



Canadian Solar Inc. v. Maxeon Solar Pte. Ltd.

IPR2024-01039 (U.S. Patent No. 8,222,516)

IPR20240-1040 (U.S. Patent No. 8,878,053)

Patent Owner's Oral Argument (October 15, 2025)

Maxeon's Exhibit 2025
DEMONSTRATIVE EXHIBIT - NOT EVIDENCE

Summary of Grounds

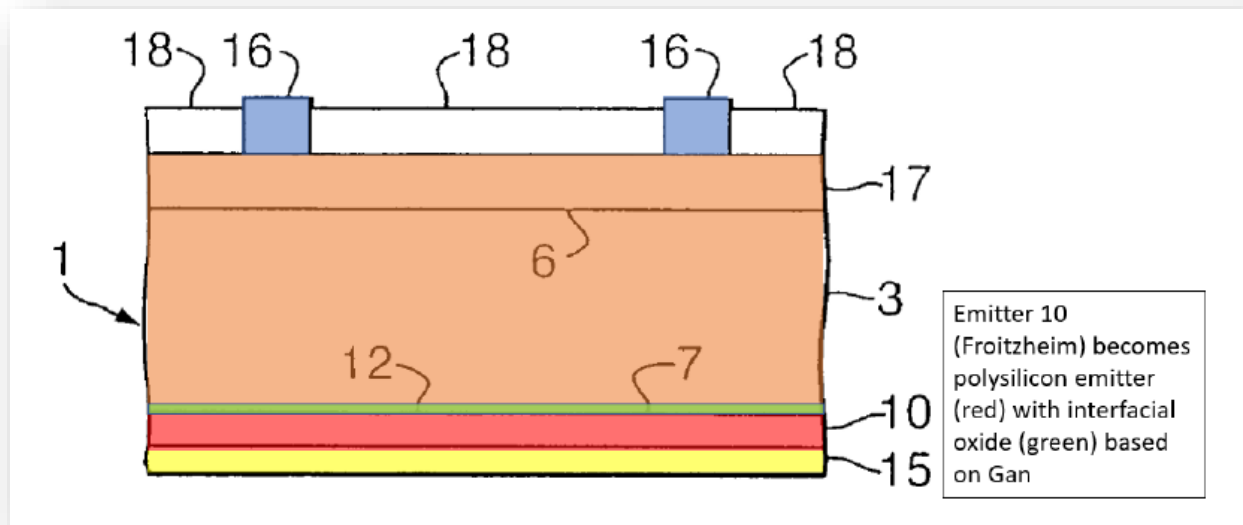
IPR2024-01039 (re the '516 patent)

- Collateral estoppel based on prosecution history and appeal of related applications
- Meier, Okayasu, Borden, and Jordan (Claims 9-11)
- Meier, Okayasu, Foglietti, Gan, and Jordan (Claims 9-11)
- Froitzheim and Gan (Claims 9-12)
- Froitzheim and Kwark (Claims 9-12)
- Froitzheim in view of Borden (Claims 9-12)

IPR2024-01040 (re the '053 patent)

- Froitzheim and Gan (Claims 9-11, 14, 16-17, 19-20)
- Froitzheim and Gan in further view of Hartiti or Sivoththaman (Claims 11-13, 15, 18)
- Froitzheim and Kwark (Claims 9-11, 14, 16-17, 19-20)
- Froitzheim and Kwark in further view of Hartiti or Sivoththaman (Claims 11-13, 15, 18)
- Prosecution history and appeal of related applications

Arguments Against the Proposed Froitzheim-Gan Combination



The Proposed Froitzheim-Gan Combination
(illustrated in IPR2024-01039, Paper 2-Petition, 42;
see also IPR2024-01040, Paper 1-Petition, 29)

- Froitzheim's anneal temperature would have led to high resistivity and high recombination (IPR2024-01039, Paper 25-POR, 43-46, 49-52; see also IPR2024-01040, Paper 25-POR, 43-47, 50-52);
- A POSITA would not have been able to consistently grow Gan's oxide layer (IPR2024-01039, Paper 25-POR, 46-49; see also IPR2024-01040, Paper 25-POR, 47-50)

What Is Really “Useful” in Gan

The data shown in Fig. 6 are quite useful for silicon solar cells. First, most of J_o are below $5 \times 10^{-14} \text{ A/cm}^2$ which is about one order magnitude lower than that of diffused-emitters. Second, most of ρ_c are also lower than $5 \times 10^{-5} \text{ } \Omega\text{-cm}^2$. This means that the potential drop across the contact is negligible as long as the current density is less than 100 A/cm^2 . It is interesting to see how much of the cell efficiency can be improved with polysilicon emitters of characteristics given here. With the cell modeling, which is similar to the one reported by Sinton [8], more than one absolute percent of the cell efficiency is obtained for a backside contact solar cell with polysilicon emitters with characteristics shown here ($J_o=2 \times 10^{-14} \text{ A/cm}^2$ for the n-type, $J_o=3.5 \times 10^{-14} \text{ A/cm}^2$ for the p-type, and $\rho_c=1 \times 10^{-5} \text{ } \Omega\text{-cm}^2$ for both types).

Ex. 1007-Gan, 249
(quoted in IPR2024-01039, Paper 2-Petition, 43-44;
see also IPR2024-01040, Paper 1-Petition, 30)

CONCLUSIONS

To conclude, we showed that polysilicon emitters with low J_o and ρ_c can be obtained with a very small fraction of interfacial oxide breakup. Typically, $\rho_c \sim 1 \times 10^{-5} \text{ } \Omega\text{-cm}^2$ and $J_o \leq 5 \times 10^{-14} \text{ A/cm}^2$ are obtained for both n- and p- type polysilicon emitters. From the cell modeling, polysilicon emitters with these qualities can be quite useful for silicon concentrator solar cells. Because only small fraction of interfacial oxide is broken, the J_o is primarily dominated by the recombination at the oxide interface and in the single-crystal diffusion region. Consequently, an interfacial oxide of good quality is important to obtain low J_o . Our results also indicates that ρ_c drops drastically when the oxide starts to breakup. This is explained by the transition of the dominant majority-carrier transport from the tunneling to the channel resistance.

Ex. 1007, 249
(quoted in IPR2024-01039, Paper 25-POR, 17, 43;
see also IPR2024-01040, Paper 25-POR, 17, 44)

The Proposed Combination Does Not Use Gan's Second-Step Anneal

- Start of process used in Gan** ➡
1. Field oxidation (2000 Å)*.
 2. Polysilicon-substrate contact opening*.
 3. Thin thermal oxide growth at 800 °C*. (10-minute oxygen flow)
 4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C)*.
 5. First-step anneal *.
 6. Polysilicon finger definition.
 7. Undoped glass deposition (2000 Å).
- End of process used in Gan** ➡
8. Metal-polysilicon and metal-substrate contact opening.
 9. Doped glass deposition on both sides of the wafer*.
 10. Drive-in; 900-1000 °C*.
 11. Doped glass stripping and Al-1% Si alloy deposition.
 12. Metal finger definition.

