

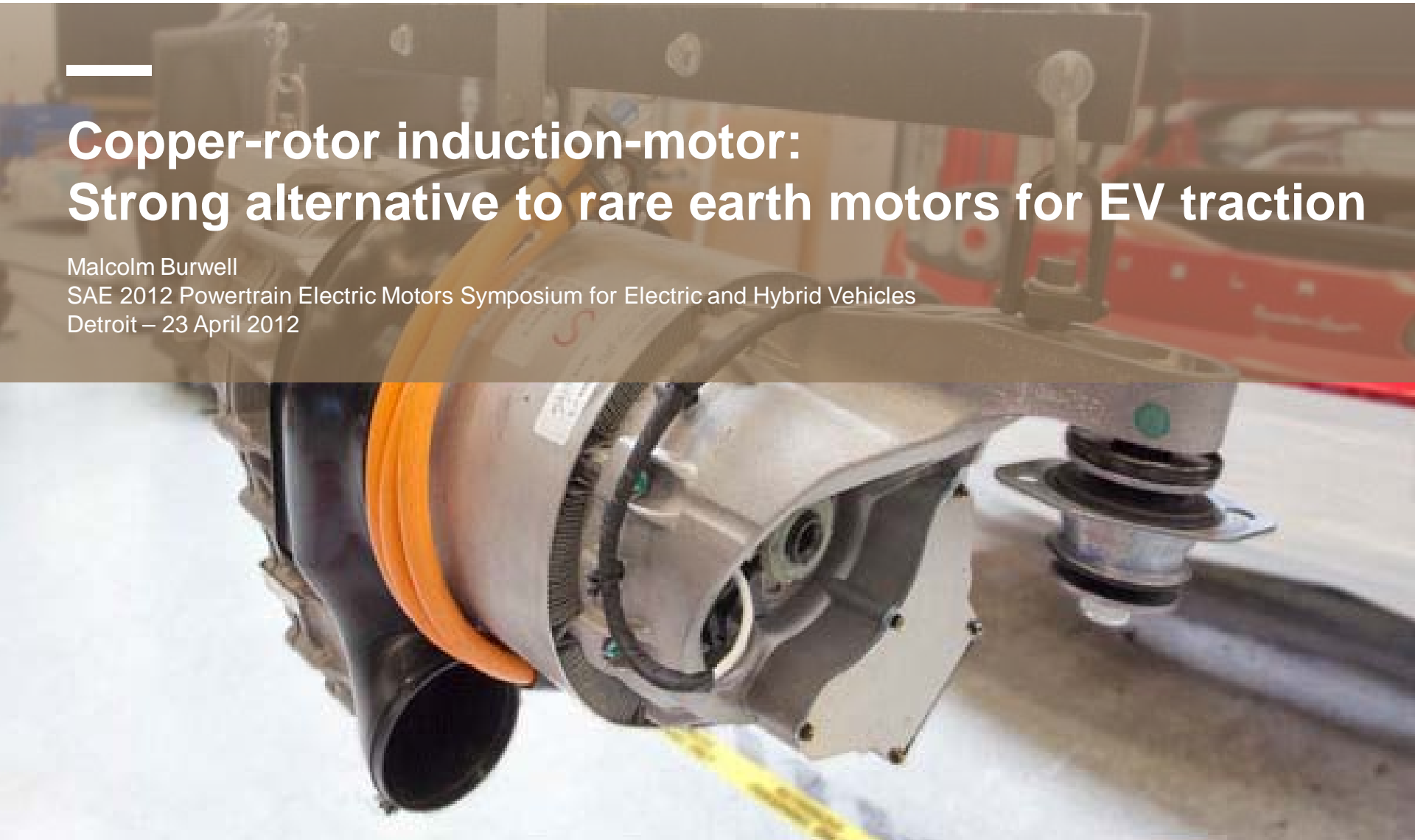


**International Copper  
Association**  
Copper Alliance

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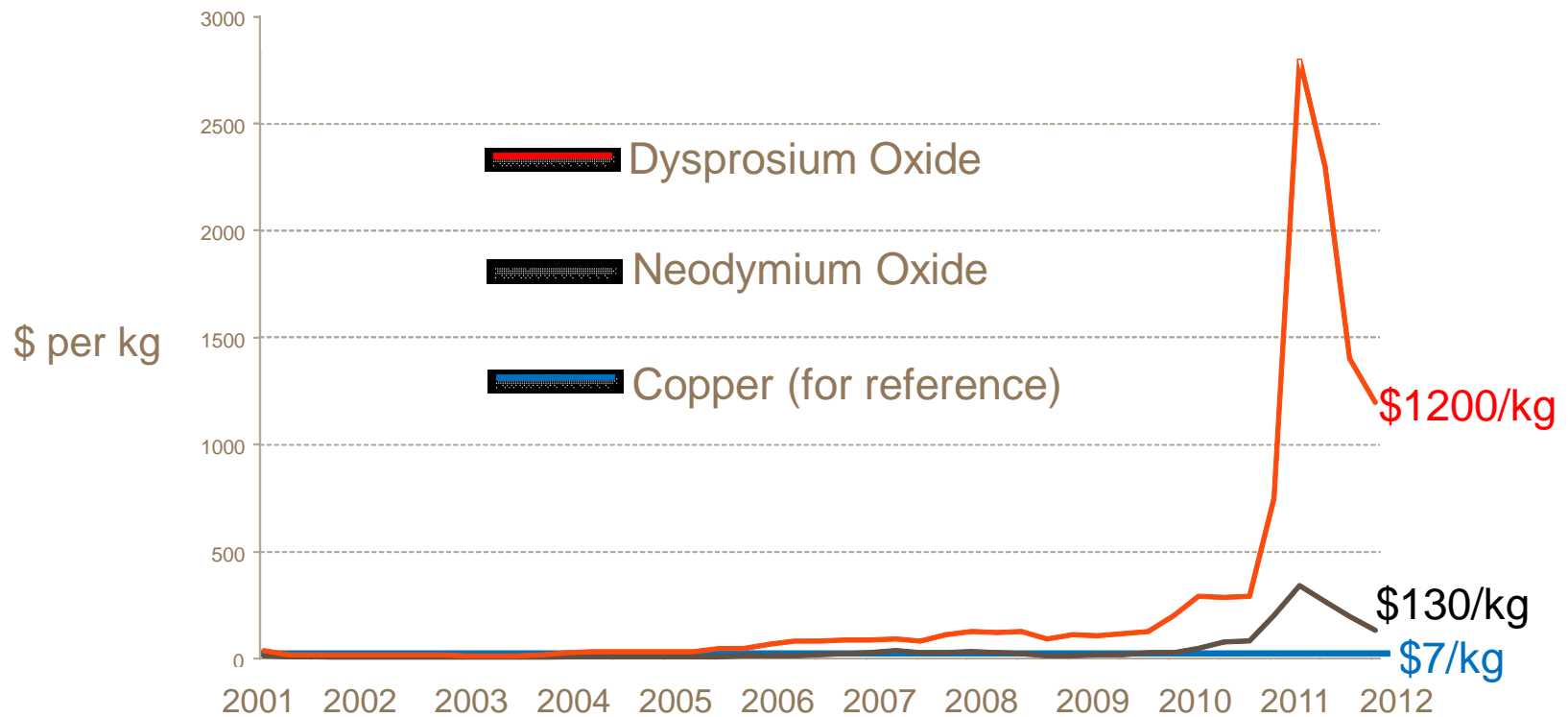
# Copper-rotor induction-motor: Strong alternative to rare earth motors for EV traction

Malcolm Burwell  
SAE 2012 Powertrain Electric Motors Symposium for Electric and Hybrid Vehicles  
Detroit – 23 April 2012



