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Energy harvesting from pavement via polyvinylidene fluoride: hybrid piezo-pyroelectric effects

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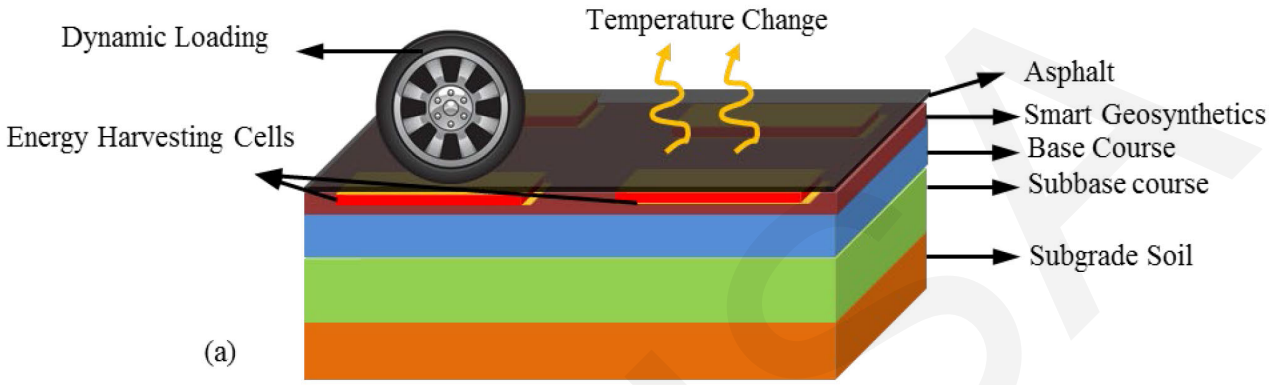
Potential energy harvesting strategies from pavements



- Total roadway length in USA: 6 million km
- Total registered vehicle number: 250 million
- Wasted energy: Vibration; Deformation; Heat

Objective

- Understand the hybrid piezo-pyroelectric effect
  - Is there any strengthening or weakening effect when coupled?
- Estimate the energy harvesting potential from pavement system with hybrid piezo-pyroelectric effects
- Establish a framework for future design optimization

$$V_{hybrid} = V_{piezo} + V_{pyro} \quad ?$$

or

$$V_{hybrid} > V_{piezo} + V_{pyro} \quad ?$$

or

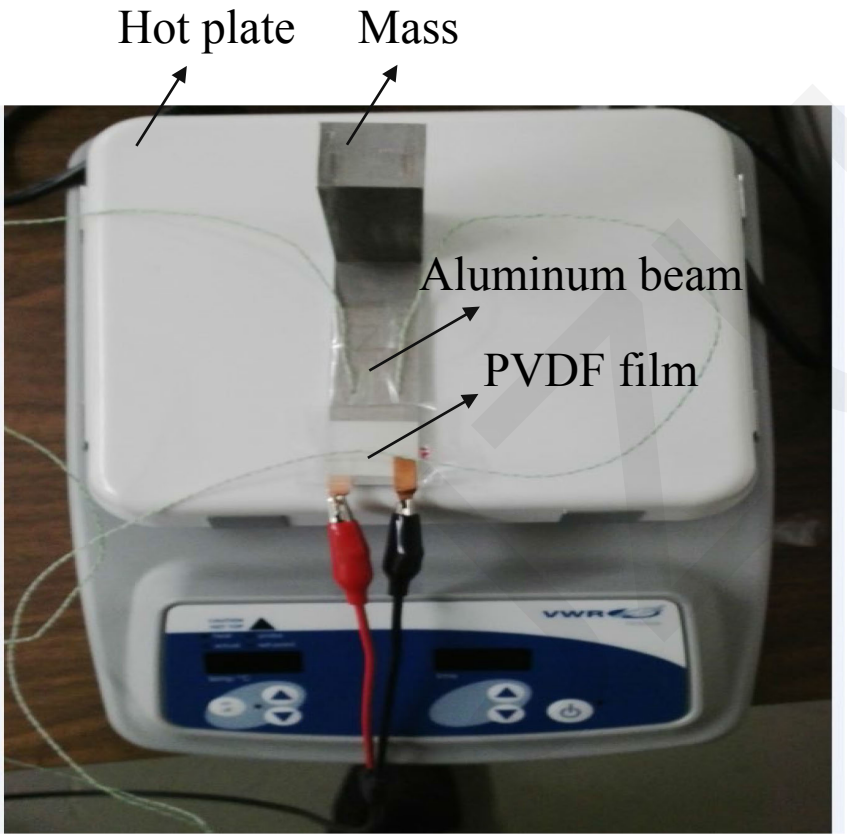
$$V_{hybrid} < V_{piezo} + V_{pyro} \quad ?$$

