导热绝缘电子封装材料研究新进展

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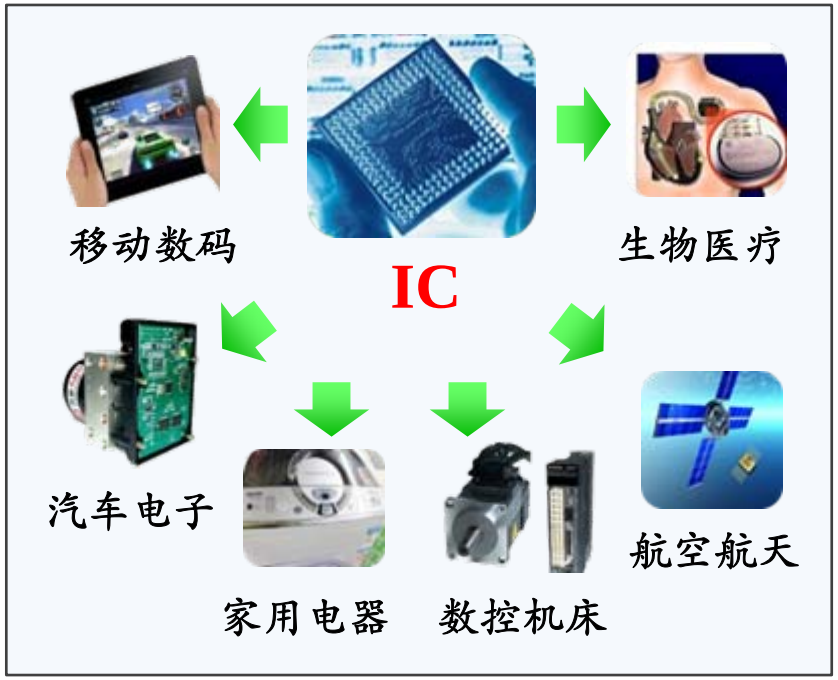
2013-5-8重庆

