

### Breakthrough Silicon-Lead Battery Technology

# Gridtential

### World Market for Grid Storage \$125 \$100 Billion (USD) (HWD) \$75 Energy





# Silicon Joule™ Technology

- acid architecture to deliver premium performance
- Coupling of solar-wafer and lead-acid manufacturing infrastructures to lower grid storage costs





Cycle life @ 80-100% depth of discharge





Integration of silicon wafer plates into an advanced lead-



\$100/kWh

**Price target with** 75% lower LCOE



## Silicon Joule™ Technology



Technology Innovations
Silicon wafer substrate
Same active material
Low-cost solar processing

Design Advantages
Bipolar configuration
Uniform current density
Scalable platform

**Traditional Lead Acid** 

• High current around contacts

• Electrolyte stratification

Hot spots from paste uniformity



## Lead Battery Configurations

### **Bipolar Configuration**

- Perpendicular current flow
- Uniform current distribution
- Efficient thermal management

## Historical Bipolar Obstacles

 Material compatibility Surface electrochemistry • Cell-to-cell leakage Compression uniformity • Thermal management



# Advantages of Silicon

Silicon Joule<sup>™</sup> **Current Collector** 



 Light and stiff, doped to low resistivity Impervious to sulfuric acid High thermal conductivity • Contact layer has wide electrochemistry window • Edge sealed to eliminate intercell leak Adhesion layer compatible with paste chemistry Low cost processing by solar infrastructure





#### Substrate Material

### Silicide **Contact Layer**





- Light and stiff
- Impervious
- Conductive

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- Low resistivity
- Stable surface
- Compatible electrochemistry

## Silicon Joule<sup>TM</sup> Plate Processing

#### Sealed Wafer Frame

### PbSn **Adhesion Layer**





- Strengthened edge
- No intercell leak
- Manufacturable

- Paste adhesion
- Tailored composition



**PAM** Pasting







NAM Pasting

## Silicon Joule<sup>TM</sup> Cell Construction

2V Stacking





Positive Active Material

Silicon Biplate

#### End Cap

### Unique stacking assembly for low cost and easy scale-up

12V Battery



Absorbed Glass Matt Separator

> Negative **Active Material**

Casing Frame

Silicon Biplate

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### Silicon Joule™ Battery Architecture

- Silicon wafers isolate hermetically each electrolyte
- Stack-and-seal casing design leads to efficient thermal management in simple mechanical package



compartment and connect all cells electrically in series





## Silicon Joule<sup>™</sup> Process Compatibility **AGM VRLA Battery Manufacturing**

#### **Grid Casting**



### **Gridtential Bipolar Battery Manufacturing**

### **Purchase Silicon Biplates**

Paste and Cure on **Plastic Grids** 



Strap, Weld, Box and Seal

### **Fill and Form**

### **Stack and Seal**



### **Fill and Form**



# Alpha Battery Testing

- Over 250 6-Volt Alpha units built to date
- Scalable to 12-Volt stack
- Scalable capacity by parallel connection
- Customer achieved > 1500 cycles at 0.50C discharge rate and 100% depth of discharge
- No thermal runaway at 2.45V up to 80°C
- No change after SAE J930 vibration test
- Six alpha partners in US, Europe, and Asia

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## Alpha Battery Performance



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- Significant improvement seen with each Alpha generation
- Improvements to assembly method decrease dry-out
- Commercial sealing expected to yield significant performance gain



# Deep Discharge Advantage

- Energy battery designed for 2-4 hour load shifting usage
- Long cycle life under harsh cycling
  - Uniform current density distribution decreases sulfation
  - Low-resistance current path decreases electrolyte stratification
- Wide operating temperature range afforded by thermally stable silicon
- Easily parallelized for increased capacity







## Power Advantage

- 48V packs can achieve SAE LV148 requirements
  - Capable of > 250A (Power) or > 300A (Power + Hybrid) at  $\geq$  1.72Vpc
- Electrochemically stable silicon decreases side reactions and subjects to less self discharge
- Thin active layers are less stressed but highly utilized
- silicon to form hybrid devices
- No thermal buildup in current collectors Deposition of carbon ultra-capacitor onto

**Gridtential**™





# The Silicon Joule™ Advantage

### **High Performance**

- 40% less weight at same capacity
- Efficient at 2-4 hour discharge
- Up to 5× cycle life improvement compared to traditional AGM

### Safe and Sustainable

- Efficient thermal management
- Uses 40% less lead
- Recyclable at existing facilities



### Low Cost Manufacturing

- Trailing edge solar processing
- Compatible with existing lead acid manufacturing infrastructure

### **Flexible Platform**

- Deep discharge for renewables
- Power advantage for automotive
- Scalable platform for energy, power, and hybrid batteries





### Christiaan Beekhuis, CEO Gridtential Energy, Inc. | cbeekhuis@gridtential.com



## Thank You!

## Gridtential