Ex. 1007-Gan, 246 (Gan's 12-Step Process)
(cited in IPR2024-01039, Paper 25-POR, 12; *see also see also* IPR2024-01040, Paper 25-POR, 12)
(annotated in Paper 25)

The Proposed Combination Uses Froitzheim's Steps to Add Dopant

6 Q Oh. Then after you add the oxide in the
7 polysilicon layer from Gan, then you would follow
8 Froitzheim steps to add the dopant. Correct?

9 A Yes.

10 Q And would that be the same with Kwark and
11 Borden?

12 A Well, this part, essentially, yes.

Ex. 2023-Banerjee Dep. Tr., 89:6-12
(quoted in IPR2024-01039, Paper 25-POR, 12;
see also IPR2024-01040, Paper 25-POR, 12)

Froitzheim's Steps to Add Dopant Includes High Temperature Drive-In

35 **[0041]** In general terms, a diffusion source layer that contains boron as a dopant is applied, e.g. spun, only onto the back of the n- doped silicon wafer. The diffusion source layer is one that contains boron and out of which the boron is thermally driven. The diffusion source layer is preferably applied by means of a boron doping resist. In addition to boron or its compounds, this resist contains powdery SiO₂ in a suspension. This doping resist is normally used for generating high dopings in power semiconductors. It may be applied in liquid form and may for example be spun on.

40 **[0042]** A suitable doping liquid is Siodop (TM) of Merck. Then the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between 1000 and 1100 degree C, to generate an oxide layer and to drive in the dopant.

45 **[0043]** The further steps for providing the front side n+ layer and the front and rear side contacts for manufacturing a cell of the invention can also be conducted according to the steps disclosed in US 5899704 and 6096968, incorporated by reference.

Ex. 1006-Froitzheim, ¶ [0042]
(quoted in IPR2024-01039, Paper25-POR, 8, 14, 21, 33, 45, 57;
see also IPR2024-01040, Paper 25-POR, 8, 14, 21, 27, 34, 46, 53)

Gan's Data on High Temperature Drive-In (Second-Step Anneal)

Table 1: The effect of the second-step anneal on J_o and ρ_c .

	N-type		P-type	
	$J_{o,e} (\times 10^{-14} \text{ A/cm}^2)$	$\rho_c (\mu\Omega\text{-cm}^2)$	$J_{o,e} (\times 10^{-14} \text{ A/cm}^2)$	$\rho_c (\mu\Omega\text{-cm}^2)$
900 °C-4 hour	2.4	18	3.5	18
1000 °C-30 min	4.5	~ 6	8.2	3.8
1000 °C-60 min	7.9		10.5	

The effect of the second-step anneal (dopant drive-in) on both the J_o and the ρ_c were also investigated. All samples (and devices) received a first-step anneal at 1050 °C for one hour, followed with various treatments in the second-step anneal. The results are summarized in Table 1. The label on the right most column represents the second-step anneal condition of that sample. As shown in the table, the J_o increases with the temperature and time of the second-step anneal. In the meantime, the ρ_c decreases as the drive-in temperature increases. Considering the significant increase of J_o caused by increasing the drive-in temperature from 900 to 1000 °C, it is beneficial to use the two-step anneal to optimize J_o .

Ex. 1007-Gan, 248 (Table 1)
(quoted in IPR2024-01039, Paper 25-POR, 13, 20, 45;
see also IPR2024-01040, Paper 25-POR, 13, 21, 46)

Ex. 1007, 248
(quoted in IPR2024-01039, Paper 25, 14, 20;
see also IPR2024-01040, Paper 25, 14, 20-21)

Gan's Data on High Temperature Drive-In (Second-Step Anneal)

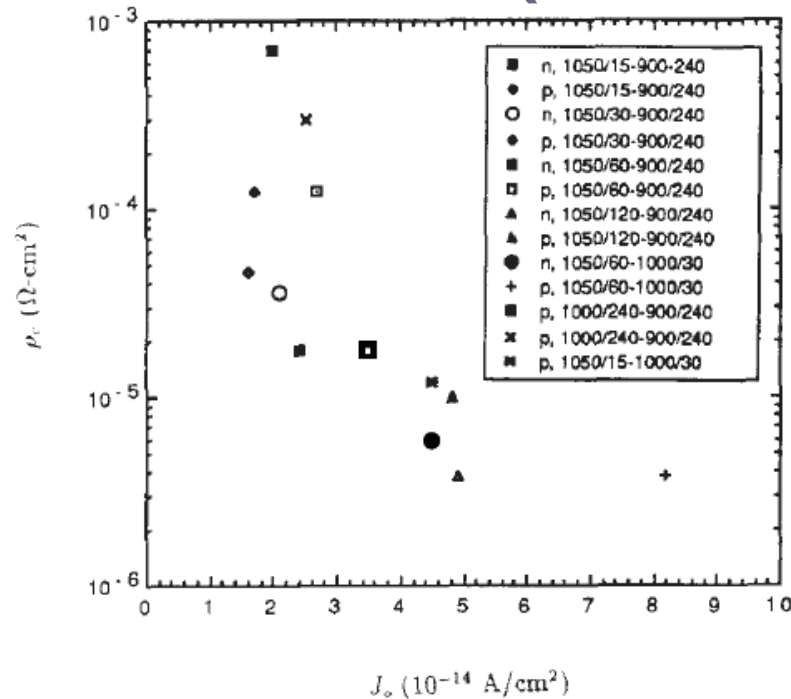


Figure 6: ρ_s - J_o of this work.

Ex. 1007-Gan, 249 (Fig. 6)
(quoted in IPR2024-01039, Paper 25-POR, 19;
see also IPR2024-01040, Paper 25-POR, 19-20)

7 Q Why would they prefer to use 1000 to 1100
8 degrees, do you know?

...

7 So you are trying to achieve a certain
8 junction depth and a certain doping concentration.
9 And the two main parameters, the diffusion
10 temperature and the diffusion time. Longer the
11 diffusion time, higher the temperature.
12 Everything else being the same, you'd get a deeper
13 junction and the higher concentration of the
14 surface. Shorter the temperature -- or diffusion
15 time and lower the temperature, you get a shallow
16 junction. So those are the norms that a POSITA
17 would use.

Ex. 2023-Banerjee Dep. Tr., 85:7-86:17
(quoted in IPR2024-01039, Paper 25, 8-9;
see also IPR2024-01040, Paper 25-POR, 9)

Anneal Temperature and Time Are Crucial Variables for Gan

Fig. 2 shows two R_c -plots for the p-type polysilicon contacts. One has the first-step anneal at 1050 °C for 30 minutes, the other has 1050 °C for 2 hours. Each data point is the average of 16 measurements across the wafer and the error bar is drawn with 4 standard deviations. Since devices were made on the wafers of about the same resistivity, the slopes of the linear-fit lines are almost identical. Note that, the devices that received a 30-minute first-step anneal have higher intercepts than those that received a 2-hour first-step anneal. This indicates that more oxide breakup occurs when the anneal time increases. Another characteristic of the interfacial oxide breakup can also be seen from the spread in the data (the length of the error bar). The magnitude of the error bar is not due to the measurement uncertainty; instead, it results from the random distribution of the oxide breakup. When only a very small fraction of the interfacial oxide is broken, it is possible that the interfacial oxide on each contact may not be broken equally. Consequently, this gives rise to the fluctuation of the resistance measured. On the other hand, the fluctuation will be subdued when more oxide is broken. This explains the different appearance of error bars observed between these two sets of data.

