# Design of Automobile Waste Heat Harvesting System

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## Motivation and Summary

A modern car wastes 70-85% of its total energy output in the form of heat. How to recover the wasted heat from exhaust system to generate power for onboard electronics without additional batteries?

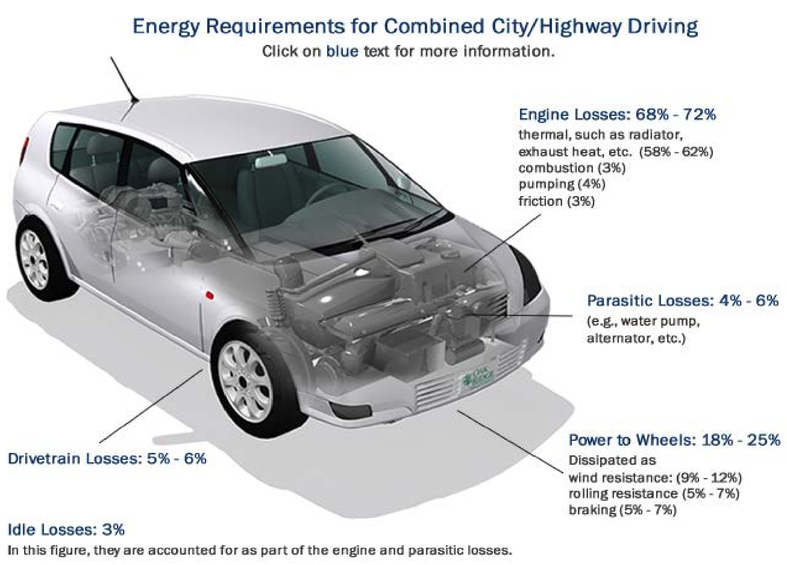



**Figure 1.** Energy loss in the car

Using solid thermionic emission mechanism based on graphene sandwich structure, wasted heat above 400 K can be converted into electricity with efficiency of 10 % above.

## Method

**Conventional Richardson law**

$$J = AT^2 \exp[-\frac{\Phi}{k_B T}]$$

$$A = \frac{4\pi m {K_B}^2 e}{h^3}$$

**Thermionic emission from graphene**

$$J = A^* T^3 \exp[-\frac{\Phi - E_F}{k_B T}]$$

$$A^* = \frac{{K_B}^3 e}{\pi \hbar^3 {v_f}^2}$$

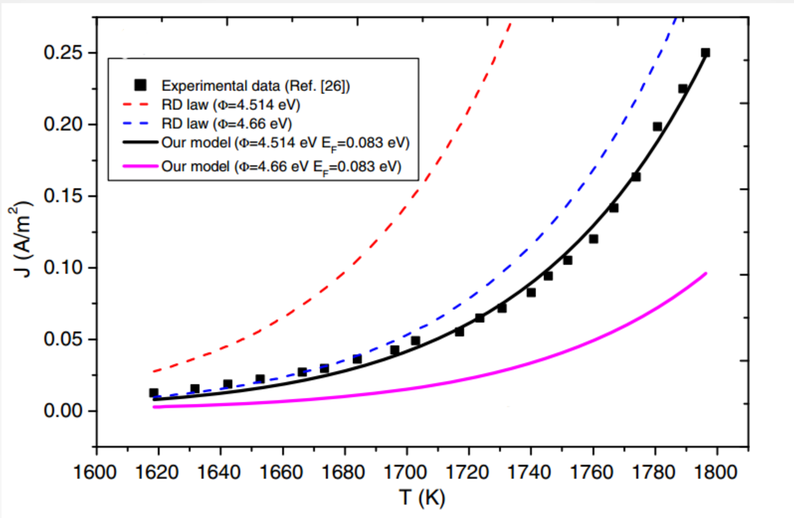
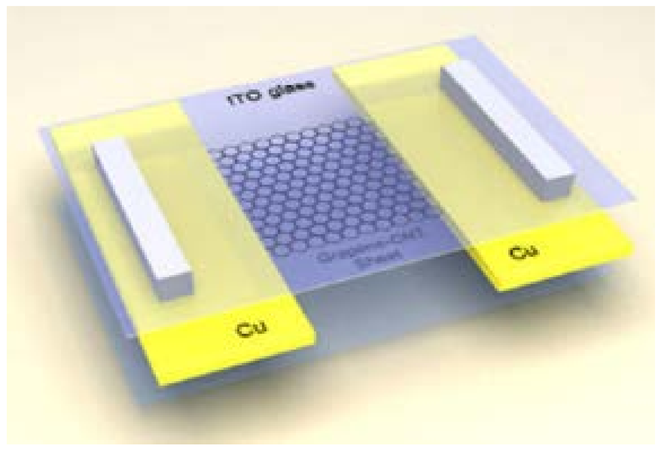