# The challenge for electric traction motors: Rare earth cost-levels and cost-volatility

Cu



Source: metal-pages.com, Kidela Capital

# Copper rotor induction motor history

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## Vehicles with copper rotors



1990

2000

2005

2010

2012

2013

Rotor manufacturing

Die-casting of copper rotors

Fabrication of copper rotors

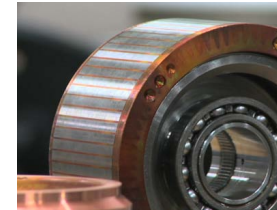
Tier-1 suppliers

# Performance/cost analysis: Two similar HEV motors

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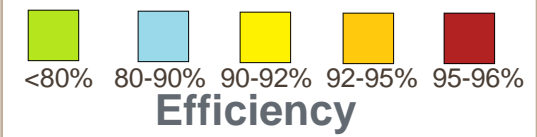
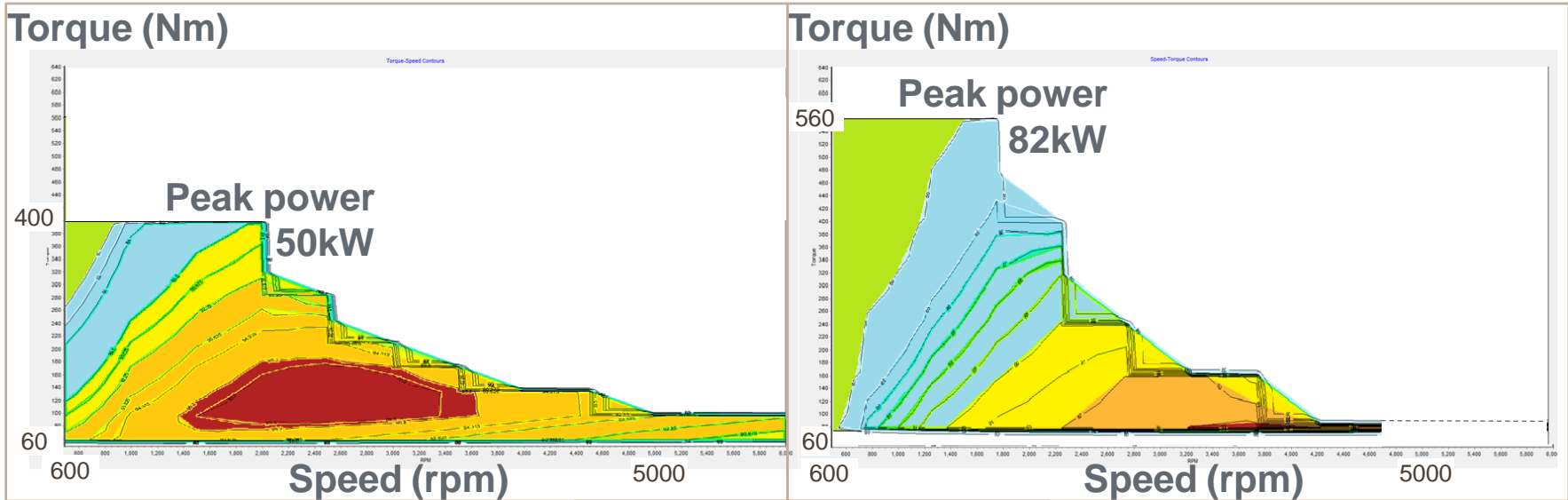
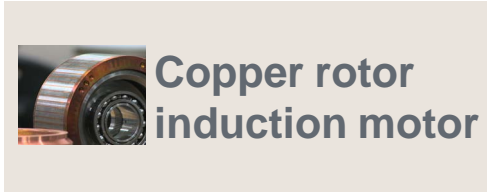
**Toyota Prius with  
THS II (PM) motor**