研究背景

微电子是世界支柱产业，集成电路 (IC)芯片是基石

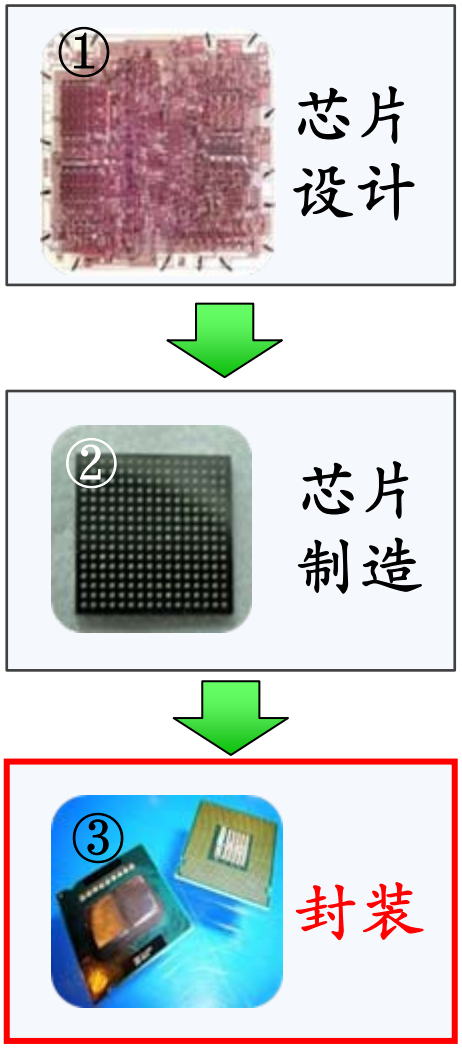


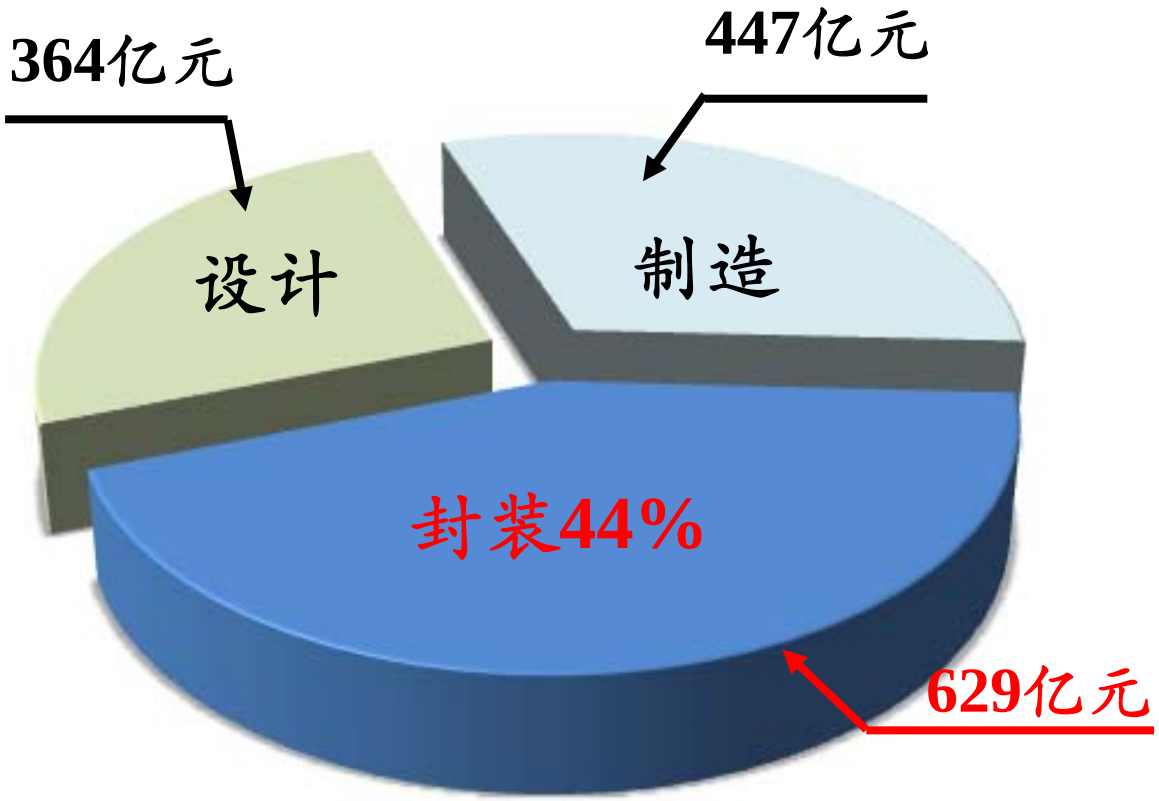
IC的广泛应用

2010年我国进口数据

IC芯片是我国进口金额最大的单宗商品

电子封装是IC产业链的关键环节，占IC产业总值的44%

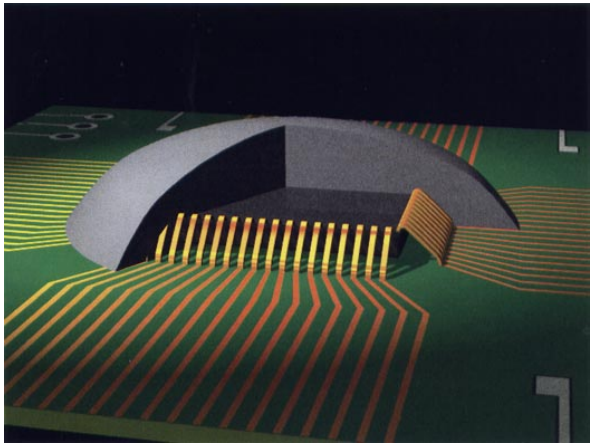


