Inert Piezoelectric Inkjet Print Head Technology for Alkaline Etch Process in Solar Cell Fabrication

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Abstract

Piezoelectric inkjet technology is being used, tested and evaluated to replace traditional manufacturing processes in three main industries - flat panel display, printed electronics, and solar cells due to (1) efficient material usage (cost saving and environmentally friendly), (2) direct write process (an additive process), (3) speedy set-up (digital printing and no masks needed), (4) large area printing, (5) high productivity by increasing number nozzles and jetting frequency, (6) non contact printing for sensitive substrate, (7) print heads and jetting materials tailored for specific applications and (8) ultimately low capital investment . Especially, the emerging market opportunities in production of efficient "Gen. 5" solar panel different from conventional silicon wafer solar cell/modules manufacture will require two inkjet alkaline etch processes and thus inert piezoelectric inkjet print head design. This paper focuses on material compatibility associated with an aggressive alkaline etch process in the solar panel fabrication. Also reported is a life time study with customized Trident's 256Jet-D print heads.

Introduction

Trident has been involved in the fabrication process of the thin film deposition using the piezoelectric inkjet technology to replace conventional manufacturing method and has a success in LCD industry and others [1-3]. Similar approaches have been expanded to emerging market opportunities in solar industry driven by energy independence policy, oil price pressures, caps on green house gases, carbon tax penalties for green house gases, federal and state tax incentives, technology jumps, and so forth. The global photovoltaic market is expected to increase from 13 billion in the year 2007 to 40 billion by the year 2012.

Historically, the crystalline silicon-based solar cell fabrication was established based on 1970's semiconductor business. And this conventional approach has faced major difficulty which includes silicon wafer supply shortage, wafer breakage while screen printing the silver fingers, and efficiency. Cost wise, the thickness of silicon wafer would ideally be reduced to 100 um range and in term of solar cell efficacy, the silver finger width would be ideally decreased to 50 um range. However, with conventional screen printing the silicon wafer breakage issue comes to picture. And thus there is a need to take inkjet advantage of non contact printing for sensitive thin silicon wafer substrate. Beyond conventional silicon, thin film technologies have advanced. They are Amorphous silicon (a-Si), Cadmium telluride (CdTe), Copper Indium Callium Selenide (CIS/CIGS), and Dye Sensitized Solar Cells (DSSC) and based on source US department of Energy, thin film market share 61%, 34%, 4%, and ~1% respectively. This study is related to amorphous silicon thin film solar module fabrication. Its silicon thickness is approximately 1.6 um and 150 times less silicon is used compared to in conventional silicon wafer modules. The associated inkjet process in "gen 5" solar panel is to deposit small dots of a caustic alkaline fluid in order to etch through resin film/silicon layer and to form electric contacts after metallization process.

Versatile Trident's 256Jet-D (table 1 and figure 1) inkjet print head features a durable, serviceable design and stainless steel construction which allows for printing of a wide variety of direct write, printable electronic applications with up to five times higher resolution than possible with screen printing. It allows manufacturers to print exactly the amount of material they need, exactly where they need it, thus manufacturers save significant time and expense when compared to subtractive printing methods that waste valuable printing materials. The inert stainless steel construction is resistant to the corrosive, aggressive alkaline materials often used in the deposition of printable electronic components. With the ability to be heated to 70^0C and to jet fluids up to 30 cps, the 256Jet-D can print materials with twice as much viscosity as traditional inkjet systems, giving users wider flexibility in material loading and fluid formulation.

Table 1. 256Jet-D specifications

	256Jet-D (inline)	256Jet-D (dual line)
# of addressable channels	256	256
nozzle spacing	0.397mm	0.794mm
Drop volume*	7-120PL	7- 120PL
Drop velocity	5-8 m/s @ 1mm standoff	5-8 m/s @ 1mm standoff
Drive voltage	< 90 volts	< 90 volts

Note*: a wide range of drop volume can be covered by using different nozzle diameters and different actuator configurations.

