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Title: Novel Carbon Materials for Electronic Devices Fabrication

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Intended for: Deliver talk, which is not related to my work or job in LANL.

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Novel Carbon Materials for Electronic Devices Fabrication

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Oct. 14th, 2015

Background

Carbon Materials

Advantages:

Chemical inertness,

Relatively wide potential window,

Cheap.

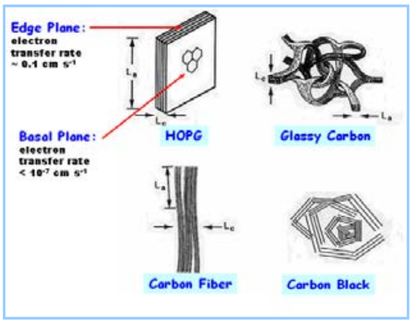
For examaple:

Edge plane pyrolytic graphite,

Basal plane pyrolytic graphite,

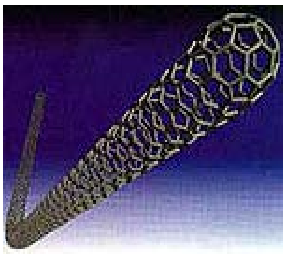
Carbon nanofibers,

Carbon nanotubes and etc..



R. L. McCreery, in *Electroanalytical Chemistry*, Ed. A. J. Bard, 17, 221-374 （1991）. *Nat. Mater.* 2007, 6, 183.

Carbon Nanotubes



Single-wall nanotubes （SWNTs）

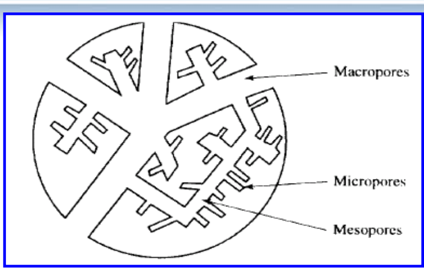
Diameter: 1-6 nm

Multi-wall nanotubes （MWNTs）

Diameter: from nm to μm

Carbon nanotubes have emerged as a new class of nanomaterials with their electronic, mechanical and chemical properties which have been claimed to be extremely attractive for use as chemical sensors, in particular *via* electrochemical detection.

Porous Carbon Materials

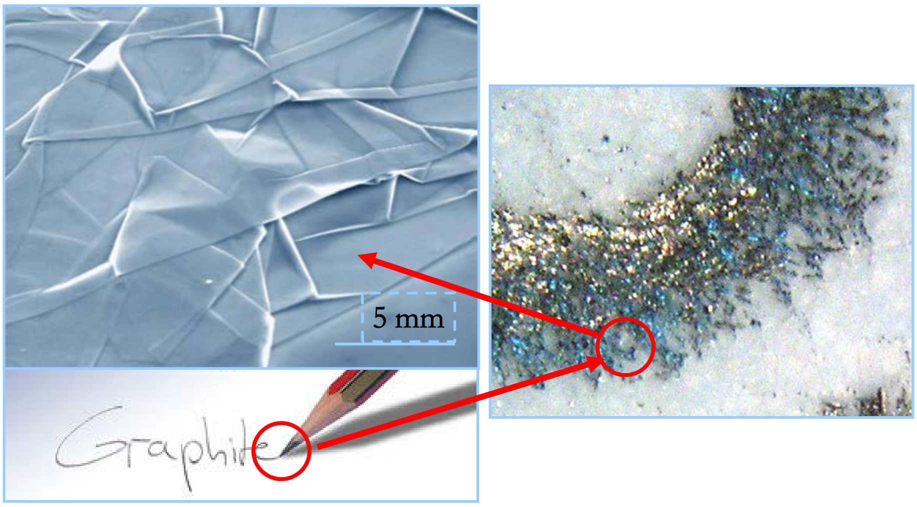


Porous Carbon Materials

- Microporous （<2 nm） → Microporous activated carbons
- Mesoporous （2-50 nm） → CMK-X, SNU-X
- Macroporous （>50 nm） → Coral

Adv. Mater. 2006, 18, 2073.

