# TEMPERATURE-DEPENDENT RAMAN SPECTROSCOPY OF FULLERENE AND CARBORANE NANOCAR WHEELS

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Characterizing the substrate coupling of nanocar wheels is crucial to understanding the types of movement observed in nanocars. Prior studies have determined only that nanocars exhibit either pivoting or translational movement depending on various factors, but further details are not well known. Thus, we analyze the nanocars to determine whether rotation and translation play separate roles. Using a thermo electric controller (TEC) with a home-built Scanning Tunneling Microscope (STM) and a modified Raman microscope, we investigate the effects of temperature between 10$^{o}$C and 70$^{o}$C on fullerene and carborane nanocar wheels. Raman spectroscopy is used to study the spinning and sliding behavior of the wheels on different surfaces through spectral analysis. Identifying the specific conditions that result in rotational or translational movement is important for the synthesis of future nanocars. Furthermore, characterizing the movement of nanocar wheels may have potential implications for self-assembling nanostructures, chemical catalysis and biomedical drug delivery.

# Temperature-Dependent Raman Spectroscopy of Fullerene Nanocar Wheels

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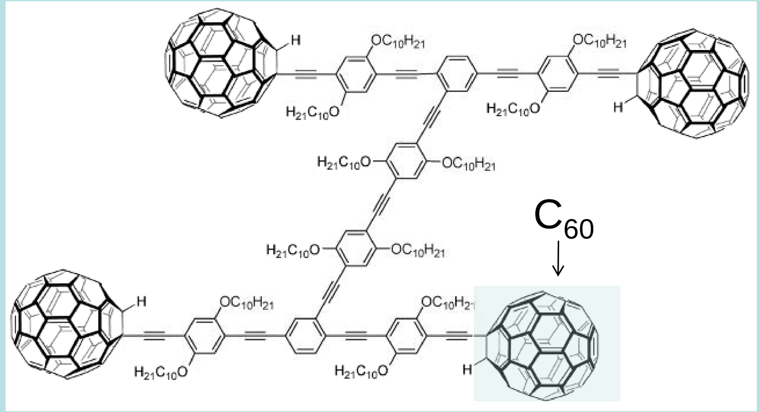
## Nanocars as Delivery Vehicles

Nanocars are a type of machine consisting of wheels, axles, and a chassis. The four fullerenes, which act as wheels, are attached at the corners of the H-shaped chassis.

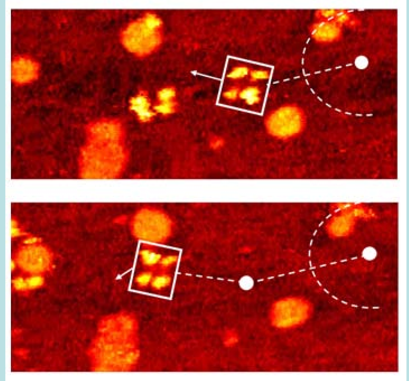
Both fullerenes and nanocar molecules have been shown to exhibit rotational movement under various temperatures.

We aim to characterize translational and rotational movement in nanocars, as well as the effects of temperature and substrate.

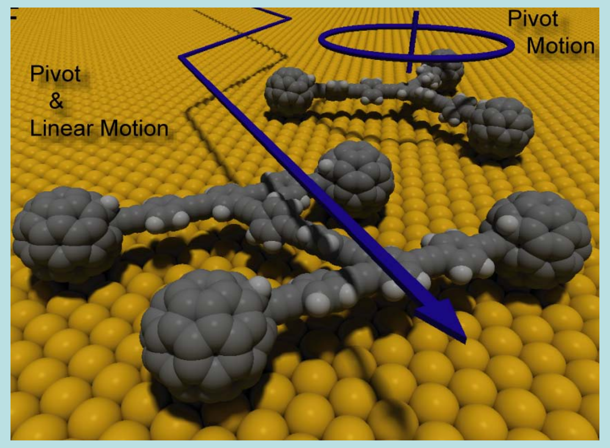
We want to lay the foundations for self-assembling nanostructures, chemical catalysis and biomedical drug delivery.




Molecular structure of a fullerene nanocar.



Scanning Tunneling Microscopy image of nanocar movement under temperature increase



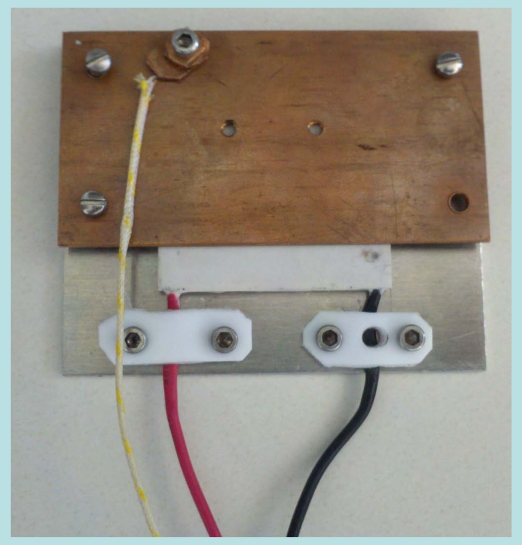

Axis of movement of the nanocar.