Ex. 1007-Gan, 247

(quoted in IPR2024-01039, Paper 35-Sur-Reply, 2;
see also IPR2024-01040, Paper 35-Sur-Reply, 3)

In Fig. 3, ρ_c is plotted against the time of the first-step anneal for both types. Note that the ρ_c decreases as the anneal time increases. In addition, ρ_c measured from both n- and p- type devices are more or less the same, except those annealed with 120 minutes. The similarity of ρ_c between the n- and the p- type contact also indicates that the interaction between the dopant and the interfacial oxide is negligible; since such an interaction, if exists, would cause the ρ_c of the p-type to be lower [6].

The effect of the second-step anneal (dopant drive-in) on both the J_o and the ρ_c were also investigated. All samples (and devices) received a first-step anneal at 1050 °C for one hour, followed with various treatments in the second-step anneal. The results are summarized in Table 1. The label on the right most column represents the second-step anneal condition of that sample. As shown in the table, the J_o increases with the temperature and time of the second-step anneal. In the meantime, the ρ_c decreases as the drive-in temperature increases. Considering the significant increase of J_o caused by increasing the drive-in temperature from 900 to 1000 °C, it is beneficial to use the two-step anneal to optimize J_o .

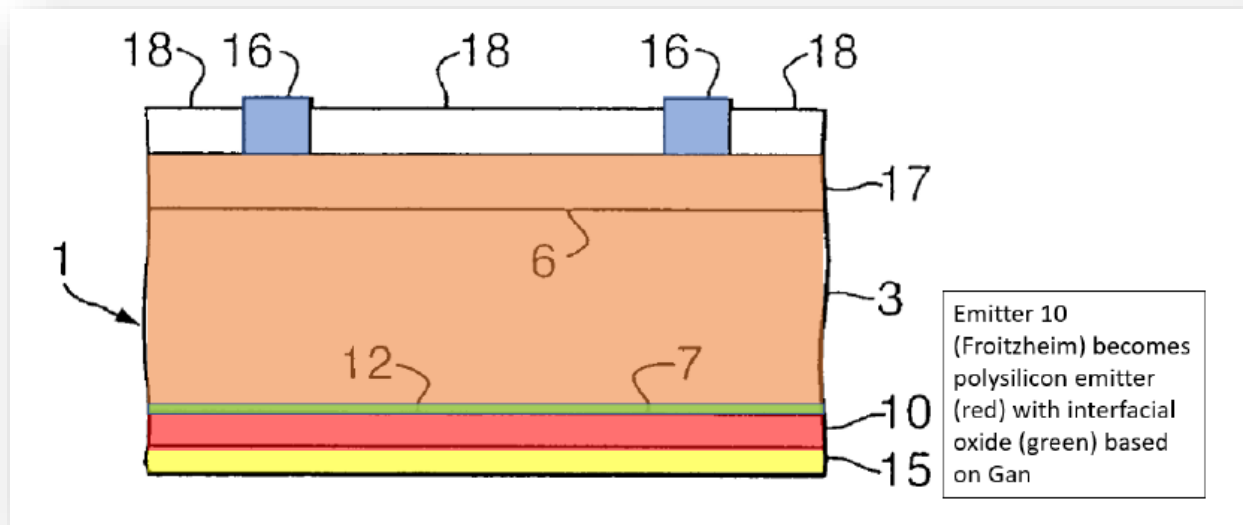
Ex. 1007, 247

(quoted in IPR2024-01039, Paper 35, 2;
see also IPR2024-01040, Paper 35, 3)

Ex. 1007, 248

(quoted in IPR2024-01039, Paper 35, 2;
see also IPR2024-01040, Paper 35, 3)

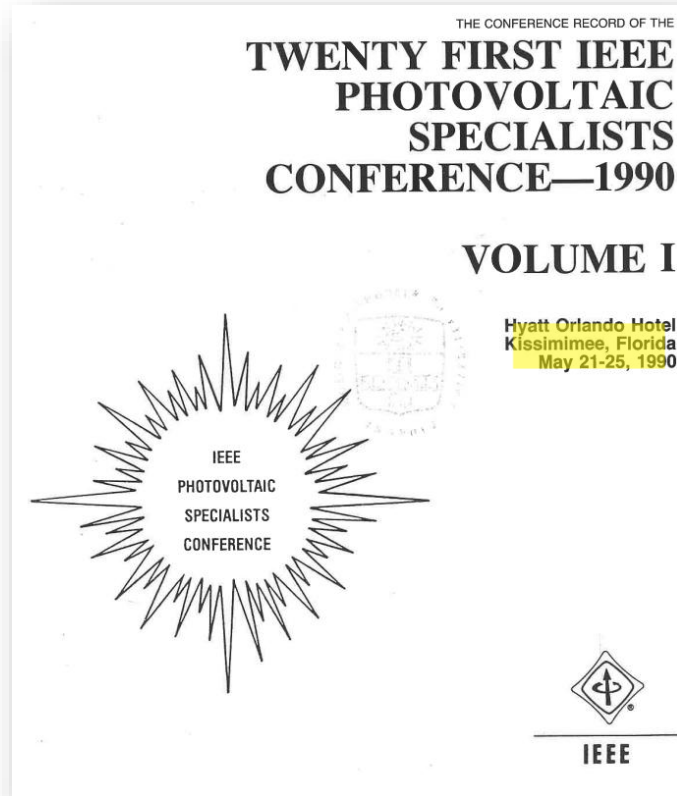
Arguments Against the Proposed Froitzheim-Gan Combination



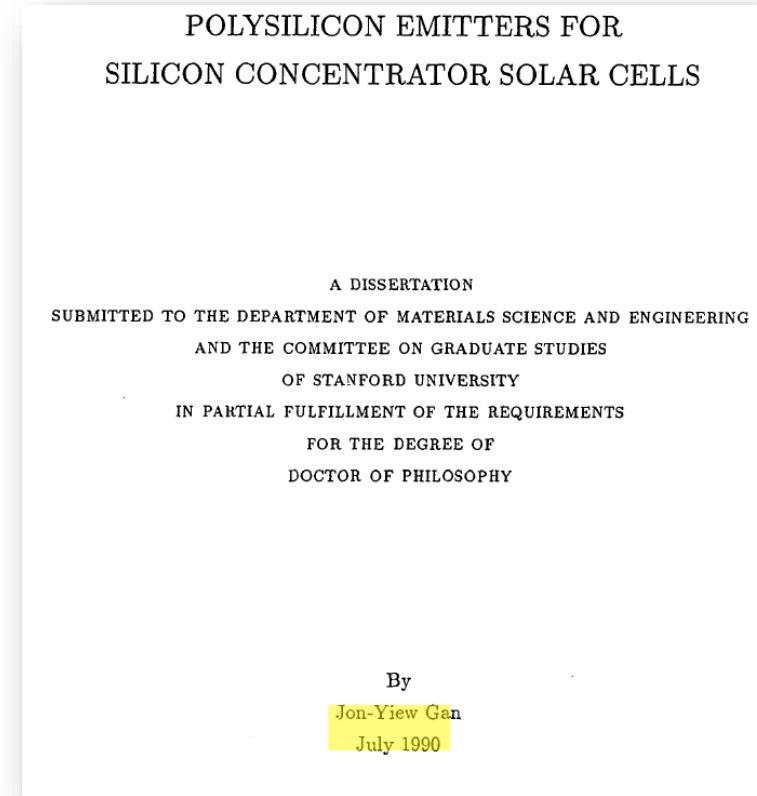
The Proposed Froitzheim-Gan Combination
(illustrated in IPR2024-01039, Paper 2-Petition, 42;
see also IPR2024-01040, Paper 1-Petition, 29)