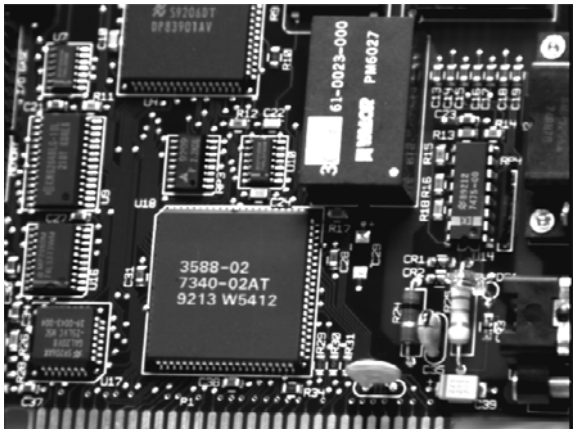


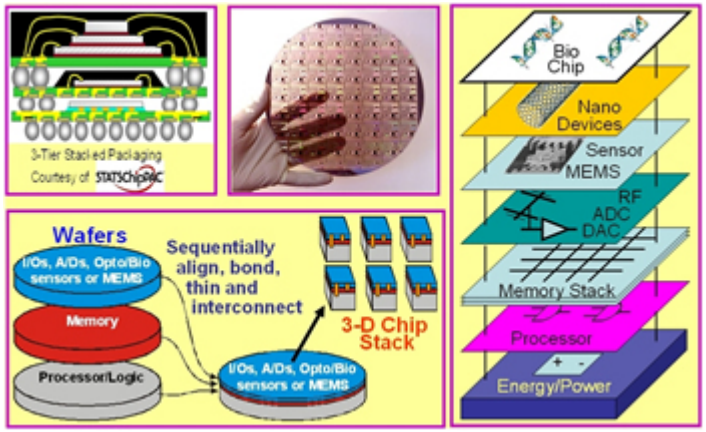
数据来源：中国IC产业报告

2010年我国IC产业链产值构成

电子封装





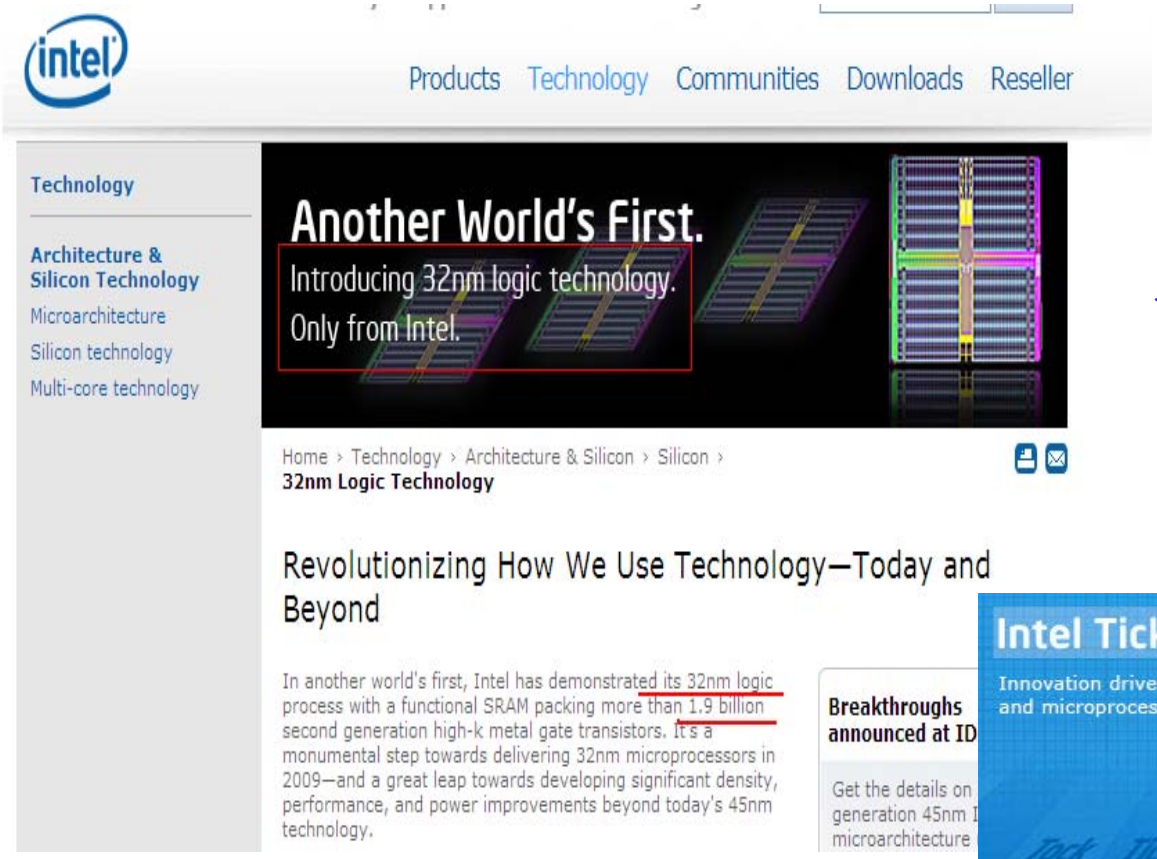


- 提供信号输入、输出通路；
- 提供热扩散通路