## Temperature Dependent Raman for Determining Rotation

**Variable Temperature Microscope Stage**
The thermoelectric effect turns a voltage drop into a temperature difference.

We can control the input voltage and current by using an external power supply.

A thermocouple attached to the surface of the heater mount is used to measure the device's temperature.

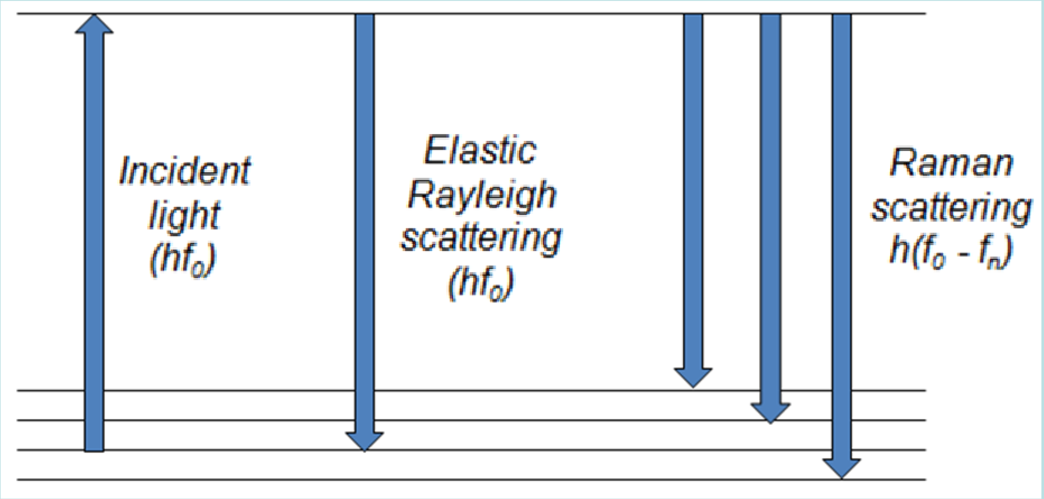


Stage used to control temperature. The red and black wires are connected to the power supply. The yellow wire is the thermocouple. The thermoelectric device is the white piece in the center.

**Raman Spectroscopy**
We want to characterize the vibrational and rotational modes in the sample.

Scanning Tunneling Microscopy established that the wheels rotate, but Raman will shed insight on rate.

We compare the $C_{60}$ and nanocar Raman spectra to determine how the molecular interactions are different.



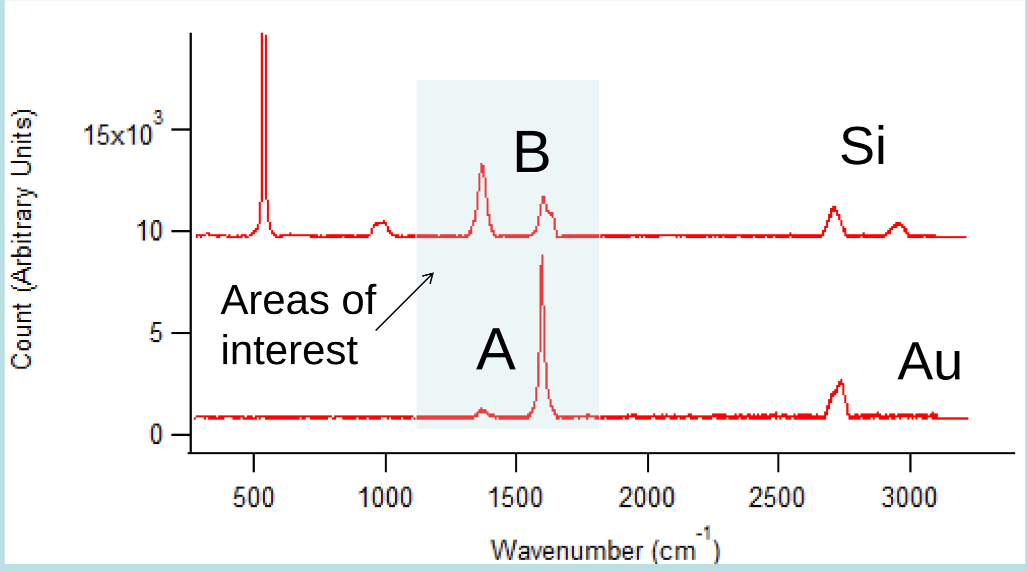

Raman Scattering is used to analyze the vibrational and rotational modes of the fullerenes and nanocars.