- Froitzheim's anneal temperature would have led to high resistivity and high recombination (IPR2024-01039, Paper 25-POR, 43-46, 49-52; see also IPR2024-01040, Paper 25-POR, 43-47, 50-52);
- A POSITA would not have been able to consistently grow Gan's oxide layer (IPR2024-01039, Paper 25-POR, 46-49; see also IPR2024-01040, Paper 25-POR, 47-50)

Gan and the Gan Thesis Are Equally Credible



Ex. 1007-Gan, Cover
(cited in IPR2024-01039, Paper 35-Sur-Reply, 11;
see also IPR2024-01040, Paper 35-Sur-Reply, 12)



Ex. 2003-Gan Thesis, Cover
(cited in IPR2024-01039, Paper 35-Sur-Reply, 12;
see also IPR2024-01040, Paper 35-Sur-Reply, 13)

Oxide Thickness

In practice, there is another difficulty we may have to face if the tunnel barrier height is around the range shown in Figure 4.3. Figure 4.3 is the transmission probability of both electrons and holes plotted with the tunneling barrier height reported by Kasprzak *et al.* As shown in the figure, for the T_h and T_e specified in the beginning of this section, it corresponds to an oxide-thickness window 15 ± 2 Å. With a window so narrow, it is not possible to have good control over the characteristics of a polysilicon SIS emitter.

Ex. 2023-The Gan Thesis, 56 (quoted in IPR2024-01039, Paper 25-POR, 28, 48; see also IPR2024-01040, Paper 25-POR, 34, 50)

Although these results can be attributed to many other reasons, the following experiment shows that the effect of the oxide thickness cannot be ignored. This, combined with the non-reliable oxide-growth recipe gives rise to the mishap of our solar-cell runs.

Ex. 2023, 111 (quoted in IPR2024-01039, Paper 25, 28, 48; see also IPR2024-01040, Paper 25, 33-34, 49-50)

It becomes clear that the wide fluctuation of our results is mainly due to the poor control over the oxide thickness. From Eqn. (4.21) (p. 61), ρ_c does not depend on the oxide thickness once the oxide breaks up. Consequently, the oxide-thickness dependence of ρ_c must result from the oxide breakup process. To see how the oxide

Ex. 2023, 114 (quoted in IPR2024-01039, Paper 25, 28, 48; see also IPR2024-01040, Paper 25-POR, 34, 50)

6.5 Conclusion

In this chapter, we found that a consistent result of ρ_c is difficult to reproduce for the polysilicon emitter with a thermally grown interfacial oxide. This is mainly attributed to the fact that our thin-oxide growth recipe is not reliable. With the same oxidation schedule, a wide variation of oxide thicknesses have been found for different times. Experimentally, the interfacial oxide breakup was also found to depend on the oxide thickness critically. Such an oxide-thickness dependence of the breakup process can be explained by a “silicon cluster nucleation” process. In order to have reproducible results, it appears that a precise control of the oxide thickness is necessary.

Ex. 2023, 116-17 (quoted in IPR2024-01039, Paper 25, 15, 26, 28, 46-47, 48; see also IPR2024-01040, Paper 25, 32, 34, 48, 50)

7.2 Suggestions for Future Study

It appears that the oxide breakup depends critically on the interfacial oxide thickness. The thin-oxide growth recipe used in this work was not reliable; the oxide thicknesses between 15 to 20 Å have been found with the same growth condition. As a result, this contributes to the fluctuation of the ρ_c results. It is then clear that a more reliable way of growing the thin oxide is needed.

Ex. 2023, 119 (quoted in IPR2024-01039, Paper 25, 26, 47; see also IPR2024-01040, Paper 25, 16, 32-33, 48)

Oxide Breakup

Although a thermally grown interfacial oxide seems essential for a polysilicon emitter to have both low J_o and ρ_c , the breakup process is still difficult to control. On several occasions, we have encountered reproducibility problems. For example, we find that the ρ_c is quite different between two separate experiments with identical processing conditions. Even worse, solar cells that were made in this study all suffered high contact resistance.

The problem is primarily due to insufficient oxide breakup, and is caused by the fluctuation of the thickness of the interfacial oxide. In the next section, we first show

Ex. 2023-The Gan Thesis, 107

(quoted in IPR2024-01039, Paper 25-POR, 15-16, 25, 27, 47;
see also IPR2024-01040, Paper 25-POR, 15, 33, 49)

Later, in the real solar cell runs, the situation got even worse. The solar cells made in the experiment are the 15- μm -contact-line IBC which have been shown and simulated in Chapter 2. We found that, with the OCVD measurement, the total specific contact resistivity ($\rho_n + \rho_p$) was higher than $1 \times 10^{-3} \Omega\text{-cm}^2$. Although the ($J_{on} + J_{op}$) measured from those cells are between 8×10^{-14} and $4 \times 10^{-14} \text{ A/cm}^2$, the cell efficiency is greatly degraded by such a high emitter resistance. Figure 6.2 is

Ex. 2023, 110 (quoted in IPR2024-01039, Paper 25, 15, 27, 48;
see also IPR2024-01040, Paper 25, 15, 33, 49)

As shown in the figure, the cell is in fact plagued by two things: the high surface recombination velocity ($S = 58 \text{ cm/sec}$), and high emitter resistance ($\rho_{cn} + \rho_{cp} = 1 \times 10^{-3} \Omega\text{-cm}^2$). The effect of high emitter resistance is shown by the difference of the cell efficiency between the curve (b) and the curve (c), while the difference between the curve (a) and the curve (c) shows the projected effect of the high surface recombination velocity. Without the high surface recombination velocity and the emitter resistance, the cell performance would be the curve formed by the maximum efficiency between the curve (a) and the curve (b) which is the ultimate performance we can have for the cell with polysilicon emitters.

From the low emitter recombination and high emitter resistance, it is clear that the interfacial oxide did not break as we expected.