- 提供电流通路
- 提供机械支撑和环境保护

Deborah D.L.Chung. Materials for Electronic Packaging. Elsevier, Newton,USA,1995

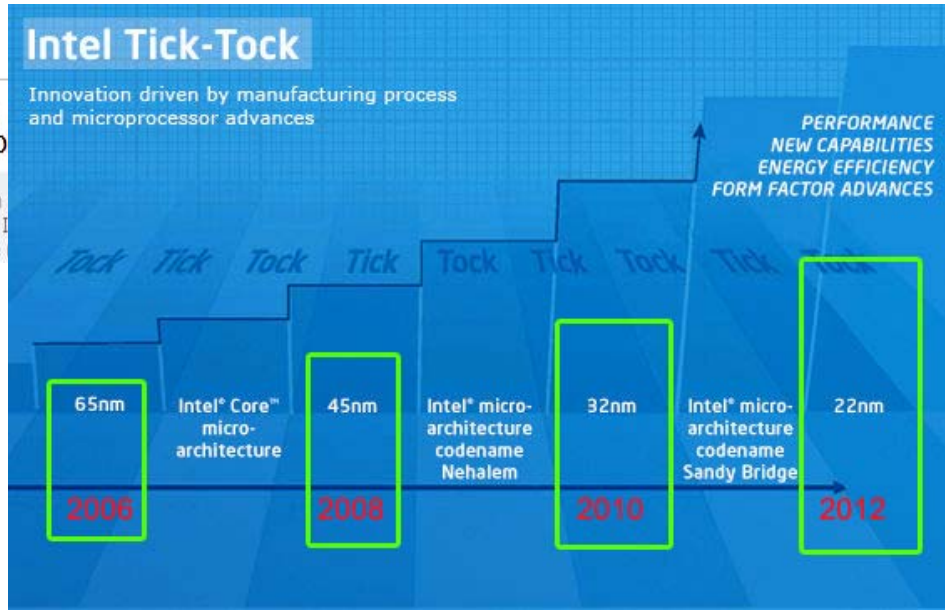
电子封装是把电子元器件或集成电路各部件按要求合理布置、组装、键合、连接起来的操作过程, 防止水分、尘埃及有害气体对器件、电路的影响。