## Raman of $C_{60}$ and Nanocar Suggests Movement

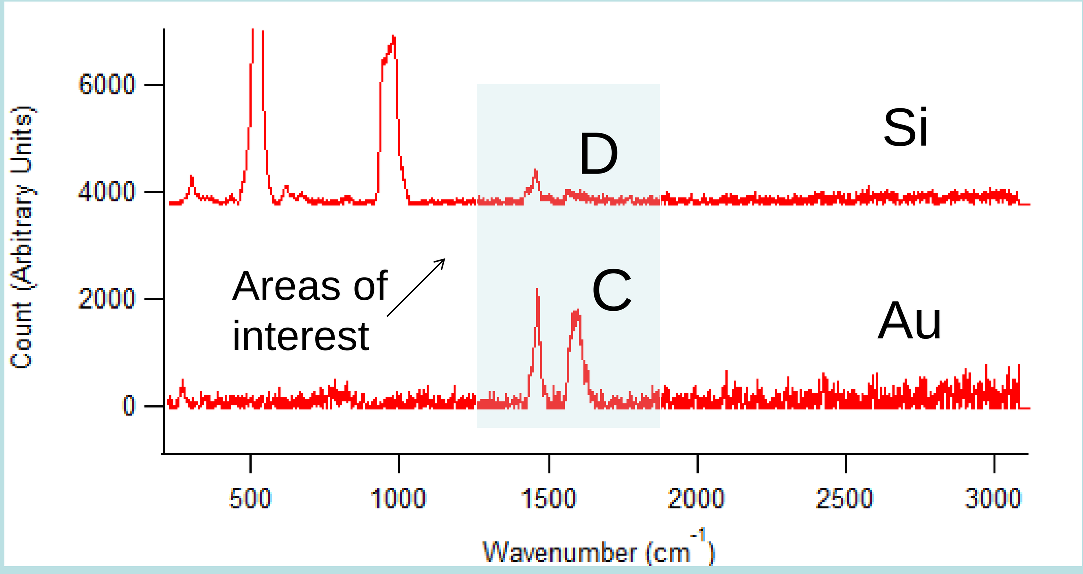
$C_{60}$ is a Van der Waals solid at room temperature, so it bonds by charge transfer which will hold it in place. This is no longer true when the temperature increases.

Exposure Time: 120 seconds
Laser Wavelength: 514.5 nm
Laser Power: 18 mW (100%)