	<b>Permanent Magnet Motor</b>	<b>Copper Rotor Induction Motor</b>
<b>Outer stator diameter</b>	<b>269mm</b>	<b>269mm</b>
<b>Outer rotor diameter</b>	<b>161mm</b>	<b>180mm</b>
<b>Axial core length</b>	<b>84mm</b>	<b>84mm</b>
<b>Active material weight</b>	<b>30kg</b>	<b>35kg</b>
<b>RMS line voltage @ 6000rpm</b>	<b>544V</b>	<b>600V</b>

*Comparison of Different Motor Design  
Drives for Hybrid Electric Vehicles  
Motor Design Ltd. – 2011 – Popescu et al*

# Performance/cost analysis: The two HEV motors perform similarly

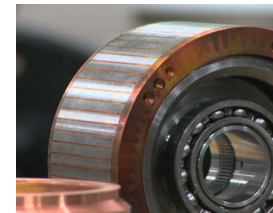


*Comparison of Different Motor Design Drives for Hybrid Electric Vehicles  
Motor Design Ltd. – 2011 – Popescu et al*

# Performance/cost analysis: The permanent magnet motor costs more

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Cost of active materials (magnets, copper, iron) in each HEV motor

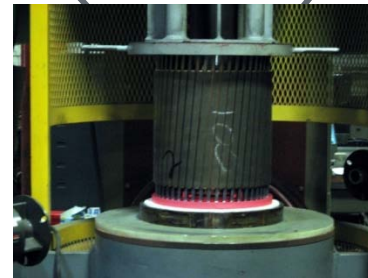
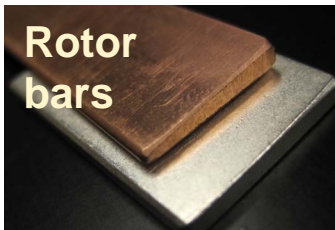
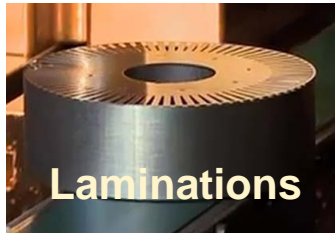


	Permanent magnet motor (Prius THS II)	Copper rotor induction motor
2008	\$242	\$129
2012	\$763	\$146

*Comparison of Different Motor Design  
Drives for Hybrid Electric Vehicles  
Motor Design Ltd. – 2011 – Popescu et al  
2012 updates from metal-pages.com*

# Manufacturing – fabricated rotor

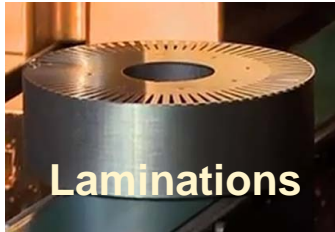
Cu



**Components - Assemble - Induction braze - Bead blast - Balance**

# Manufacturing – die cast rotor

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Components

-

Die cast

-

Quench

-

Balance



# Today's supply chain resources

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Advice and  
Introductions

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International Copper  
Association  
Copper Alliance

Outsourced  
Motor Design

MIT (US)  
Motor-Design (UK)  
WEMPEC (US)

Rotor  
Casting

Akashi (JP)  
Vforge (US)  
Favi (FR)  
Kienle + Spiess (DE)  
THT (US)  
Yunnan Copper Die-  
casting (CN)

EV Motor Manufacturing

AC Propulsion (US)  
Tesla Motors (US)  
Hyosung (KR)  
Yulon (TW)

Remy (US)  
Fukuta (TW)

Ramco (US)

Rotor Fabrication

# Copper rotor induction motor video: Comments from today's suppliers

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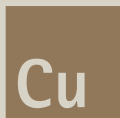


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# Copper-rotor induction-motors: Strong alternative to rare earth motors for EV traction

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To view the video of industry comments on the copper rotor induction motor go to:  
[www.copperalliance.org/motor](http://www.copperalliance.org/motor)



International Copper  
Association  
Copper Alliance