Ex. 2023, 110 (quoted in IPR2024-01039, Paper 25, 27-28, 48; see
also IPR2024-01040, Paper 25, 33, 49)

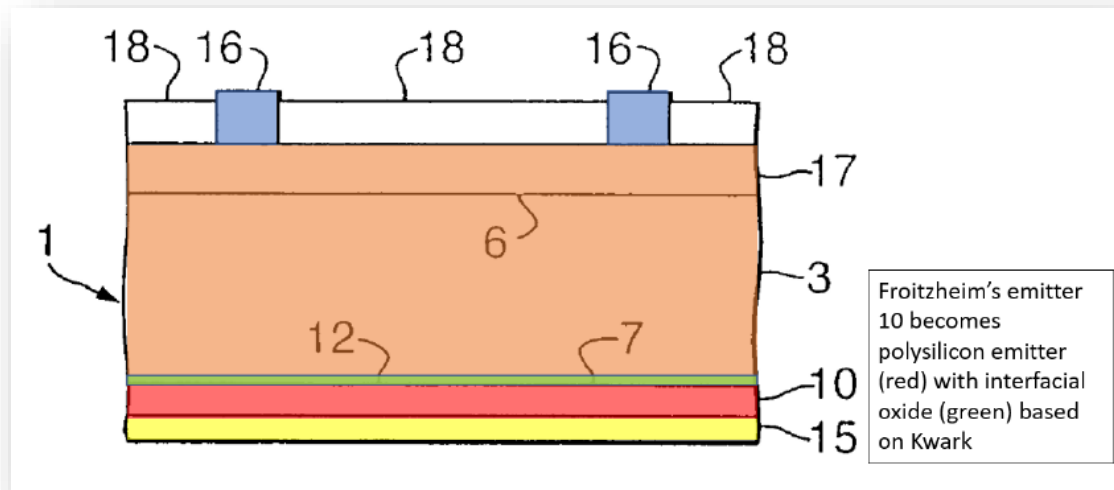
The Gan Thesis Does Not Offer a Solution

From the above, it appears that the variation of the oxide thickness results mainly from the oxide-growth step. If this is the case, it is possible that the thin-oxide growth can be improved by performing the oxidation at lower temperature such that the oxidation rate can be controlled more precisely.

To see how the oxide thickness affects the breakup process, we checked the change of the J_o of the p-type polysilicon SIS emitter upon the first-step anneal. Those emitters were made with the interfacial oxide thickness in the range shown in Figure 6.3. In addition, a much thinner polysilicon (1600 Å) was used in this experiment; therefore, the second-step anneal was performed at 900 °C for only one hour. Figure 6.4 shows the J_o measured on these samples plotted against the thickness of the interfacial oxide. Four data sets are shown in the figure; they are

Ex. 2003-The Gan Thesis, 112
(quoted in IPR2024-01039, Paper 35-Sur-Reply, 7;
see also IPR2024-01040, Paper 35-Sur-Reply, 8)

Arguments Against the Proposed Froitzheim-Kwark Combination



The Proposed Froitzheim-Kwark Combination
(illustrated in IPR2024-01039, Paper 2-Petition, 60;
see also IPR2024-01040, Paper 1-Petition, 57-58 (describing the proposed
Froitzheim-Kwark combination))

- No reasonable expectation of success combining Kwark's chemox with Froitzheim's anneal temperature (IPR2024-01039, Paper 25-POR, 56-59, 60, 61; see also IPR2024-01040, Paper 25-POR, 52-56, 57-58);
- No reasonable expectation of success growing Kwark's chemox (IPR2024-01039, Paper 25-POR, 59-61; see also IPR2024-01040, Paper 25-POR, 56-57)

The Proposed Combination Uses Froitzheim's Steps to Add Dopant

6 Q Oh. Then after you add the oxide in the
7 polysilicon layer from Gan, then you would follow
8 Froitzheim steps to add the dopant. Correct?

9 A Yes.

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12 A Well, this part, essentially, yes.

Ex. 2023-Banerjee Dep. Tr., 89:6-12
(quoted in IPR2024-01039, Paper 25-POR, 12;
see also IPR2024-01040, Paper 25-POR, 12)

Kwark's Desirable J_{oe} and its Dependency on Temperature

Abstract: Using SIPOS films (SiO_x , $x < 2$) as an emitter contact has been previously shown to reduce the emitter saturation current, J_{oe} , by at least a factor of fifty when compared to a conventional emitter structure with a metallic contact. Previous attempts to explain this J_{oe} reduction have focused on the bulk properties of the SIPOS films. Experimental results of this study which attained J_{oe} values of $2 \times 10^{-14} \text{ A/cm}^2$, suggest that an interfacial layer between the SIPOS and underlying silicon may play an important, if not dominant, role with the implication that the high oxygen concentrations previously used may not be essential for J_{oe} reduction. This would permit the use of lower oxygen content SIPOS films whose lower bulk resistivities would allow utilization of these films in structures such as scaled VLSI bipolar devices and high concentration point contact solar cells where series resistance is detrimental to device performance.

Ex. 1008-Kwark, Abstract
(cited in IPR2024-01039, Paper 25-POR, 57; see also IPR2024-01040, Paper 25-POR, 54)

bandgap in the bulk SIPOS. In fact for devices annealed at $900^\circ\text{C}/13 \text{ min}$, there is very little dependence on γ as seen in Fig. 2, although increasing the anneal temperature to 1000°C adversely affected J_{oe} . That the $\gamma=0$ films produced such good results was surprising since POLY films of comparable thickness should yield a J_{oe} an order of magnitude larger. In fact it was discovered that these $\gamma = 0$ films

Ex. 1008, 742
(quoted in IPR2024-01039, Paper 25, 32, 56; see also IPR2024-01040, Paper 25, 25, 53)

emitter. To this is added a component due to outdiffusion from the heavily doped POLY which becomes increasingly significant for annealing temperatures above 900°C . This is apparent if one notes that the increase in J_{oe} for emitter B can be accounted for by the J_{oe} of emitter C at the same temperature. At 1000°C , this outdiffusion is severe enough to dominate the J_{oe} which accounted for the lack of difference between emitters B and C.

Ex. 1008, 743
(quoted in IPR2024-01039, Paper 25, 32, 56; see also IPR2024-01040, Paper 25, 26, 53)

Kwark's Chemox in High Temperature

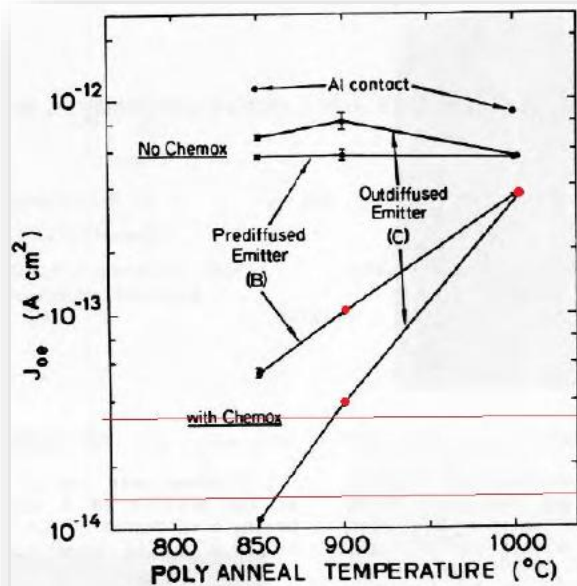


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

Ex. 1008-Kwark, Fig. 4
(quoted in IPR2024-01039, Paper 25-POR, 58;
see also IPR2024-01040, Paper 25-POR, 55)
(annotated in Paper 25)