Graphene： Easy to make, Hard to find

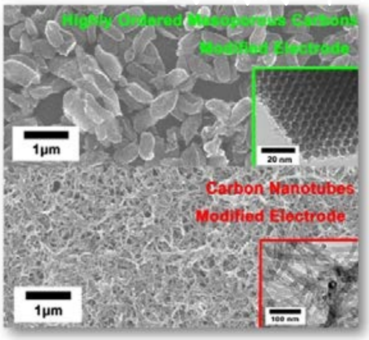


Research Ordered Mesoporous Carbons

1. **Ordered Mesoporous Carbons-based Electrochemical Sensor**

Ordered Mesoporous Carbons-based Electrochemical Sensor

Morphologies and Structures of OMCs and CNTs

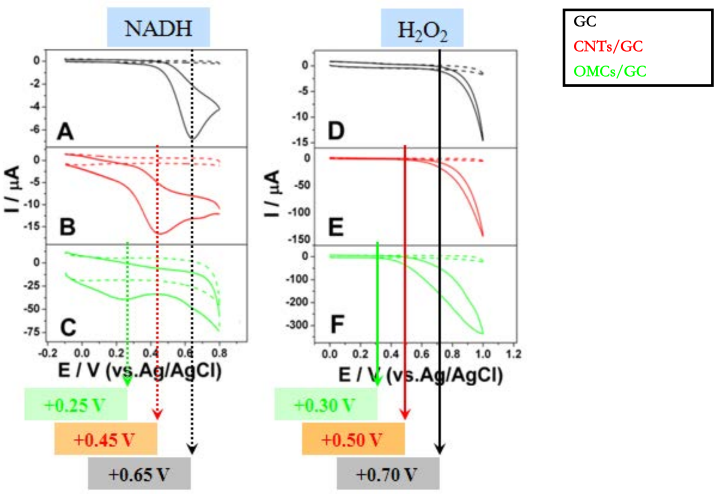


SEM image of OMCs/GE. Inset: TEM image of OMCs.

SEM image of CNTs/GC. Inset: TEM image of CNTs.

Zhou et al., *Biosens. Bioelectron.*, 2008, 24（3）: 442-447.
Zhou et al, *Electrochem. Commun.*, 2008, 10（6）: 859-863.

Electrochemical Oxidation of NADH and H_2O_2

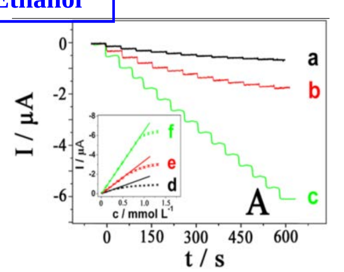


CVs for 2 mmol L^{-1} NADH and 4.2 mmol L^{-1} H_2O_2 in Electrolyte: 0.1 mol L^{-1} pH 7.0 PBS. Scan rate: 50 mV s^{-1}.

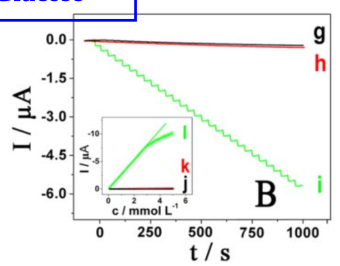
Detection of Ethanol and Glucose

GC-based, CNTs-based, OMCs-based electrode

Ethanol



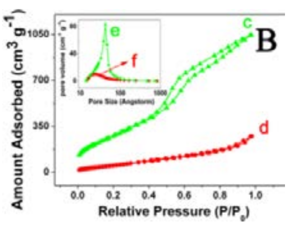
Glucose



(A) Current-time curves for Nafion/ADH/GE (at +0.65 V, curve a), Nafion/ADH-CNTs/GE (at +0.45 V, curve b) and Nafion/ADH-OMCs/GE (at +0.25 V, curve c) with successive addition of 1 mmol L^{-1} ethanol. Electrolyte: air-saturated 0.1 mol L^{-1} pH 7.0 PBS without being purged by nitrogen.

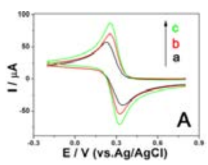
(B) Current-time curves for Nafion/GOD/GE (curve g), Nafion/GOD-CNTs/GE (curve h) and Nafion/GOD-OMCs/GE (curve i) at +0.35 V with successive addition of 1 mmol L^{-1} glucose. Electrolyte: 0.1 mol L^{-1} pH 7.0 PBS containing 10 mmol L^{-1} NAD^+.