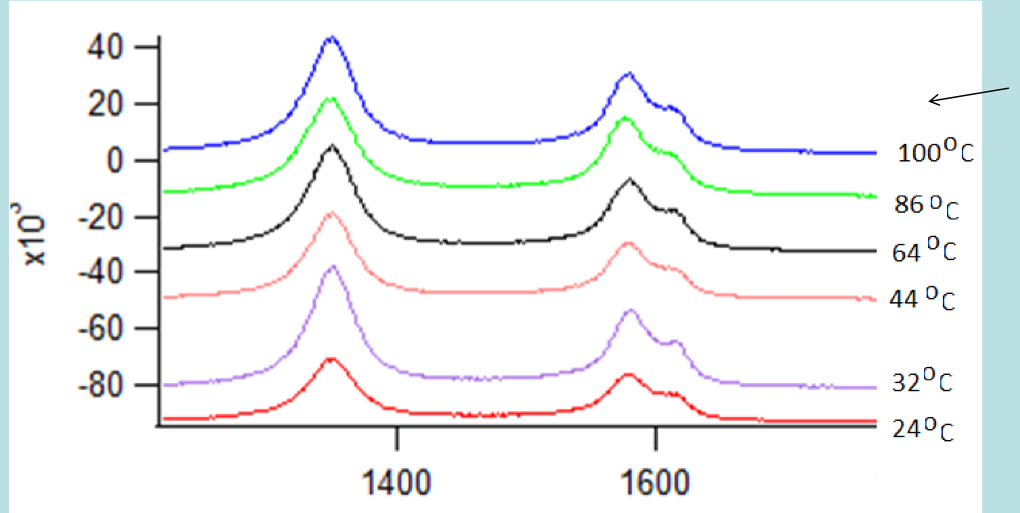
**Nanocar**



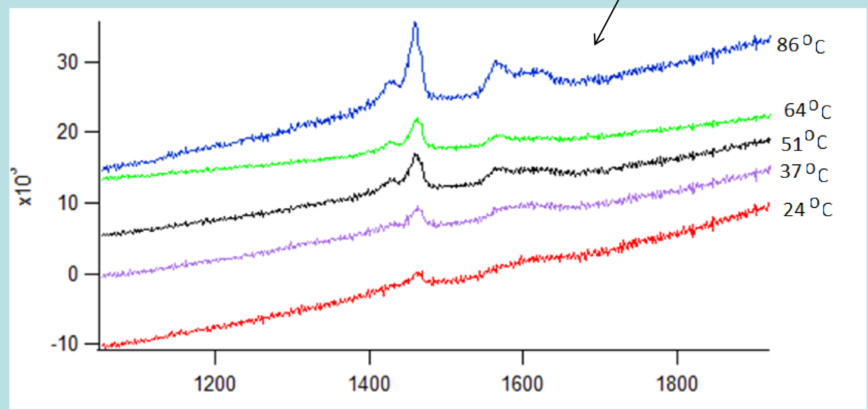

**$C_{60}$**




Primary peaks of interest are the Hg(7) and Hg(8) peaks located at 1425 and 1575 cm$^{-1}$, respectively.



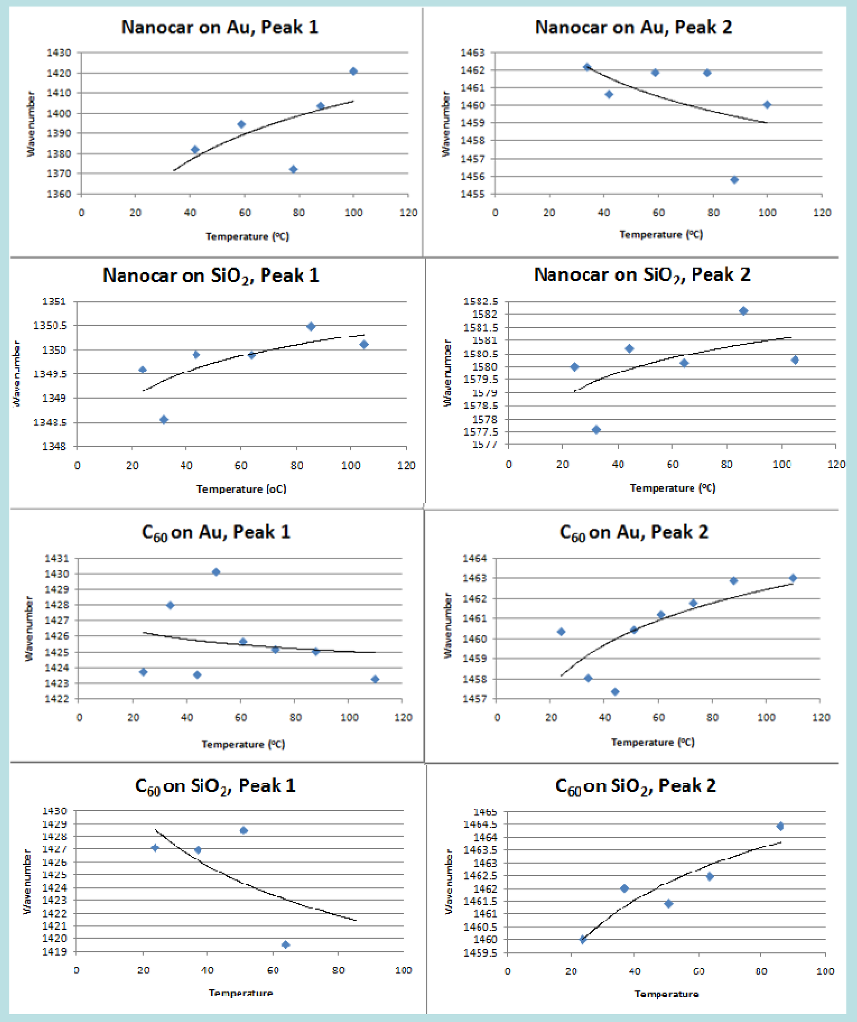

Nanocar on $SiO_2$ Spectra




$C_{60}$ on $SiO_2$ Spectra

Stacked spectra of peaks show the differences that arise due to changes in temperature.

A
B
C
D




Temperature dependent peak shifts of the nanocar/$C_{60}$ on Au/$SiO_2$

## Conclusion

We have successfully built a variable temperature microscope stage and used Raman spectroscopy to monitor the thermal activation of both $C_{60}$ and fullerene-wheeled nanocars on both gold and silicon dioxide surfaces.

The next step is to compare the energy shift in these vibrational modes with the temperature dependent tunneling microscopy measurements.

## References

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