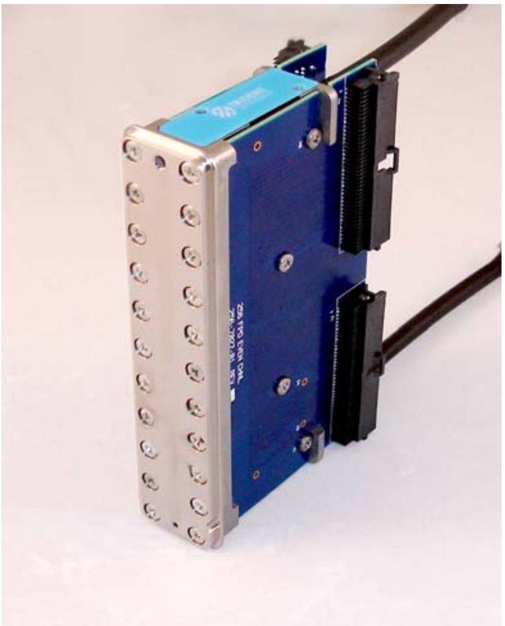

Figure 1. *256Jet-D print head*

Life Time Study

Trident 256Jet-D print head configure/material shows in figure 2. The thin stainless steel diaphragm is bonded onto pzt actuator/back print head body and separates fluidic parts from print body. The print head is designed to make the nozzle/chamber plate, restrictor, and spacer repairable or replaceable. The advantage/flexibility includes (1) that because the orifice clogging is one of major failure modes in the field, the replaceable nozzle/chamber plate significantly extends the print head life and thus reduces the total cost of ownership; (2) that one can use only a print head body to cover a wide range of drop volumes with different nozzle/chamber plates (3) that the adjustable restrictor plate is designed for a wide range of jetting fluid viscosity; that (4) the print head would be friendly for customization (5) and that two different nozzle/chamber plate configurations were designed for two different nozzle spacing. In reality, multiple inkjet print heads are integrated into the printing system of “gen 5” panel applications. The requirement of print head life time is one month under 1 Khz frequency continuous firing condition operating with a caustic jetting fluid which property is specified as 7.3 cps viscosity, 45.0 dynes/cm surface tension, and 14 PH value (for alkaline etch process). Test protocol is shown as follows:

1. Two customized 256Jet-D print heads were characterized with Trident test fluid and orifice diameter, pzt capacitance, restrictor, spacer, and diaphragm were inspected as a baseline.
2. Operated with the caustic jetting fluid under all 256 channel firing at 1 Khz frequency condition for 1 month (about 2.6 billion firing times each channel).
3. Cleaned print heads.
4. Repeat step 1.
5. Calculated/Inspected the change before and after.

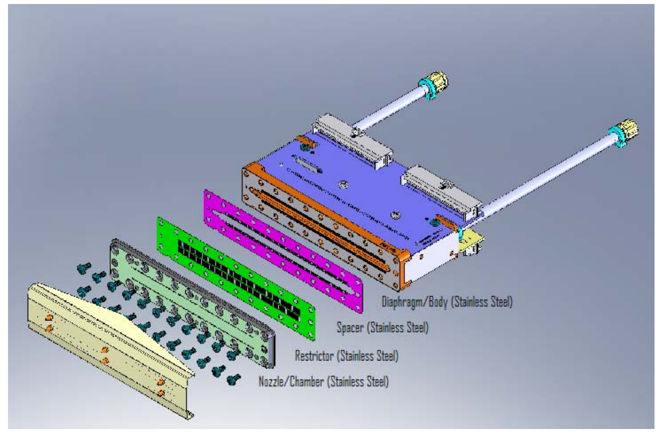

Figure 2. *Inert print head configuration/material*

Result and Discussion

Figure 3 shows that the change of drive voltage at 6 m/s drop velocity after life time test is within ~20%. The environment change and measurement error could account for 15% difference. There are little difference observed on orifice diameter and pzt capacitance as shown in figure 4 and figure 5, respectively. There are no damage observed on restrictor, spacer, and diaphragm as indicated in figure 6, figure 7, and figure 8, respectively.

