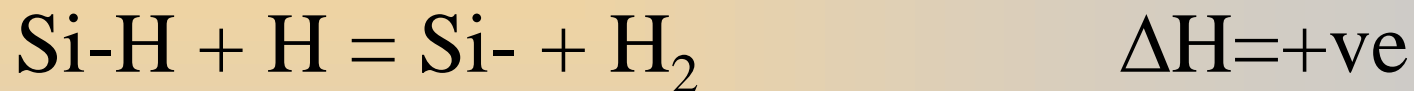# nc-Si based Solar Cells

1. Pressure dependence of nc-Si cells (50 min.)
2. 0.25, 45 and 460cm^2 a-Si/nc-Si tandem cells
3. Degradation behavior of a-Si vs. a-Si/nc-Si
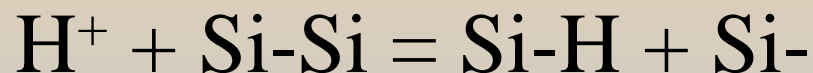4. Degradation of nc-Si cells vs. V_{oc} & H-diln.

Hydrogen atoms and ions

★ Hydrogen atom recombination on surface provides local thermal energy (E-R Process)

$$Si\text{-}H + H = Si\text{-} + H_2 \qquad\qquad \Delta H = +ve$$
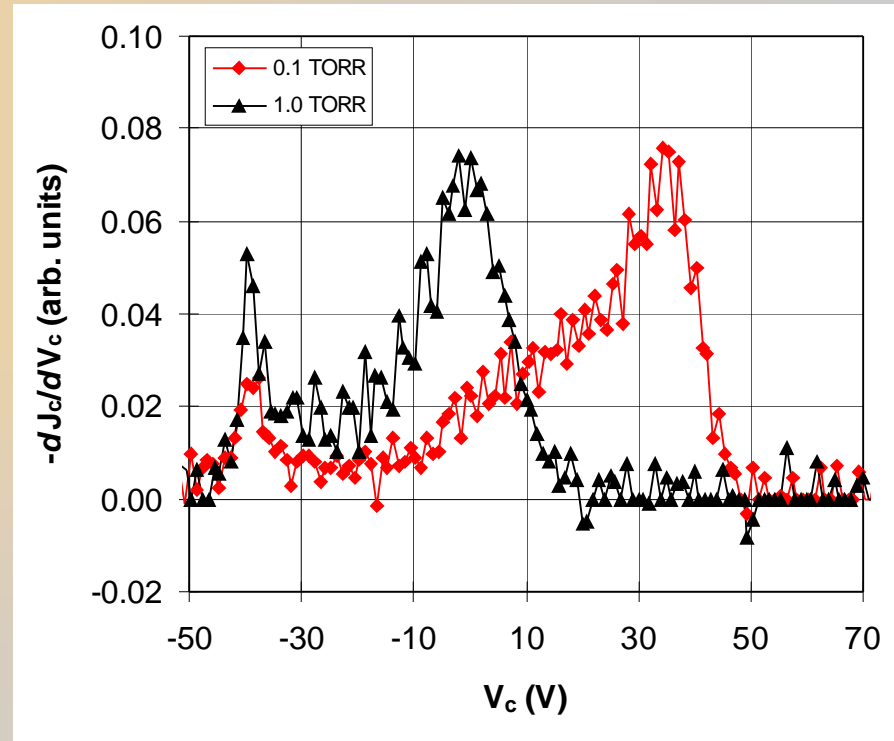
★ Hydrogen ions interrupt growth of crystallites

