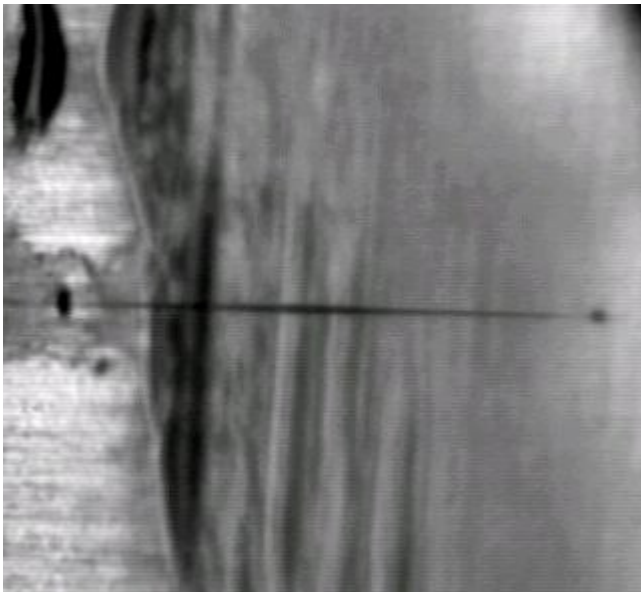


Figure 3. Trident's 256Jet-S Piezo Printhead jetting a 2.5 pH Phosphoric Acid Solution (22 cps viscosity at the printhead operating temperature).

Conclusion

The non-contact capability and precise, controlled capabilities make ink jet deposition of acidic and alkaline etchant solutions an alternative cost effective approach to traditional processes for the manufacture of solar cells.

References

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