**Figure 2.** A comparison of our calculated results and of the RD law with experimental data.

## Experiment



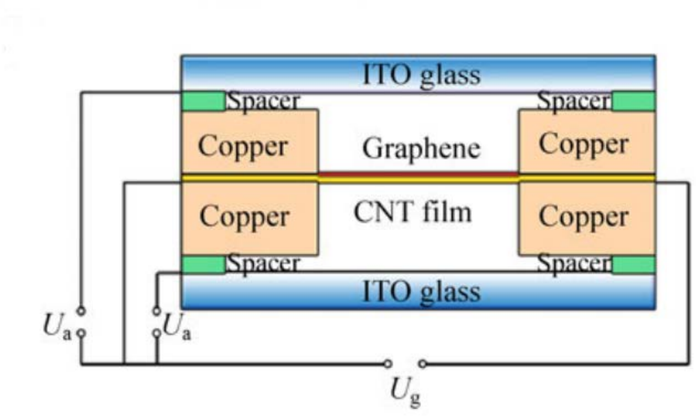
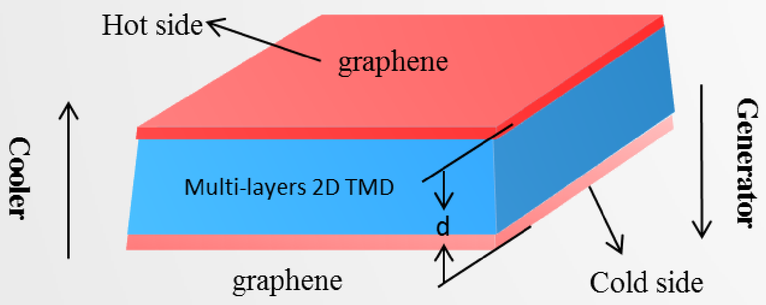




**Figure 3.** Illustration of testing structure and schematic electronic circuit of the experiment

## Modeling and Results



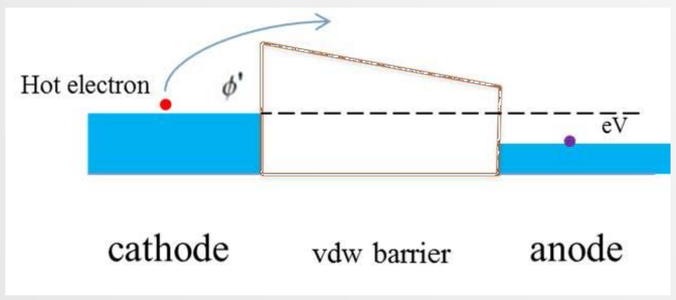
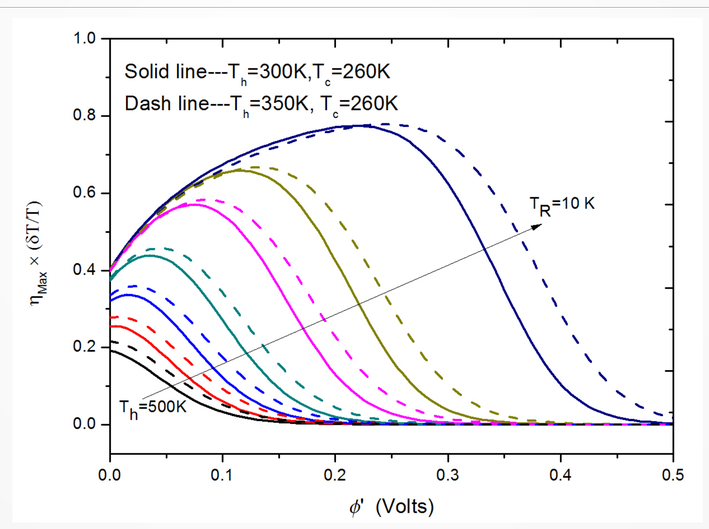
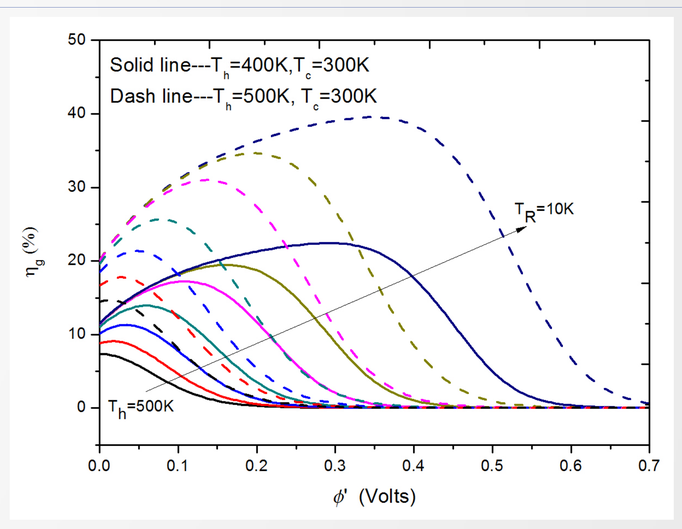




**Figure 3.** Design of wasted heat harvesting system And its operating principle




| System | Thickness d [nm] | $\kappa$ for [W/m/K] | Experiment SBH [V] | Calculated $T_R$ [K] | Optimal-SBH [V] | Maximum efficiency [%] |
|---|---|---|---|---|---|---|
| G/$MoS_2$ | 50 | 0.3 | 0 to 0.11 | 847 | 0 | 3.15 |
| G/$WS_2$ | 50 | 0.2125 | 0 to 0.37 | 758 | 0 | 3.93 |
| G/$MoSe_2$ | 70 | 0.089 | 0 to 0.4 | 501 | 0.005 | 7.28 |
| G/$WSe_2$ | 62 | 0.048 | 0 to 0.44 | 428 | 0.02 | 8.56 |

**Figure 4.** Performance of proposed heat harvesting system and identified candidate materials for devices

## Conclusion

1. As Power generator, Gr/MoSe2/Gr or Gr/WSe2/G can harvest wasted heat at **400 K** with about **7%** to **8%** in efficiency.
2. As a refrigerator, efficiency is **0.22** to **0.26** of the Carnot efficiency for a temperature difference of **40 K** between **260** and **300 K.**

## Reference


1. **Shi-Jun Liang and L.K. Ang Phys. Rev. Appl. 3, 014002 (2015)**
2. **Shi-Jun Liang et al, Scientific Report 7:46211 (4/2017)**
3. **Feng Zhu, et al, Nano Research 7, 553-560 (2014)**



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