Objectives

- Conduct case studies to assess the feasibility of nanofluidic pressure-to-potential (nanoP2P) converters for real-world applications.
- Design and construct a sealed testing system for nanofluidic devices.
- Test reliability of the system with various micro- and nanofluidic devices.

Background Information

- In 2013, the United States generated 4 trillion kilowatt-hours of electricity, 67% coming from fossil fuels [1].
- A nanoP2P converter utilizes pressure-driven flow of an ionic solution through a nanochannel or bank of nanochannels to generate a streaming potential [2].
- A nanochannel is defined as a conduit for passage of fluid with at least one dimension characteristic to the flow in the 1–100 nm range [3].
- The generated streaming potential can be collected and used to perform electrical work.
- Fluid slip and surface charge density of the substrate enhance the power conversion efficiency of the device.
- Fluid slip occurs when the velocity of the fluid is not equal to that of the wall at the boundary.

Approach

- Two Case Studies Analyzed:
  1. LED Lighting
     - Incandescent halogen bulbs are being replaced by brighter and more efficient LED bulbs throughout US cities [5]
     - A nanoP2P converter could collect pressure from cars moving through intersections.
     - Streaming potential could be used to power traffic and/or street lights.
  2. Personal Devices
     - A nanoP2P converter could be embedded in a shoe to collect pressure from walking and running.
     - Streaming potential could be used to power mobile devices.
     - Simplified schematic showing Test Setup.

LED Lighting

- Estimated 300,000 traffic lights and 26 million street lights in the US [4,5].
- Assume each traffic light has equivalent of one 15 W LED bulb lit 24/7, consuming 131 kW-hr annually.
- Assume each street light has one 25 W LED bulb lit 4100 hours per year, consuming 102.5 kW-hr annually.

Our Device

- Consider a 16.25 m wide square intersection with 12 traffic lights, consuming 1,572 kW-hr annually.
- Each device collects 590 psi from moving cars on average.
- Fluid slip increases flow rate and power generation.

Case Study Analysis

<table>
<thead>
<tr>
<th>Component</th>
<th>Consumption of 12 Traffic Lights (kW-hr/yr)</th>
<th>Power Output of Devices (W-hr/yr)</th>
<th>% Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Slip</td>
<td>30% 1972</td>
<td>2.85</td>
<td>0.14</td>
</tr>
<tr>
<td>Slip</td>
<td>50% 1972</td>
<td>4.75</td>
<td>0.23</td>
</tr>
<tr>
<td>Slip</td>
<td>70% 1972</td>
<td>6.65</td>
<td>0.42</td>
</tr>
<tr>
<td>No Slip</td>
<td>30% 1972</td>
<td>19.95</td>
<td>1.27</td>
</tr>
<tr>
<td>Slip</td>
<td>50% 1972</td>
<td>33.24</td>
<td>2.12</td>
</tr>
<tr>
<td>Slip</td>
<td>70% 1972</td>
<td>46.54</td>
<td>2.94</td>
</tr>
</tbody>
</table>

Personal Devices

- Estimated 144.5 million smart phones in the US in 2013 [6].
- Each phone consumes about 4.9 kW-hr annually from charging [6].
- Equaling ~0.018% of the electricity generated in 2013.

Our Device

- Collect 72 psi from the average adult walking, 144 psi from running.
- Pressure applied over the devices embedded in a running shoe.
- Running generates more power than walking.

Test Setup

- Compressed air at 85 psi is applied to the input reservoir and forces an ionic solution through the nanochannel or bank of nanochannels in the device. A pressure of 85 psi was selected to stay consistent with existing research in this field. The streaming potential, or voltage generated in the device, is shown.

Test Setup Components

- Leak-Free Connections
  - Stainless Steel Hose Coupling
    - Max Pressure: 300 psi
  - High-Pressure Tygon PVC Tubing
    - Max Pressure: 250 psi
    - ID: 1/4"
  - White PVDF Barbed Tubing
    - Max Pressure: 150 psi
- Leak-Free Sealants
  - Breeze Mini Hose Clamps
    - Secure pipe to connector at various joints
  - Double-Bubble Epoxy, Orange Package
    - Seal T-connector to device input reservoir
  - Tensile Strength: 250 psi

Conclusions

- It is not feasible to pursue nanoP2P converters for charging personal devices.
- NanoP2P converters are theoretically feasible for street lighting.
- Connections are leak-free as tested with bubbles, will collect streaming potential data.

References

[5] Howstuffworks, “Why are they replacing all of the traffic lights in my town?”

Further Information

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