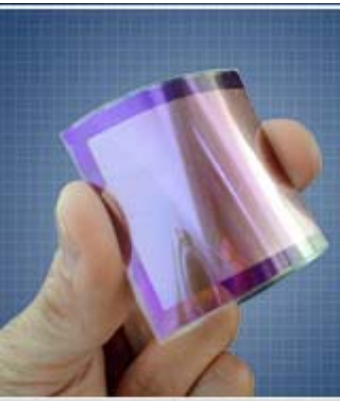
Film-Silicon PV:
Optimizing Silicon in Solar PV Technology

21st NREL INDUSTRY GROWTH FORUM
OCTOBER 2008

AMPULSE



solar made simple

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Ampulse Corporation - Mission

- **Ampulse is developing a revolutionary solar cell PV technology that optimally blends:**

- **the energy conversion efficiency of traditional c-Si**

- **the lower manufacturing costs of emerging TF-PV**

- **simplified manufacturing processes in the world's best-known material system: <u>silicon</u>**

- **to produce a new approach in PV:** *crystalline Film-Si*

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Ampulse Company Background

- **A collaborative effort between prominent clean-tech entities**

- **Ampulse President & CEO – Steve Hane**
  - experienced venture-environment executive
  - most-recent position: CEO of Picolight, a $125M M&A exit in 2007
  - strong team of experienced talent being assembled

- **Driving the Road Ahead**
  - first recipient of Technology Commercialization Funding (TCF) from the DOE
  - "seen it before" commercialization experience in technology plays
  - 60-patent IP portfolio spanning substrate and deposition techniques

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Ampulse Technology Proposition

- **Film-Si: thin-layer, oriented silicon on metallic substrate**
  - utilizes low-cost, flexible and rugged RABiTS substrate (ORNL)
  - utilizes efficient HW-CVD Si gas-deposition techniques (NREL)
  - *large-grained, crystallographically-oriented silicon*, *5 microns thick*

- **Advantages to Film-Si PV**
  - low dependency on silicon; 25-100X less than traditional c-Si PV
  - simplified manufacturing processes with less energy and material waste
  - monolithic integration of absorber, back reflector, and back contact
  - "wafer replacement-plus" PV material <$.25/W
  - high energy conversion efficiencies achievable (15%+)

- **The Endgame**
  - a real shot at being the high efficiency / low-cost player in PV

c-Si PV Wafer Production: Costly & Inefficient

- **2 yr energy payback**
- **$0.60/W - $1.00/W for feedstock alone**

Sand

Add carbon and energy

Metallurgical grade Si

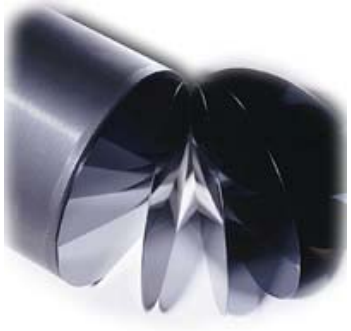
Purest material: $SiHCl_3$ or SiH_4 gas

+ heat energy (1000°C)

silicon feedstock

+ more heat energy (1500°C)

Waste ~1/2 to sawing



Use 10X more than needed

Film-Si: Breakthrough Process Efficiency

Sand

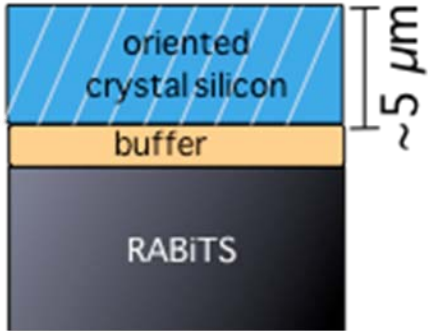
Add carbon and energy

Metallurgical grade Si

Purest material: $SiHCl_3$ or SiH_4 gas

direct-film c-Si growth

- little waste
- 2/3rd less energy input
- no Si feedstock
- monolithic integration