Nitrogen Adsorption-Desorption Isotherms and Electrochemical characteristics



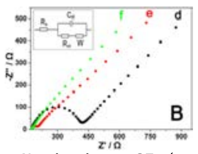
	BET surface areas (cm^2 g^{-1})	pore volumes (cm^3 g^{-1})	pore sizes (nm)
OMCs	1038	1.66	4.3
CNTs	203	0.43	2.1

Nitrogen adsorption-desorption isotherms for OMCs (curve c) and CNTs (curve d). Inset: the pore size distributions for OMCs (curve e) and CNTs (curve f).



	A	ΔE_p
OMCs/GC	0.118 cm^2	51 mV
CNTs/GC	0.090 cm^2	56 mV
GC	0.068 cm^2	60 mV

Background-corrected CVs at GE (curve a), CNT/GE (curve b) and OMC/GE (curve c) in 5 mmol L^{-1} $K_3Fe(CN)_6$/0.1 mol L^{-1} KCl solution with the scan rate of 50 mV s^{-1}.

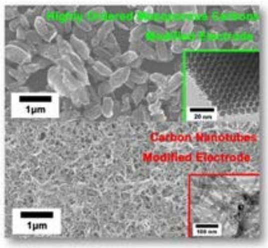


		R_{ct}
d	GC	213.6 Ω
e	CNTs/GC	95.2 Ω
f	OMCs/GC	13.2 Ω

R_{ct}: the resistance to charge transfer,
C_{dl}: the interfacial capacitance,
W: the diffusion impedance,

Nyquist plots at GE (curve d), CNTs/GE (curve e) and OMCs/GE (curve f) in 5 mmol L^{-1} $Fe(CN)_6^{3-/4-}$ containing 0.1 mol L^{-1} KCl.

Summary



We present an advanced electrochemical sensing and biosensing platform based on OMCs without purification or end-opening processing, which are usually in CNTs applications.

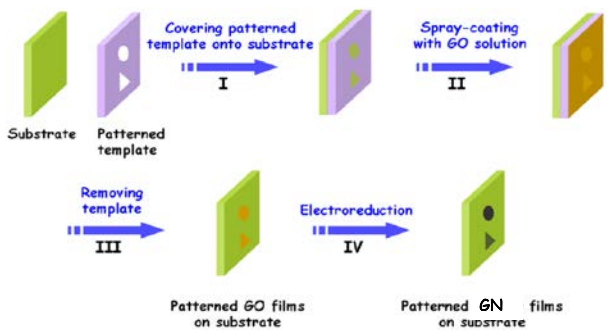
Zhou et al., *Biosens. Bioelectron.*, 2008, 24（3）: 442-447.
Zhou et al, *Electrochem. Commun.*, 2008, 10（6）: 859-863.

Research II Graphene

1. Controlled Synthesis of Large-Area and Patterned Graphene Films by Electroreduction
2. Electrochemical Sensing and Biosensing Platform Based on Graphene

1 Controlled Synthesis of Large-Area and Patterned Graphene Films

Scheme

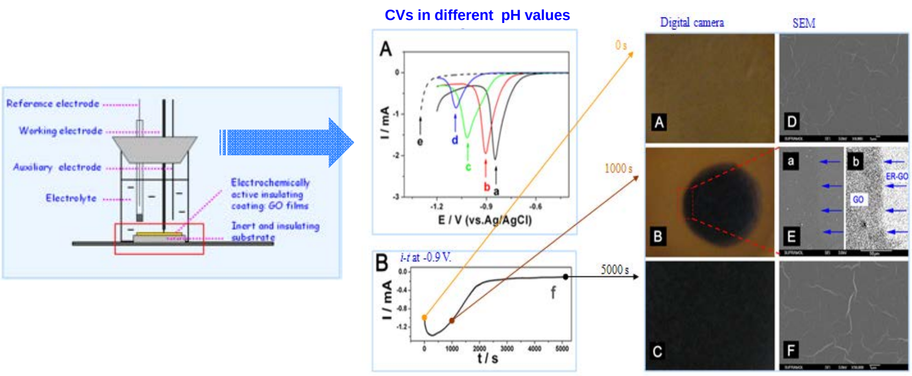


Substrate:
Insulator
Conductor

Zhou et al., *Chem. Eur. J.*, 2009 （15）: 6116-6120.