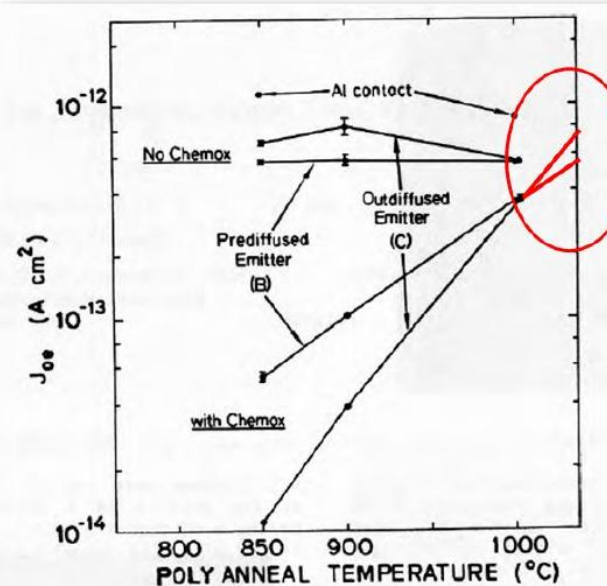


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

Ex. 1008, Fig. 4
(quoted in IPR2024-01039, Paper 25, 33, 59;
see also IPR2024-01040, Paper 25, 26, 56)
(annotated in Paper 25)

Kwark's Polysilicon Emitter

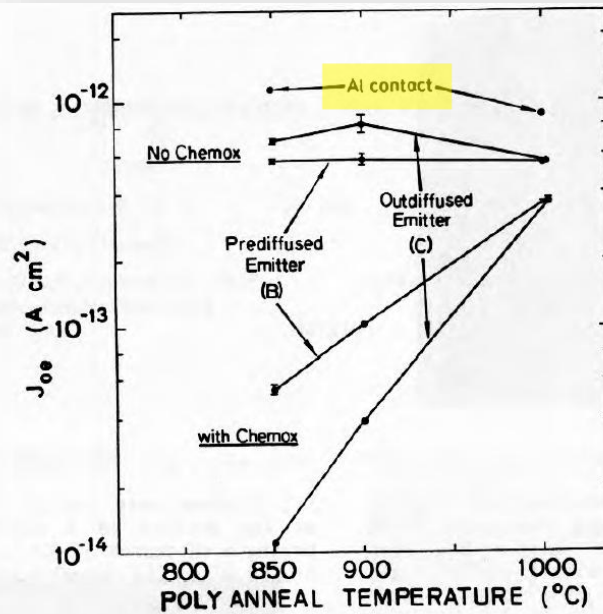


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

Ex. 1008-Kwark, Fig. 4

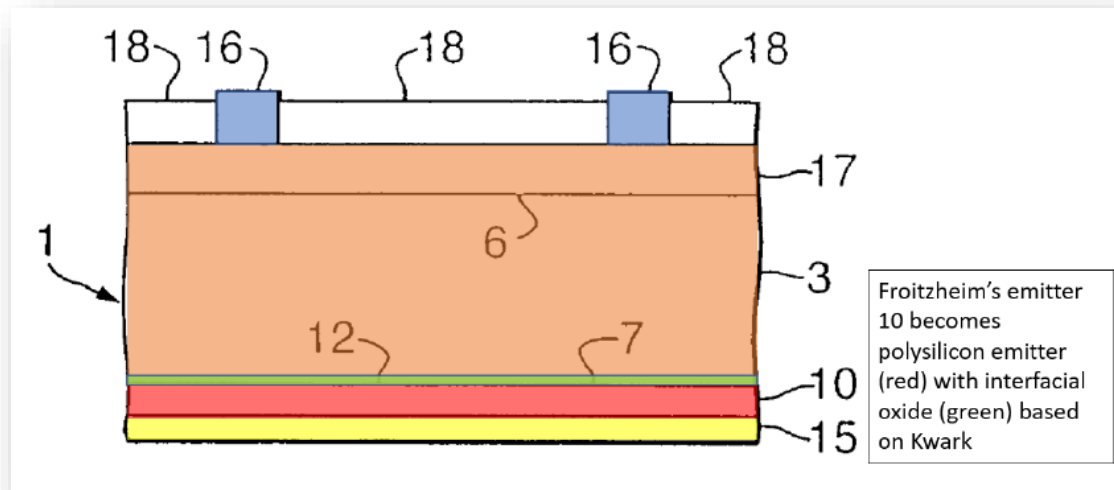
(cited in IPR2024-01039, Paper 35-Sur-Reply, 18;
see also IPR2024-01040, Paper 35-Sur-Reply, 17)

In order to establish unambiguous results for a relatively oxygen free film, POLY films doped insitu in an RF heated cold wall APCVD reactor using a hydrogen carrier were used in the next set of emitter contacts; these films did not etch in BHF. Fig. 4 displays the resulting J_{oe} as a function of annealing temperature for emitter B which had a Gaussian (3×10^{19} surface concentration, 1 micron depth into 5×10^{16} background) emitter diffused prior to the POLY deposition and emitter C which relied solely on outdiffusion from the doped POLY to form the base-emitter junction. For both structures, devices were prepared with and without a chemically grown oxide (chemox) by dipping half of the wafer which underwent a full RCA clean in dilute HF. The value for emitter B with a conventional aluminum contact is shown for reference. Addition of POLY without the chemox does not greatly impact J_{oe} as would be expected since the heavily doped POLY acts essentially as an extension of the monocrystalline emitter. Addition of the chemox greatly decreases the J_{oe} as has been previously reported (6). "Prediffused" emitter B displays a baseline J_{oe} of 5×10^{-14} A/cm^2 due to recombination in the bulk of the emitter. To this is added a component due to outdiffusion from the heavily doped POLY which becomes increasingly significant for annealing temperatures above 900 $^{\circ}C$. This is apparent if one notes that the increase in J_{oe} for emitter B can be accounted for by the J_{oe} of emitter C at the same temperature. At 1000 $^{\circ}C$, this outdiffusion is severe enough to dominate the J_{oe} which accounted for the lack of difference between emitters B and C.

Ex. 1008, 743

(quoted in IPR2024-01039, Paper 35, 18;
see also IPR2024-01040, Paper 35, 17)

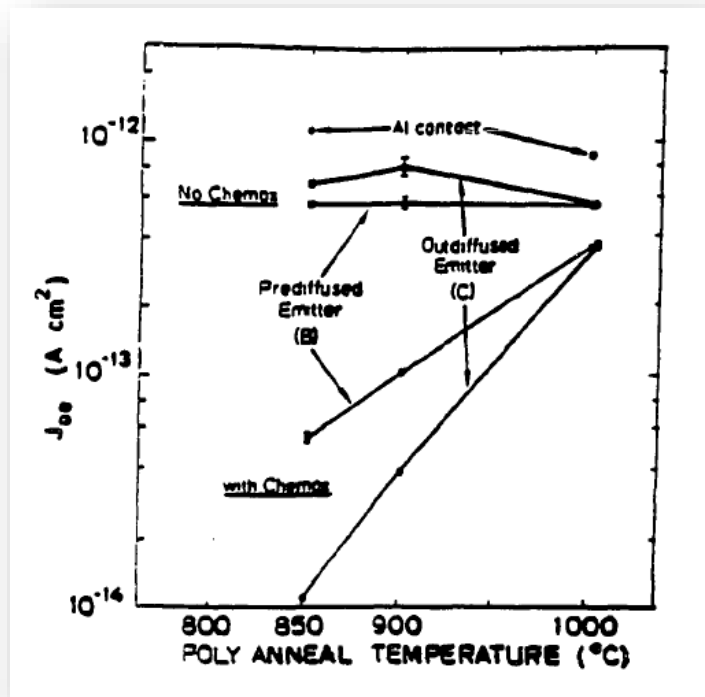
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The Proposed Froitzheim-Kwark Combination
(illustrated in IPR2024-01039, Paper 2-Petition, 60;
see also IPR2024-01040, Paper 1-Petition, 57-58 (describing the proposed
Froitzheim-Kwark combination))