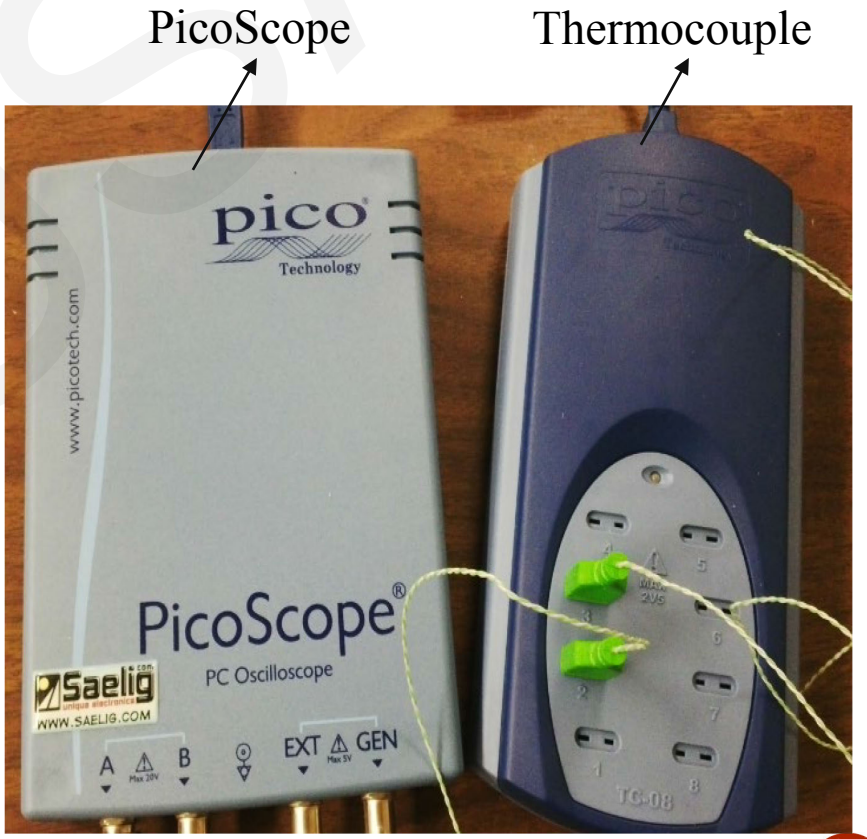
Energy harvesting from pavement via PVDF: hybrid piezo-pyroelectric effects