$$H^+ + Si\text{-}Si = Si\text{-}H + Si\text{-}$$

G. Ganguly, M. Fukawa, T. Ikeda and A. Matsuda, J. Non-Cryst Solids 227-230 (1998)

UNI-SOLAR®
United Solar Ovonic

Hydrogen Atom vs. Ion
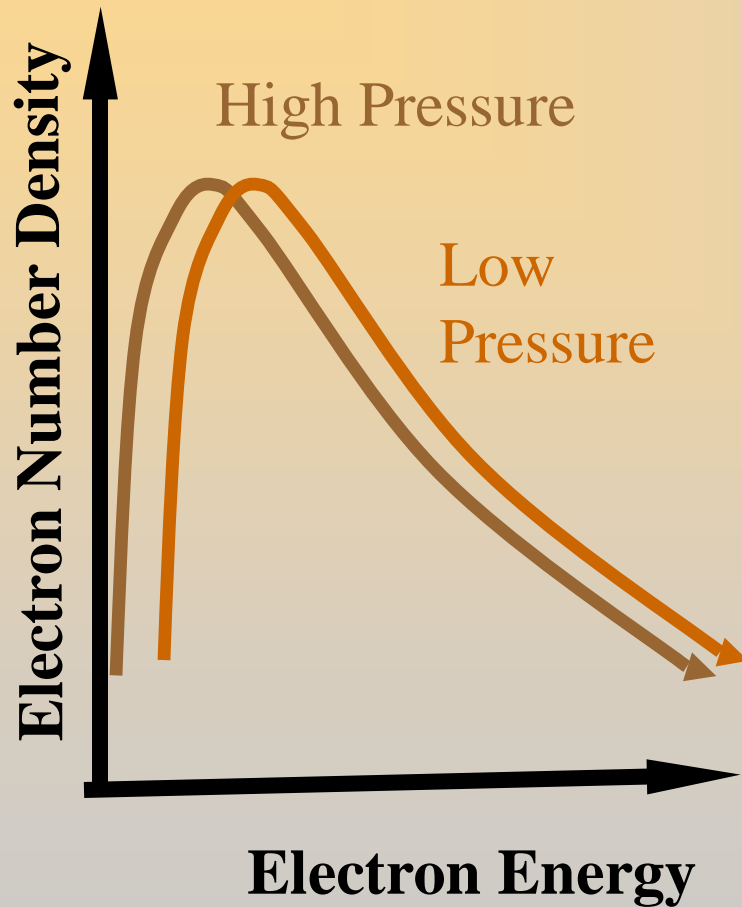
B. Yan, J. Yang, S. Guha and
A. Gallagher, MRS 557 (1999) 115

Pressure:nc-Si cells (~50mins.)

Cell #	Area (cm^2)	V$_{oc}$ (V)	FF	Pressure (Torr)	J$_{sc}$ (mA/cm^2)	Efficiency (%)
10138 LC1	0.25	0.336	0.407	Low	18.02	2.46
10153 LC1	0.25	0.460	0.644	Medium	20.90	6.19
10192 LC1	0.25	0.484	0.666	High	22.62	7.29

	Initial	LS 310h
V$_{oc}$(V) =	0.484	0.473
FF =	0.666	0.654
J$_{sc}$ (mA/cm^2) =	22.62	22.6
Eff.(%)=	7.29	6.99

● 310h LS
□ Initial
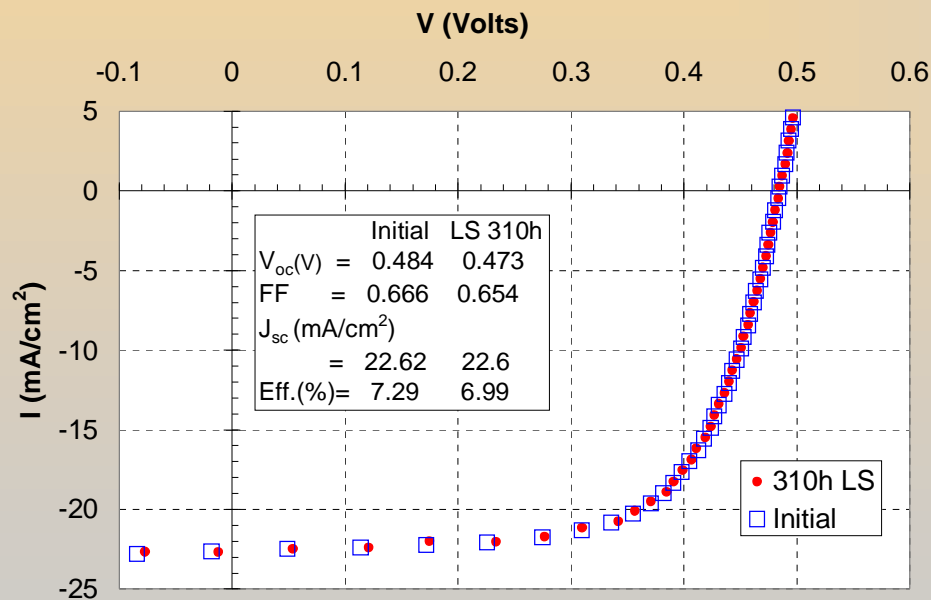
★ The performance improves with increasing pressure