- No reasonable expectation of success combining Kwark's chemox with Froitzheim's anneal temperature (IPR2024-01039, Paper 25-POR, 56-59, 60, 61; see also IPR2024-01040, Paper 25-POR, 52-56, 57-58);
- No reasonable expectation of success growing Kwark's chemox (IPR2024-01039, Paper 25-POR, 59-61; see also IPR2024-01040, Paper 25-POR, 56-57)

Kwark in the Context of the Gan Thesis



Ex. 2023-The Gan Thesis, 34 (Fig. 3.6)
(cited in IPR2024-01039, Paper 25-POR, 22-23, 26,
28, 34, 60; see also IPR2024-01040, Paper 25-
POR, 27, 29, 32, 34, 56)

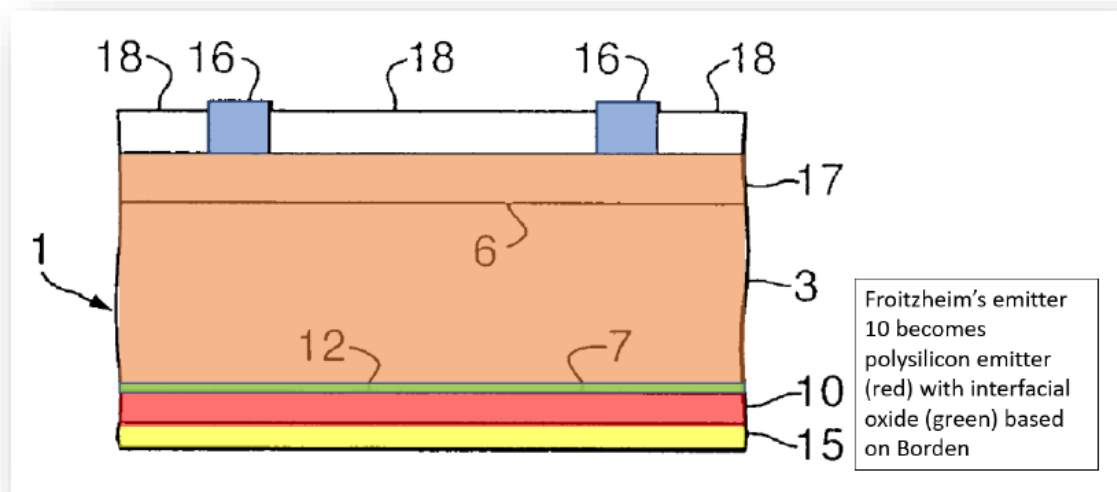
Note that the comparison made above is based on the current gain improvement and cannot be used as an evidence that the J_o of a polysilicon SIS emitter is reduced. However, the very low J_o of the polysilicon SIS emitter has been demonstrated by other authors [7,10]. Figure 3.6 is the J_o of polysilicon SIS emitter reported by Kwark [7]. Note that J_o of 1×10^{-14} A/cm² was observed on the device annealed at 850 °C. The rapid increase of J_o upon the anneal temperature is due to the breakup of the interfacial oxide which will be discussed later. A relatively intact interfacial oxide also explains a much lower J_{os} observed on the 900 °C-1 hour curve in Figure 3.3.

Ex. 2023, 33-34 (quoted in IPR2024-01039, Paper 25, 24;
see also IPR2024-01040, Paper 25, 30)

As mentioned previously, a very low J_o can be obtained (see Figure 3.6) for the n-type polysilicon SIS emitter with a chemically grown interfacial oxide. However, the corresponding ρ_c of such device can be as high as 4×10^{-4} Ω-cm² at the doping concentration of 1×10^{20} cm⁻³, which is the typical doping concentration of the emitter. This is four times higher than the value mentioned in the previous chapter as our goal, and the potential drop across the polysilicon SIS emitter would be intolerable.

Ex. 2023, 33-34 (quoted in IPR2024-01039, Paper 25, 60;
see also IPR2024-01040, Paper 25, 56-57)

Argument Against the Proposed Froitzheim-Borden Combination



The Proposed Froitzheim-Borden Combination
(illustrated in IPR2024-01039, Paper 2-Petition, 65)

No motivation to combine because Borden's purported benefits are not directed to polysilicon emitter cells but **HIT** cells and **amorphous silicon** (IPR2024-01039, Paper 25-POR, 62-65)

Borden's Actual Benefits

(57) Abstract: The present invention relates to improved HIT type or polysilicon emitter solar cells. According to certain aspects, the invention includes forming a masking oxide layer on the front and back of the cell and then patterning holes in the masking oxide. A HIT cell structure or polysilicon emitter solar cell structure is then formed over the patterned oxide, creating the cell junction only in the areas where holes have been cut. Benefits of the invention include that it provides a controlled interface for the HIT cell through insertion of a thin tunnel oxide. Moreover, the tunnel oxide prevents epitaxial growth of amorphous silicon, allowing it to remain amorphous for the optimum band structure. Still further, it provides a layer to protect the surface from plasma damage during deposition of the a-Si layer. Further, it may be used in conjunction with a point contact structure to further increase efficiency.

Ex. 1009-Borden, Abstract (quoted in IPR2024-01039, Paper 25-POR, 63)

[0008] The present invention relates to improved HIT type or polysilicon emitter solar cells. According to certain aspects, the invention includes forming a masking oxide layer on the front and back of the cell and then patterning holes in the masking oxide. A HIT cell structure or polysilicon emitter solar cell structure is then formed over the patterned oxide, creating the cell junction only in the areas where holes have been cut. Benefits of the invention include that it provides a controlled interface for the HIT cell through insertion of a thin tunnel oxide. Moreover, the tunnel oxide prevents epitaxial growth of amorphous silicon, allowing it to remain amorphous for the optimum band structure. Still further, it provides a layer to protect the surface from plasma damage during deposition of the a-Si layer. Further, it may be used in conjunction with a point contact structure to further increase efficiency.

Ex. 1009, ¶ [0008]
(cited in IPR2024-01039, Paper 35-Sur-Reply, 25)

[0020] The benefits provided by dielectric layer 228 are several-fold. For example, it may be formed using conventional surface cleaning and preparation methods, as are used to make MOS gates for ICs. Therefore, the surface preparation is well known and understood, and routinely implemented in high volume manufacturing. Moreover, as it is an amorphous layer, it separates the subsequent a-Si layer from the substrate, preventing epitaxial seeding of crystal growth in the a-Si layer. Further, it provides an intervening layer to protect the crystal silicon surface from plasma damage during deposition of the a-Si layer.