Electroreduction of GO films on Insulating Substrate

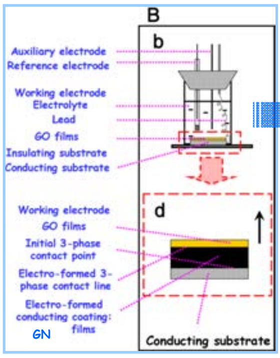
On quartz substrate

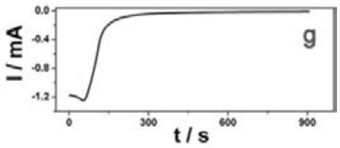


GO + aH^+ + be^- → GN

Fabricating Graphene Films on Conducting Substrate

On glassy carbon substrate

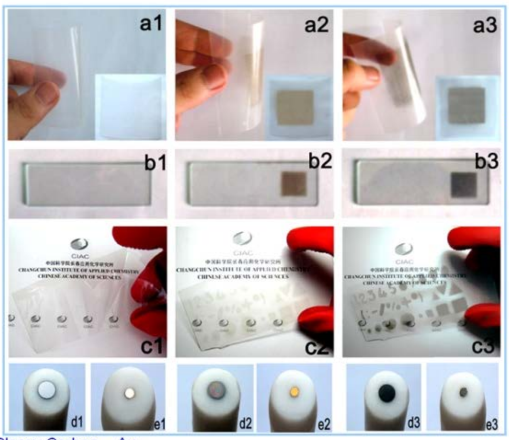




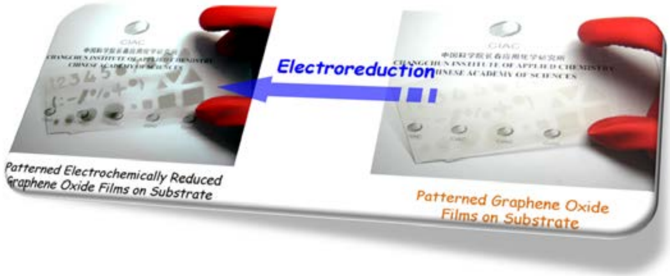
Sample	O/C ratio (%)	
	Surface [a]	Bulk [b]
GO films	69.2	68.6
GN films	4.11	4.02

[a], determined by XPS. [b], determined by elemental analysis.

Large-Area and Patterned Graphene Films



Conclusion

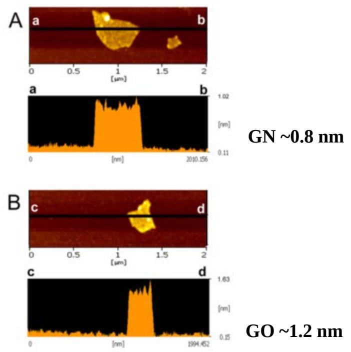


A simple, low-cost, efficient, green and environment-friendly electrochemical method has been demonstrated to fabricate graphene films.

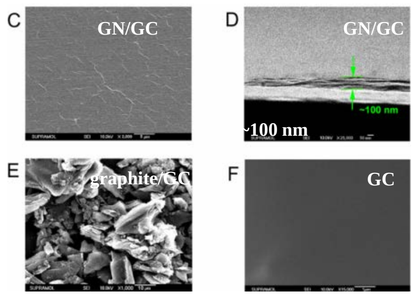
Zhou et al., *Chem. Eur. J.*, 2009 （15）: 6116-6120.
Times Cited: 104

2 Electrochemical Sensing and Biosensing Platform Based on Graphene

Morphologies and Structures of GN and Gaphhite



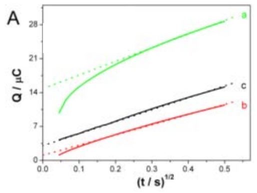
Tapping mode AFM images of GN (A) and GO (B) on freshly cleaved mica substrates.



SEM images of CR-GO/GC (C and D), graphite/GC (E) and GC (F). D is the side-view SEM image of CR-GO/GC.