UNI-SOLAR
United Solar Ovonic

a-Si/nc-Si (~50mins.) Tandem Cells

2B 10478 LC1 (0.25cm²)

V_{oc} = 1.421V
FF = 0.778
J_{sc} = 10.14mA/cm²
$\eta_{Total\ Area}$ = 11.2%

2B 10478 LC1
J_{sc} (QE)=20.59mA/cm²

10.1
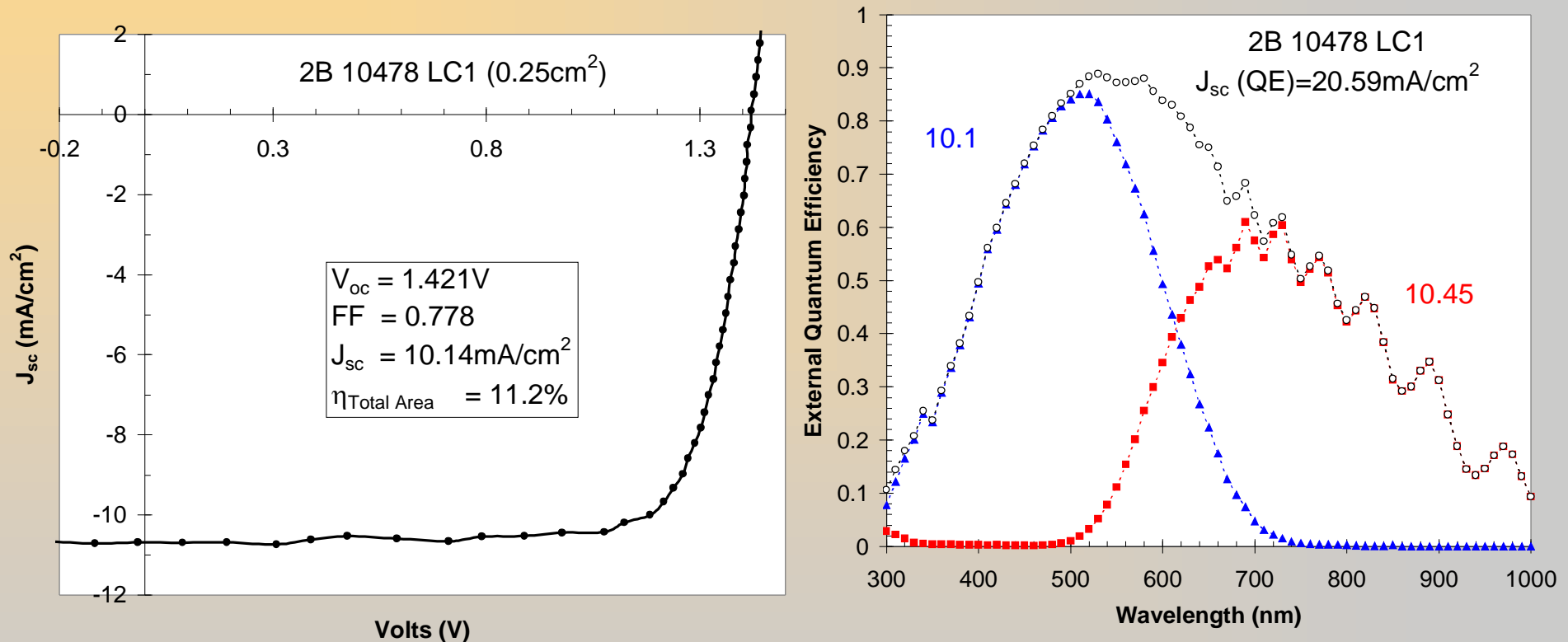
10.45

★ We have been able to obtain a total area efficiency of 11.2%

UNI·SOLAR
United Solar Ovonic

Degradation of 0.25 cm^2 a-Si/nc-Si(50mins.) Tandem Cells

Run	State	Cell	Filter	V_{oc}	FF	J_{sc}-Top (mA/cm^2)	J_{sc}-Bot (mA/cm^2)	η (%)
10478 LC1	Initial	32	AM 1.5	1.42	0.778	10.14	10.45	11.2
	1002h	32	AM 1.5	1.39	0.725	9.9	10.4	10.0
	Degr.(%)			*2.3*	*6.8*	*2.0*	*0.4*	*10.7*
10485 LC1	Initial	32	AM 1.5	1.4	0.778	10.45	10.24	11.16
	1002h	32	AM 1.5	1.38	0.742	10.33	10.4	10.57
	Degr.(%)			*1.5*	*4.6*	*1.2*	*-1.5*	*5.3*

★ Best Stable Efficiency is >10%

★ Degradation is 5-10%

UNI-SOLAR
United Solar Ovonic

a-Si / nc-Si (50min.) Tandem cells

45 cm^2 and 460 cm^2

Serial #	Area	V$_{oc}$	FF	J$_{sc}$	η$_{Aperture\ Area}$
	(cm^2)	(V)		(mA/cm^2)	**(%)**
10500E3	45	1.429	0.756	10.71	11.62
F1		1.430	0.738	11.46	12.12
F2		1.432	0.736	11.64	12.31
G3		1.441	0.743	11.37	12.22
10582	460	1.440	0.729	10.23	10.76
10583		1.440	0.722	10.13	10.51
10534		1.425	0.694	10.49	10.39
10536		1.422	0.708	10.33	10.43
10587		1.44	0.689	10.66	10.58