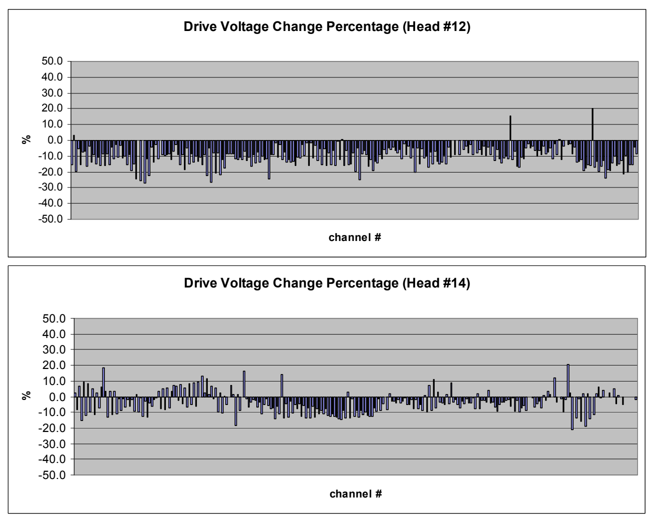

Figure 3. *Drive voltage change on Head #12 and Head #14*

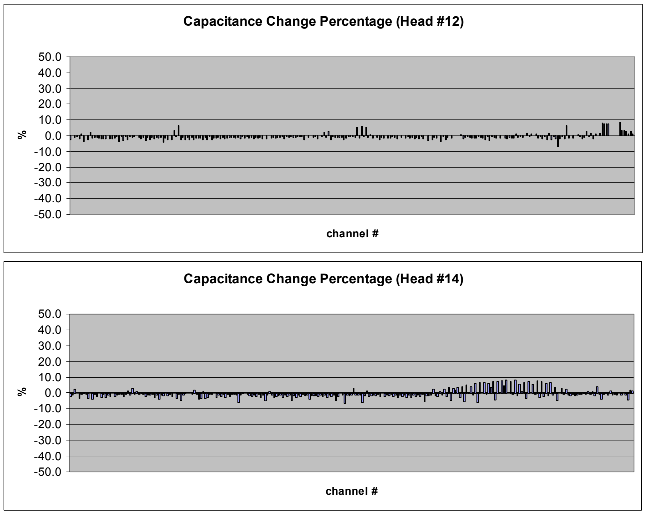

Figure 4. *PZT Capacitance change on Head #12 and Head #14*

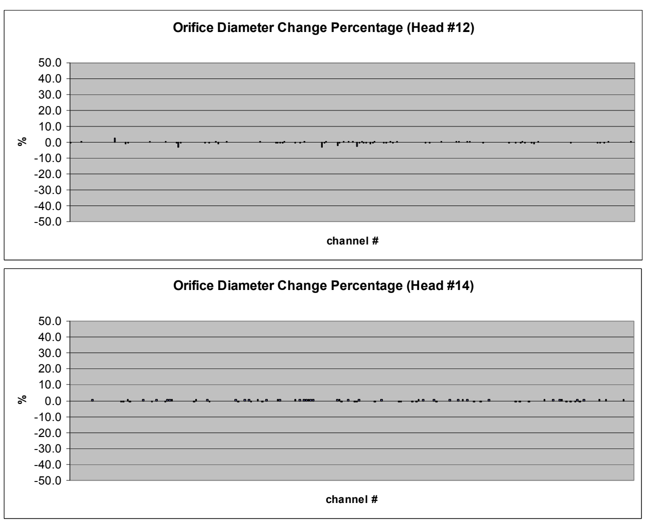

Figure 5. *Orifice diameter change on Head #12 and Head #14*

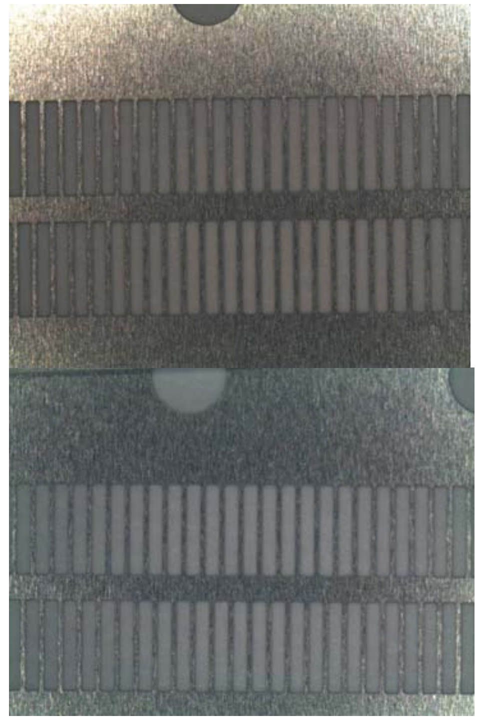

Figure 6. *Restrictor inspection: upper one (initial), lower one (after test)*

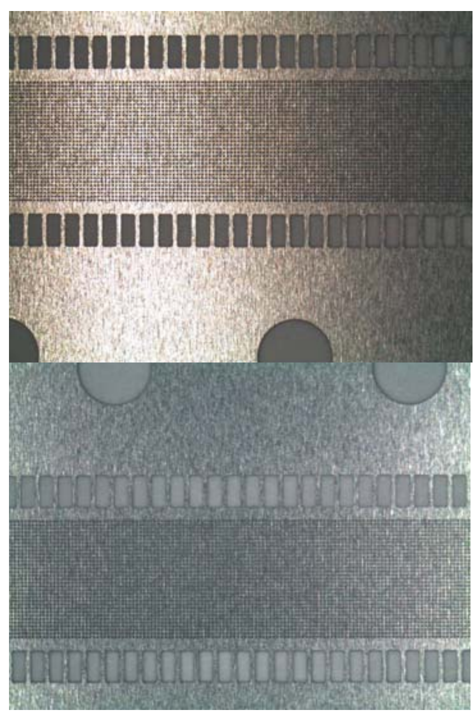

Figure 7. *Spacer inspection: upper one (initial), lower one (after test)*

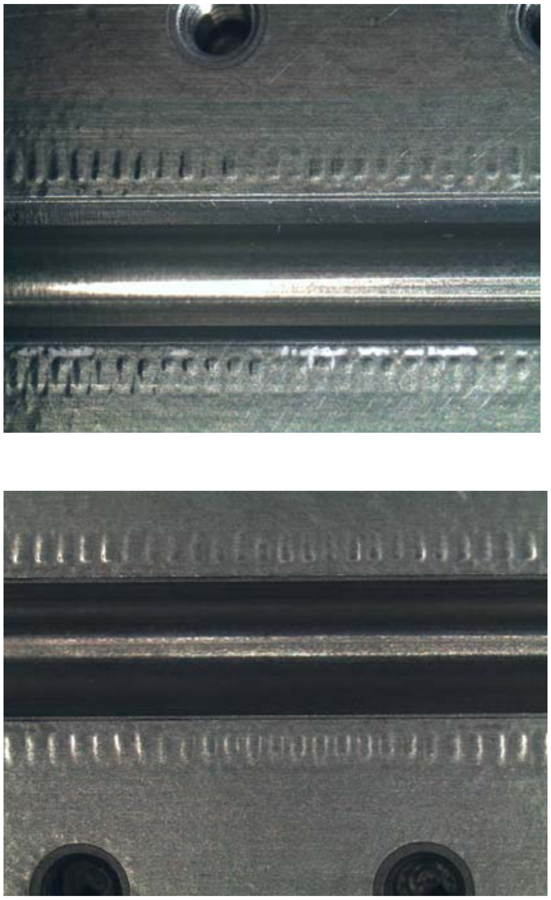

Figure 8. *Diaphragm inspection: upper one (initial), lower one (after test)*

Conclusion

After 1 month life time test with the caustic jetting fluid for alkaline etch process in the solar cell/module fabrication, the following conclusions could be made:

1. No significant change on pzt capacitance.
2. No significant change on orifice diameter.
3. No damage observed on the spacer part.
4. No damage observed on the restrictor part.
5. No damage observed on the diaphragm part.
6. A little change on drive voltage.
7. Two print heads function normally.

References

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Author Biography

Ty Chen received his Ph.D. in Mechanical Engineering from University of Wisconsin at Milwaukee. He works as the R&D manager at Trident, an ITW company. His work has primarily focused on piezoelectric and other actuators, MEMS processes, and inkjet print head design and analysis for emerging markets. He is a member of IS&T.