Experiment Scheme

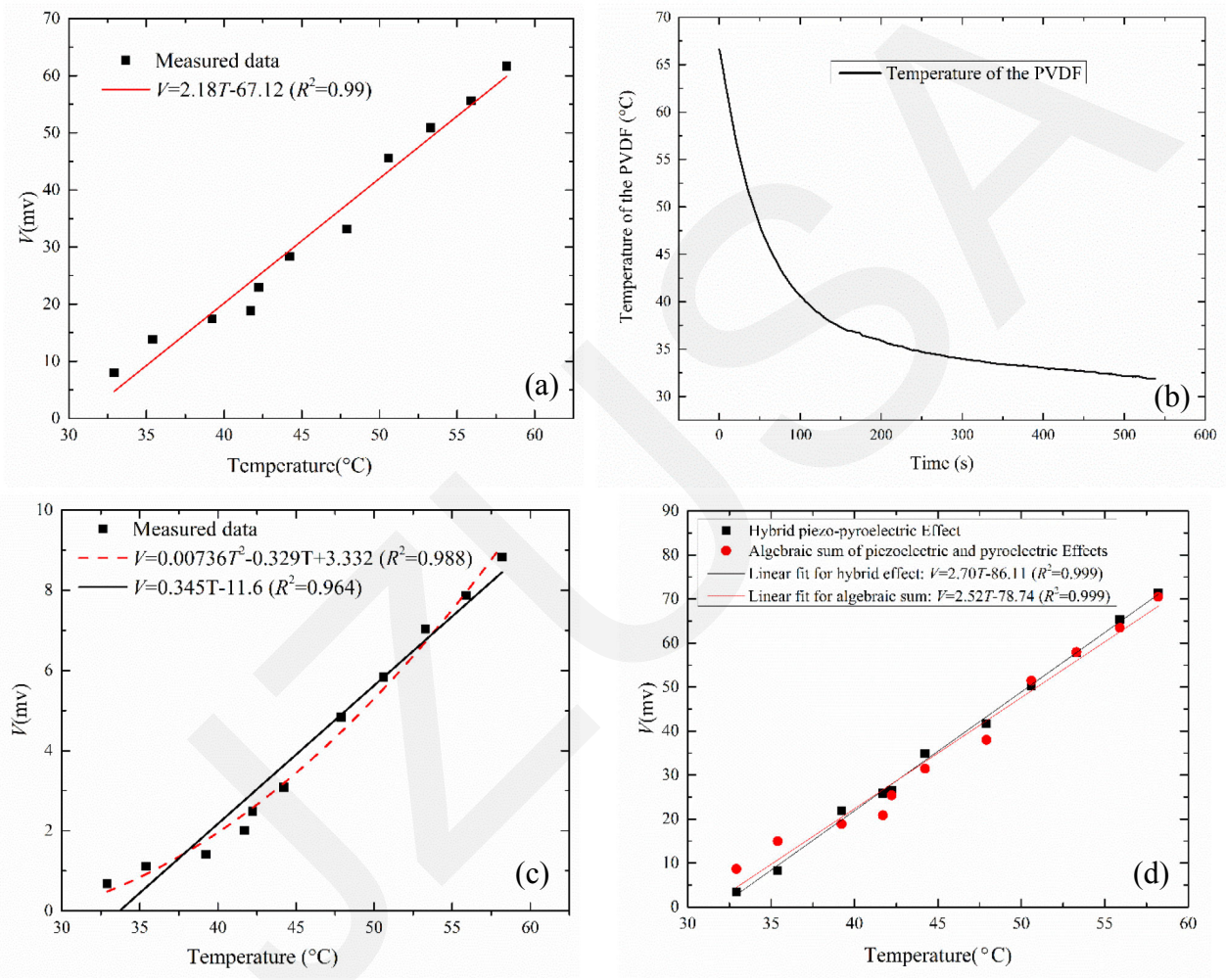
I. Pure piezoelectric effect
II. Pure pyroelectric effect
III. Hybrid piezo-pyroelectric effect