Ex. 1009, Ex. 1009, ¶ [0020]
(cited in IPR2024-01039, Paper 35, 25)

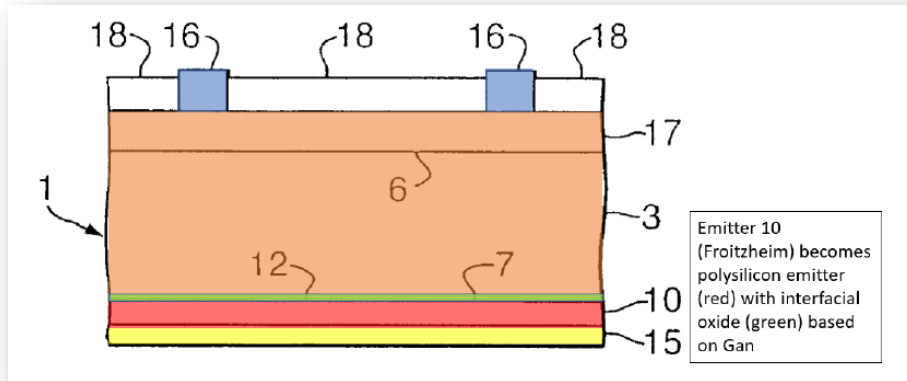
Arguments Against the Limitations of Claim 12

12. The solar cell of claim 9 wherein the second metal contact comprises silver **formed over** a layer of silicon dioxide.

Ex. 1001-The '516 Patent, Claim 12
(quoted in IPR2024-01039, Paper 25-POR, 63)

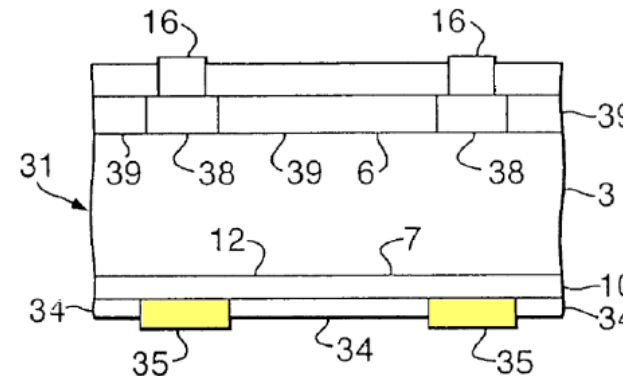
- The improper alternative Froitzheim-Gan combination (IPR2024-01039, Paper 25-POR, 52-53);
- Froitzheim's screen printing does not satisfy the claim limitation (IPR2024-01039, Paper 25, 53-55)

The Improper Alternative Froitzheim-Gan Combination



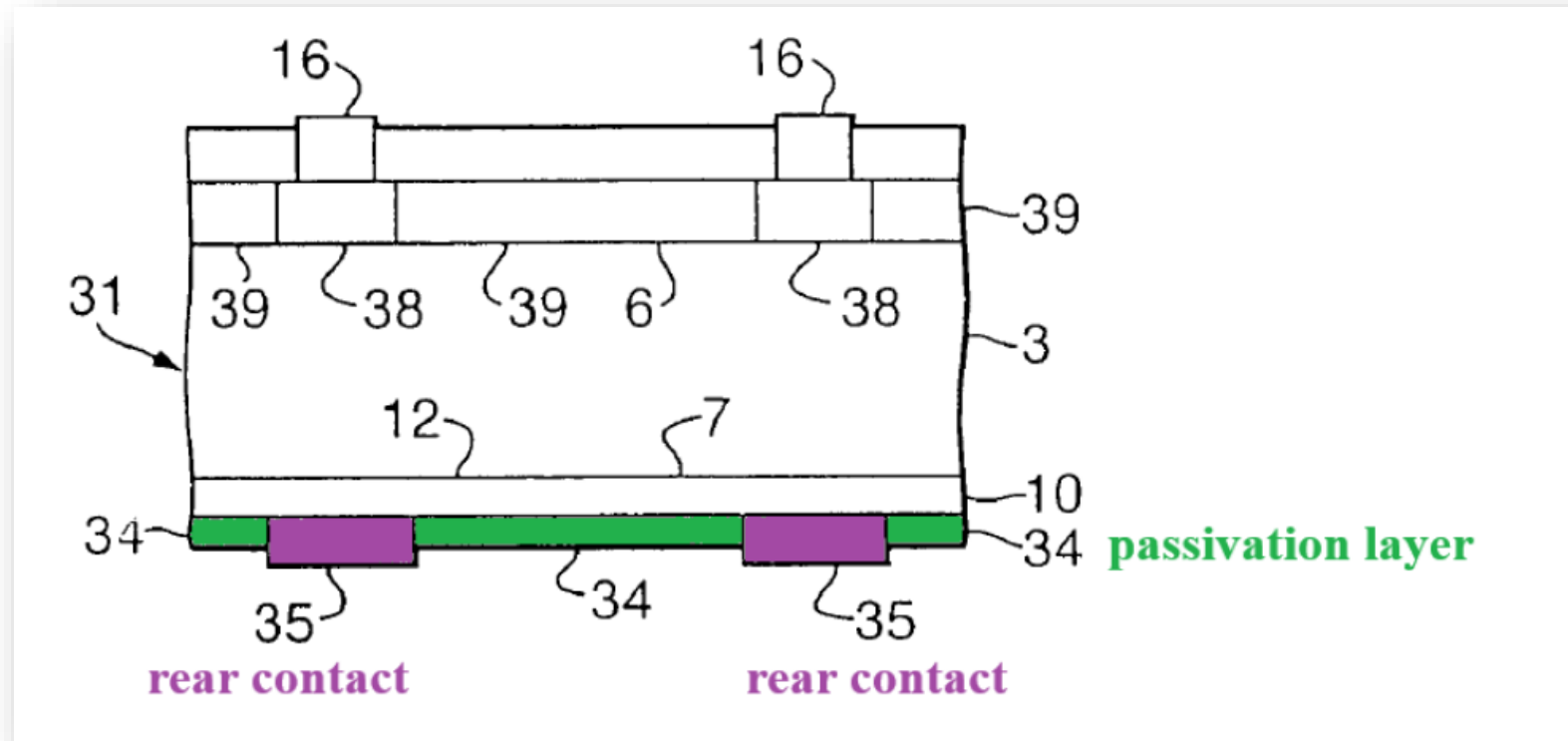
The Proposed Froitzheim-Gan Combination
(illustrated in IPR2024-01039, Paper 2-Petition, 42)

Second, FIG. 3 of Froitzheim disclosed an alternative embodiment of the back contacts 35 (yellow) where only a portion of the back is screen-printed. EX1003, ¶180; EX1006, ¶33. “In this way, less material such as *Ag [i.e., silver]* or Al is required for the contacts, which could have the shape of a finger structure.” EX1006, ¶20. Layer 34 in FIG. 3 is identified as a passivation layer “for which the same type of layers can be used as for the front side.” EX1006, ¶33. Froitzheim expressly disclosed that silicon dioxide (“SiO₂”) is one of the possible passivation material on the front side, and thus it could also be used for layer 34 on the back side because Froitzheim taught the same type of passivation layer can be used for both front and back. EX1006, ¶¶19, 30, 33.



IPR2024-01039, Paper 2-
Petition, 56
(argument re claim 12)

Froitzheim's Screen Printing



Ex. 1006-Froitzheim, Fig. 3
(quoted in IPR2024-01039, Paper 25-POR, 54)
(annotated in Paper 25)



Canadian Solar Inc. v. Maxeon Solar Pte. Ltd.

IPR2024-01039 (U.S. Patent No. 8,222,516)

IPR20240-1040 (U.S. Patent No. 8,878,053)

Thank You

Maxeon's Exhibit 2025
DEMONSTRATIVE EXHIBIT - NOT EVIDENCE