★Initial Efficiency is 12.3% (45cm^2)
& 10.8% (460cm^2)

UNI-SOLAR
United Solar Ovonic

a-Si / nc-Si (50min.) 45 cm^2 and 460 cm^2

Serial #	Area (cm^2)	State	V$_{oc}$ (V)	FF	J$_{sc}$ (mA/cm^2)	η$_{Aperture\ Area}$ (%)
10490F2	45	Initial	1.425	0.741	11.40	12.07
		624h	*1.400*	*0.688*	*11.24*	*10.87*
G3		Initial	1.437	0.735	11.30	11.97
		624h	*1.420*	*0.671*	*11.39*	*10.86*
10500F1		Initial	1.430	0.738	11.46	12.12
		624h	*1.410*	*0.670*	*11.40*	*10.77*
F2		Initial	1.432	0.736	11.64	12.31
		624h	*1.410*	*0.680*	*11.38*	*10.92*
G3		Initial	1.441	0.743	11.37	12.22
		624h	*1.420*	*0.686*	*11.12*	*10.84*
10534	460	Initial	1.425	0.694	10.49	10.39
		624h	*1.410*	*0.653*	*10.32*	*9.51*
10536		Initial	1.422	0.708	10.33	10.43
		624h	*1.410*	*0.652*	*10.13*	*9.32*

★ Stable Efficiency is 10.9% (45cm^2) & 9.5% (460cm^2)

UNI-SOLAR
United Solar Ovonic

Degradation of Tandem vs. Top cell

Run	State	Filter	V_{oc}	FF	J_{sc}-Top (mA/cm^2)	J_{sc}-Bot (mA/cm^2)	$\eta_{Total\ Area}$ (%)
10478 LC1	Initial	<585	1.34	0.805			
		>630	1.31	0.756			
		AM 1.5	1.42	0.778	10.14	10.45	11.2
	1002h	<585	1.3	0.788			
		>630	1.25	0.683			
		AM 1.5	1.39	0.725	9.9	10.4	10.0
	Degr.(%)		*2.3*	*6.8*	*2.0*	*0.4*	*10.7*
10469 A1	Initial	AM 1.5	1.001	0.745	9.79		7.3
	1002h		0.97	0.645	9.42		5.9
	Degr.(%)		*3.1*	*13.4*	*3.8*		*19.3*