directly deposit enough pure Si for light absorption, via HW-CVD process

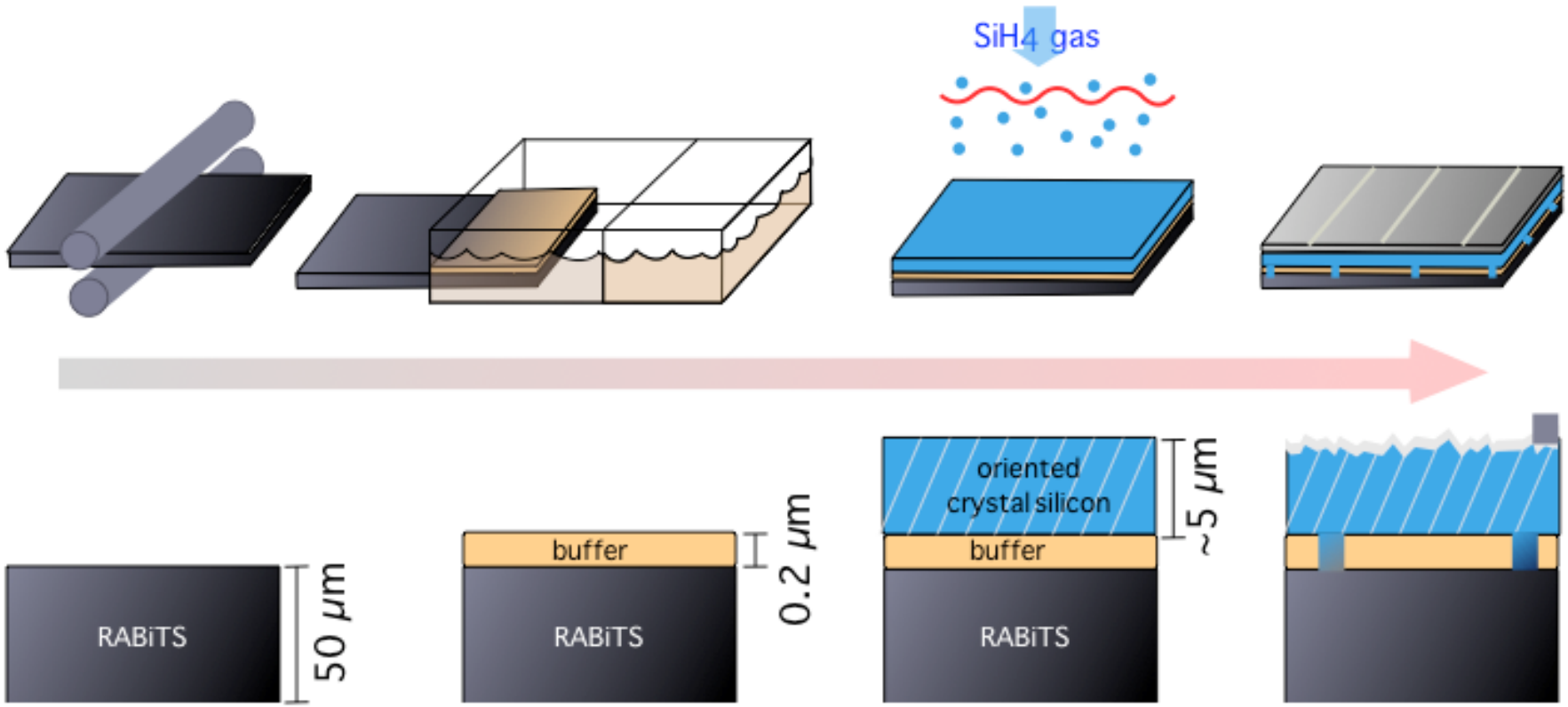
Ampulse Manufacturing Process Flow

Rolling & Heating

Solution-based buffer growth

HW-CVD Si deposition
(replacing numerous and costly Si-processing steps)

Cell Fabrication
(common techniques for light trapping, top contacts, etc.)



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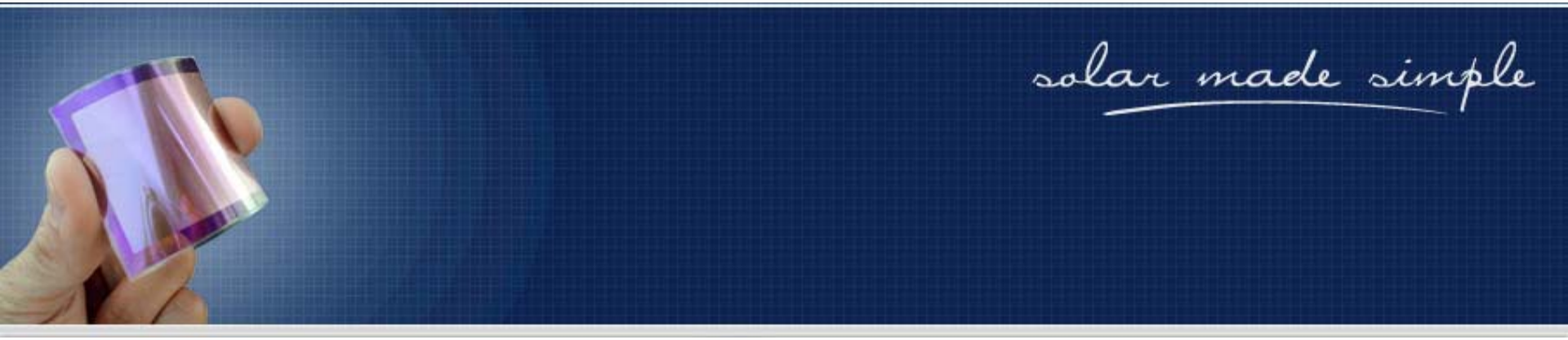
Film-Si PV: The Balanced Solution for PV

	c-Si	A-Si	CIGS	CdTe	Film-Si
15% efficiency potential	✓	X lowest	✓	X	✓
abundant raw material / used efficiently	X	✓	X Indium	X Tellurium	✓
non-toxic material	✓	✓	X	X Cadmium	✓
simplified mfg. processes	X	✓ simplest	✓	✓	✓
mfg process tolerances	✓	✓	X	✓	✓
low energy payback	X	✓	✓	✓	✓
Lowest total cost solution / best balance of efficiency, costs, materials					✓

Thank You

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