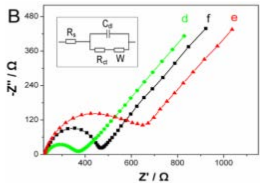
Zhou et al., *Anal. Chem.*, 2009 （81）: 5603-5613.

Electrochemistry



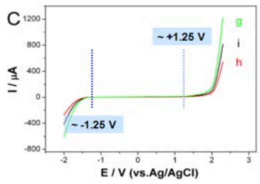
(A) Chronocoulometric curves at CR-GO/GC (a), graphite/GC (b) and GC electrodes (c) for the reduction of 1 mM K3Fe(CN)6 with 2 M KCl. The initial potential was 0.65 V and the potential was stepped to -0.05 V.

	A
GN/GC	**0.0920cm^2**
GC	**0.0706 cm^2**
graphite/GC	**0.0560 cm^2**



(B) Nyquist plots at CR-GO/GC (d), graphite/GC (e) and GC (f) in 5 mM $Fe(CN)_6^{3-/4-}$ containing 0.1 M KCl.

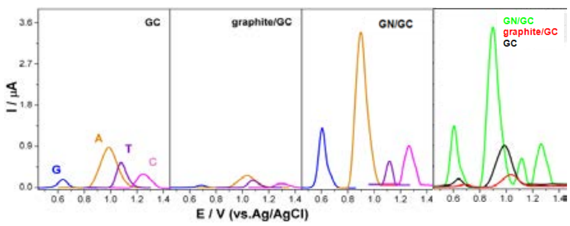
	R_{ct}
GN/GC	106.8 Ω
GC	200.7 Ω
graphite/GC	407.6 Ω



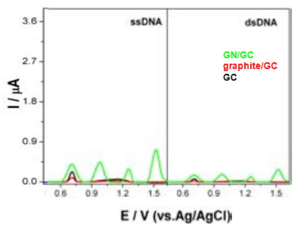
(C) LSVs of CR-GO/GC (g), graphite/GC (h) and GC (i) in 0.1 M pH 7.0 PBS. Scan rate: 50 mV s^{-1}.

~2.50 V

Detection of Four Free DNA Bases and DNA at Physiological pH

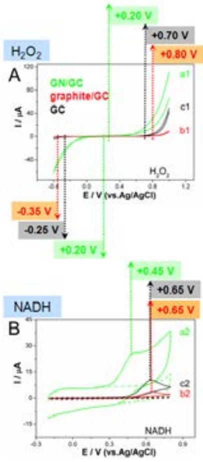


Electrolyte: 0.1 M pH 7.0 PBS.
Concentrations for different species (A-D): G, A, T or C: 10 μg mL-1.

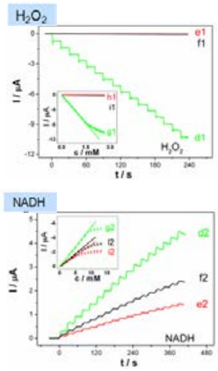


Concentrations for different species for ssDNA and dsDNA: 10 μg mL^{-1} ssDNA. Electrolyte: 0.1 M pH 7.0 PBS.

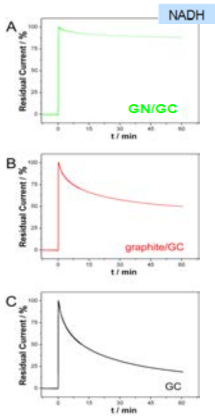
For the Detection of NADH and H_2O_2



Background-subtracted CVs for 4.2 M H_2O_2 (A) and CVs for2 M NADH (B) in Electrolyte: 0.1 M pH 7.0 PBS. Scan rate: 50 mV s-1.



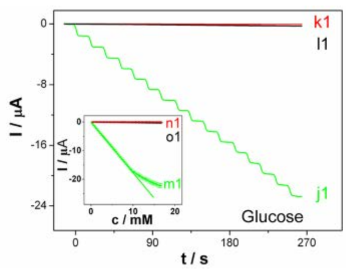
(Left) Current-time curves for GN/GC (d1), graphite/GC (e1) and GC (f1) at -0.20 V with successive addition of 0.1 mM H2O2. Inset: calibration curves.
(Right) Current-time curves for GN/GC (at +0.45 V, d2), graphite/GC (at +0.65 V, e2) and GC (at +0.65 V, f2) with successive addition of 0.1 mM NADH. Inset: calibration curves. Electrolyte: magnetically stirred 0.1 M pH 7.0 PBS.