★ a-Si cell FF degrades less in tandem structure than in single cell (0.683 vs. 0.645)
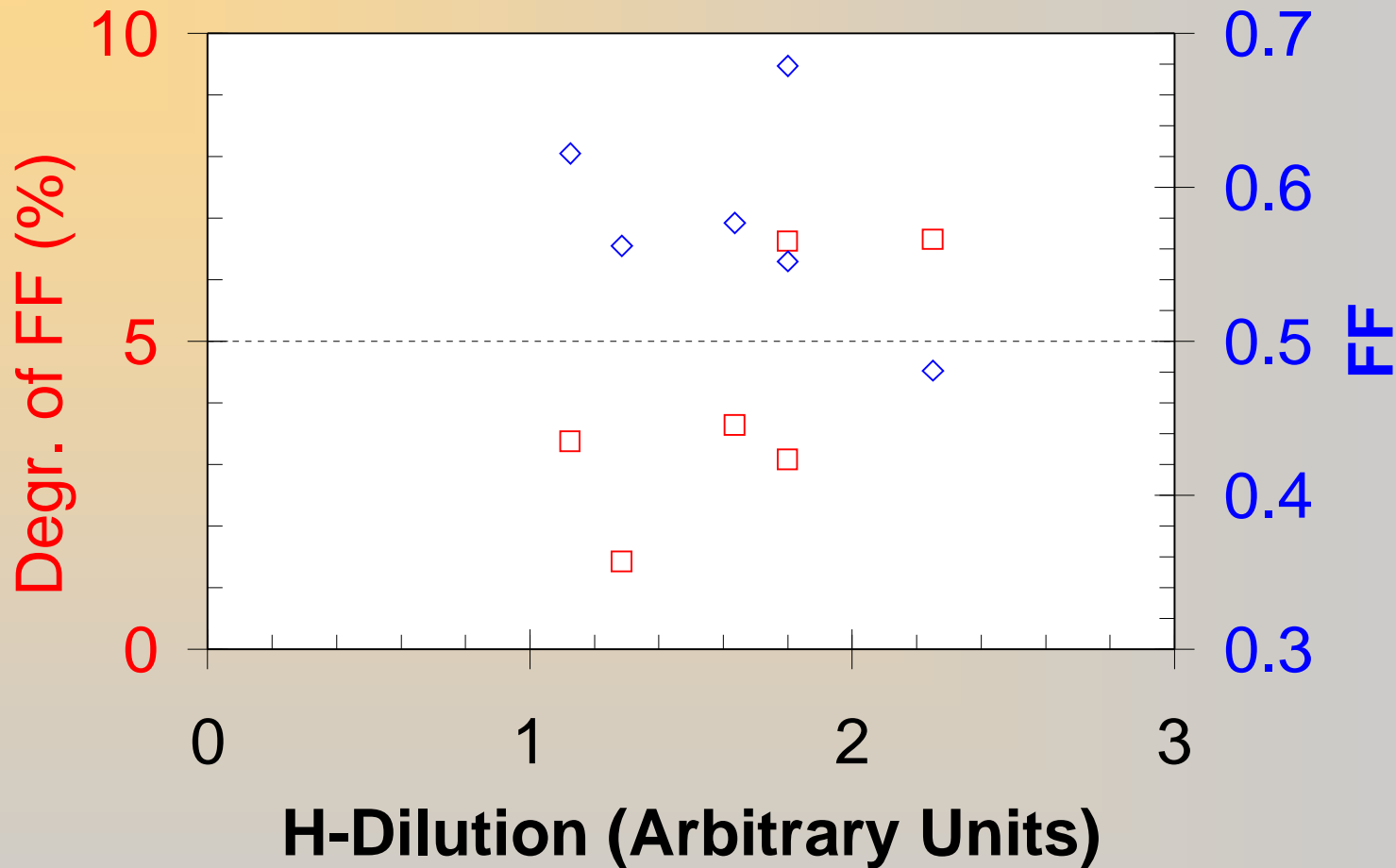
UNI-SOLAR.
United Solar Ovonic