Experiment Setup





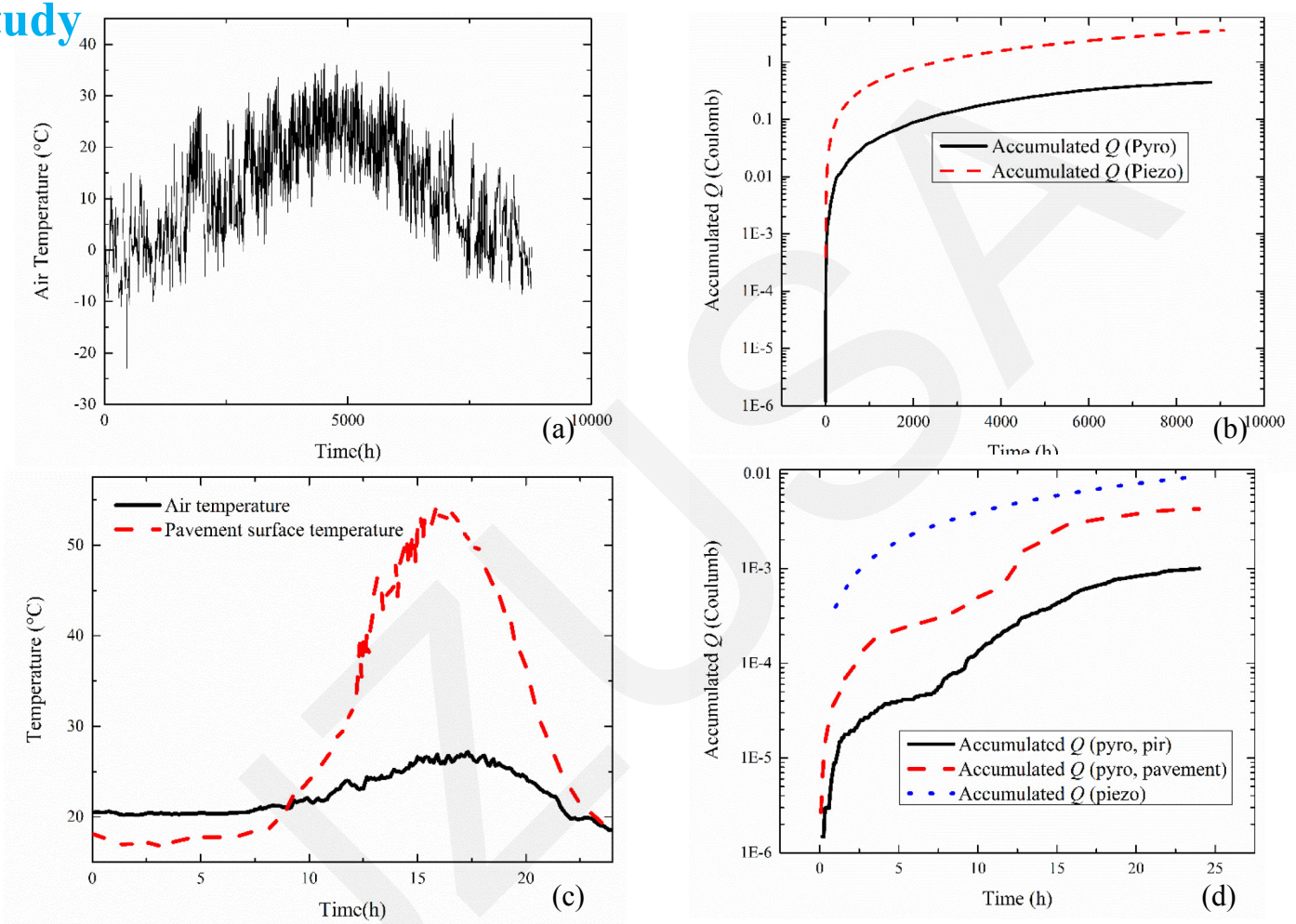
Experiment Results



Experiment results: (a) pure piezoelectric effect; (b) temperature profile; (c) pure pyroelectric effect; (d) hybrid piezo-pyroelectric effect.

Energy harvesting from pavement via PVDF: hybrid piezo-pyroelectric effects

Case Study



Case study condition and results: (a) air temperature in one year in Wooster, Ohio; (b) accumulated charge by pure piezoelectric and pyroelectric effect under air temperature in one year; (c) pavement surface temperature during a summer day in Cleveland, Ohio; (d) accumulated charge by pure piezoelectric effect during a summer day; and charges by pyroelectric effect under air and pavement temperature during a day.

Conclusion

- Hybrid piezo-pyroelectric effect can be modeled as the algebraic sum of the piezoelectric effect and the pyroelectric effect

$$V_{hybrid} = V_{piezo} + V_{pyro}$$

- Case study
  - For PVDF, pyroelectric energy is relatively small comparing to the piezoelectric energy, but it is still a considerable contribution if effectively harvested (with proper circuit and bonding location);
  - Piezoelectric nanocomposites are promising to improve the hybrid pizeo-pyroelectric energy harvesting efficiency

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