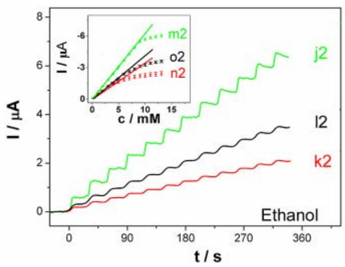


Stability of the response to 0.4 mM NADH using GN/GC (A, with the applied potential of 0.45 V), GT/GC (B, at 0.65 V) and GC electrodes (C, at 0.65 V). Electrolyte: magnetically stirred 0.1 M pH 7.0 PBS.

For the Detection of Glucose and Ethanol

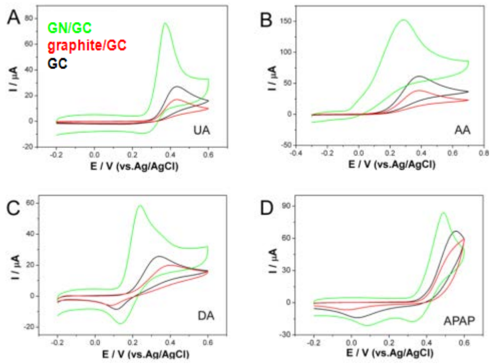
GC-based, graphite-based, GN-based bioelectrodes





(Left) Current-time curves for GOD/GN/GC (j1), GOD/graphite/GC (k1) and GOD /GC (l1) at -0.20 V with successive addition of 1 mM glucose. Inset: calibration curves. Electrolyte: air-saturated and magnetically stirred 0.1 M pH 7.0 PBS without being purged by nitrogen.
(Right) Current-time curves for ADH/GN/GC (at +0.45 V, j2), ADH/graphite/GC (at +0.65 V, k2) and ADH/graphite/GC (at +0.65 V, l2) with successive addition of 1 mM ethanol. Inset: calibration curves. Electrolyte: magnetically stirred 0.1 M pH 7.0 PBS containing 10 mM NAD^+.

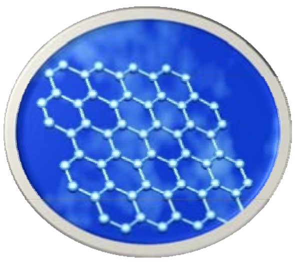
Other Important Biomolecules



CVs for 3 mM UA, AA, DA and APAP in 0.1 M pH 7.0 PBS.
Scan rate: 50 mV s^{-1}.

UA： uric acid
AA： ascorbic acid
DA： dopamine
APAP： acetaminophen

Conclusion



GN showing favorable electrochemical activity should be extremely attractive for a wide range of electrochemical sensing and biosensing applications ranging from amperometric sensors, to amperometric enzyme biosensors and label-free DNA biosensors.

Zhou et al., *Anal. Chem.*, 2009 （81）: 5603-5613.
Times Cited: 727

Highlight

SELECT WHAT'S HOT IN CHEMISTRY PAPERS

What's Hot in Chemistry

Rank	Paper	Cites This Period May-Jun 11	Rank Last Period Mar-Apr 11
	Stovring, Denmark] *663GP		
8	J.F. Li, *et al.*, **"Shell-isolated nanoparticle-enhanced Raman spectroscopy,"** *Nature*, 464(7287): 392-5, 18 March 2010. [Xiamen U., China; Georgia Tech, Atlanta] *570EG	22	9
9	M. Zhou, Y. Zhai, S. Dong, **"Electrochemical sensing and biosensing platform based on chemically reduced graphene oxide,"** *Anal. Chem.*, 81(14): 5603-13, 15 July 2009. [Chinese Acad. Sci., Changchun, China] *472MF	21	†
10	B. Walker, *et al.*, **"Nanoscale phase separation and high photovoltaic efficiency in solution-processed, small-molecule bulk heterojunction solar cells,"** *Adv. Funct. Mater.*, 19(19): 3063-9, 9 October 2009. [U. Calif., Santa Barbara] *510ZJ	21	†

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Prof. Bo Zhang in UW

Los Alamos National Laboratory

Dr. Hsing-Lin Wang in LANL

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