Degradation of nc-Si cells vs. V_{oc}
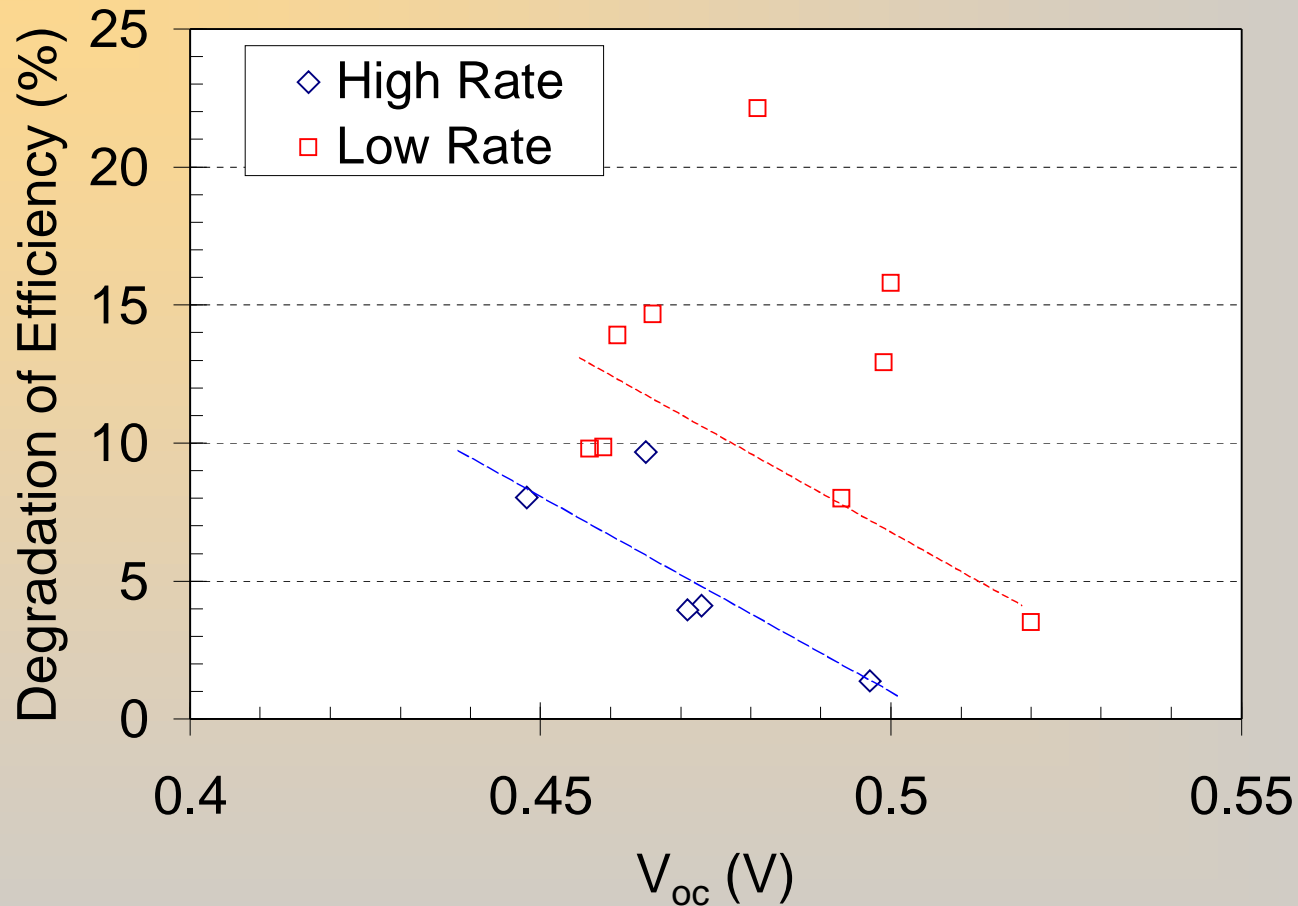
★ Higher V_{oc} cells are more stable

★ Higher Dep. Rate cells are more stable

Degradation vs. H-Dilution

★ FF Decreases but Degradation increases with H-dilution

Conclusions

★ Performance of nc-Si cells improve at higher pressure.

★ We have obtained 10.9% (45cm^2) and 9.5 % (460cm^2) stable, aperture area efficiency a-Si/nc-Si tandem cells.

★ Degradation of nc-Si cells decreases with decreasing H-dilution and with increasing V$_{oc}$ (closer to transition region)

★ Top cell degrades less in a-Si/nc-Si tandem structure than as a single on SS.

Initial and LS Efficiencies
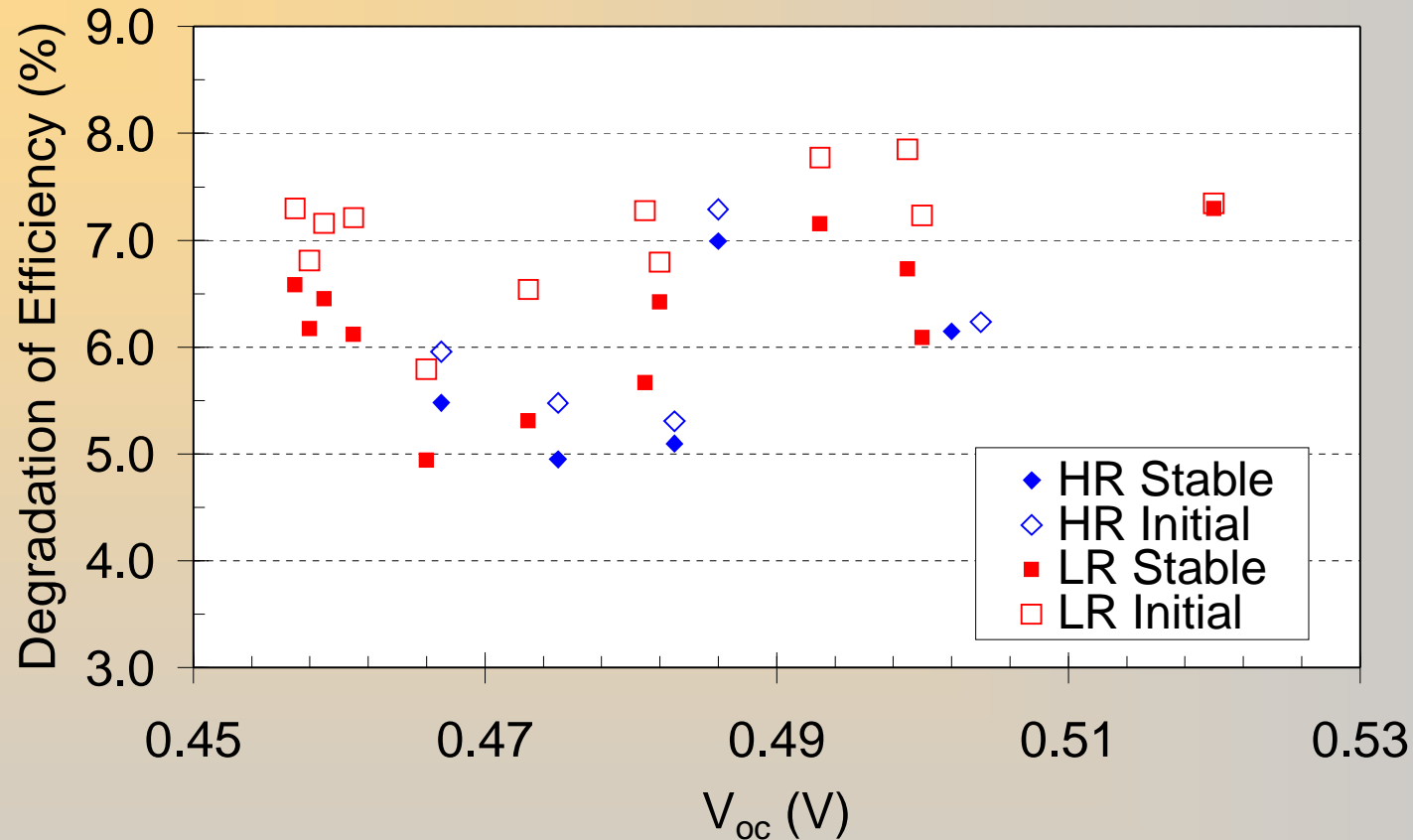
★ The lower rate cells have higher initial efficiencies but degrade more than higher rate ones