电子封装热管理



2010年

Intel新一代32nm制程
六核CPU 具有19亿个晶体管

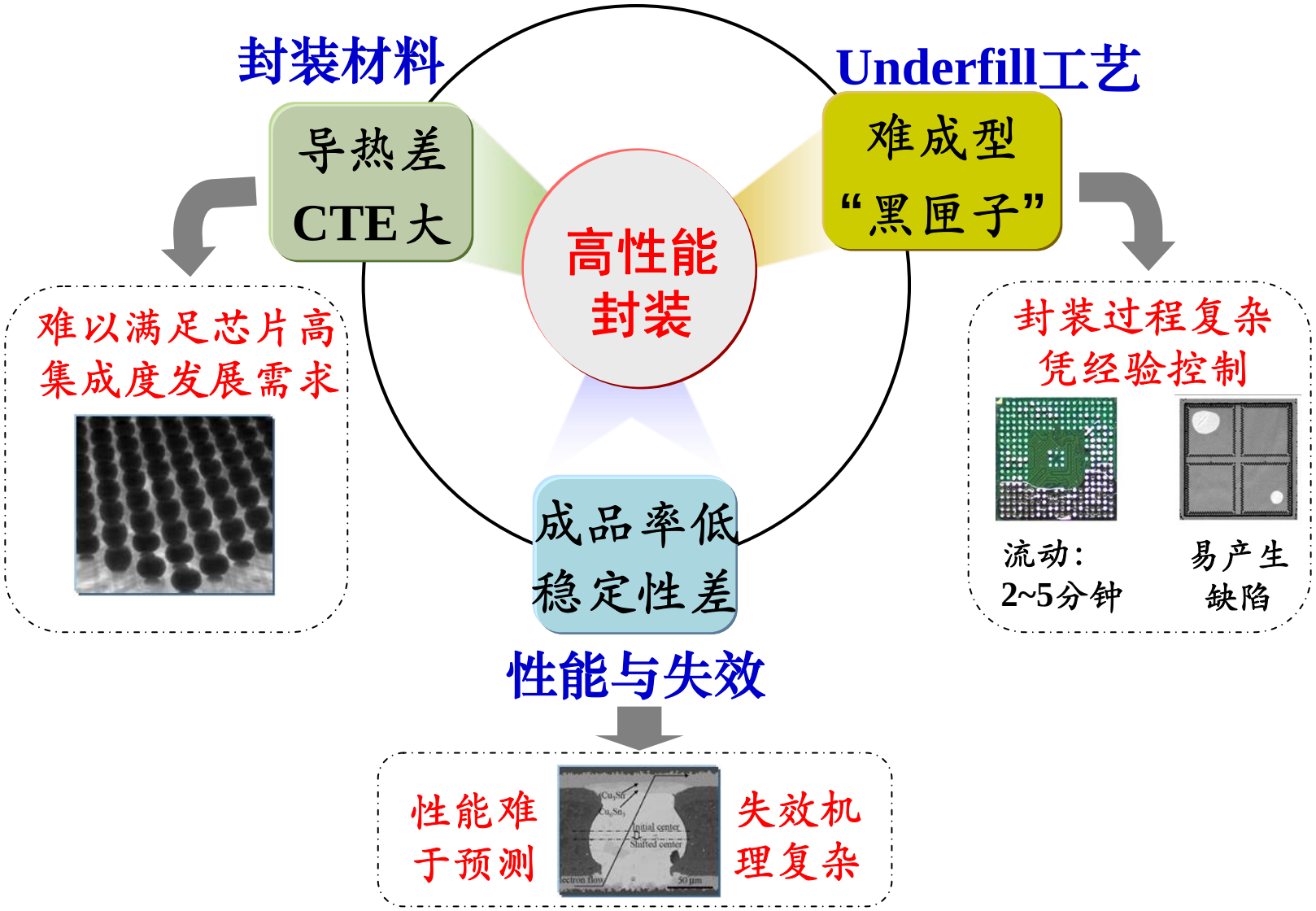


热扩散问题!!

制约电子封装领域的瓶颈问题

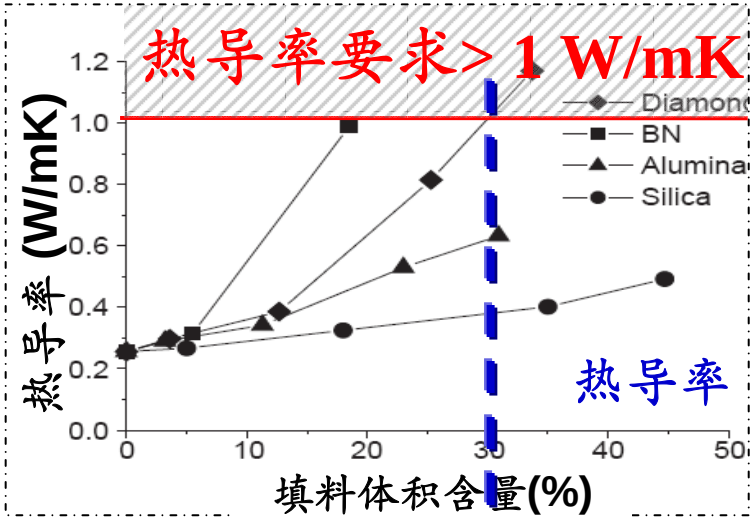
www.intel.com

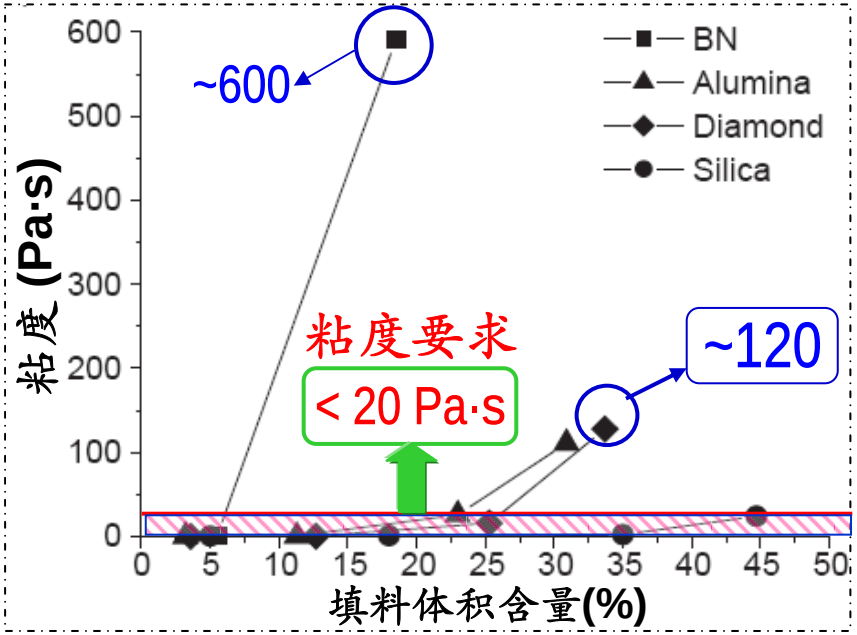
电子封装难题

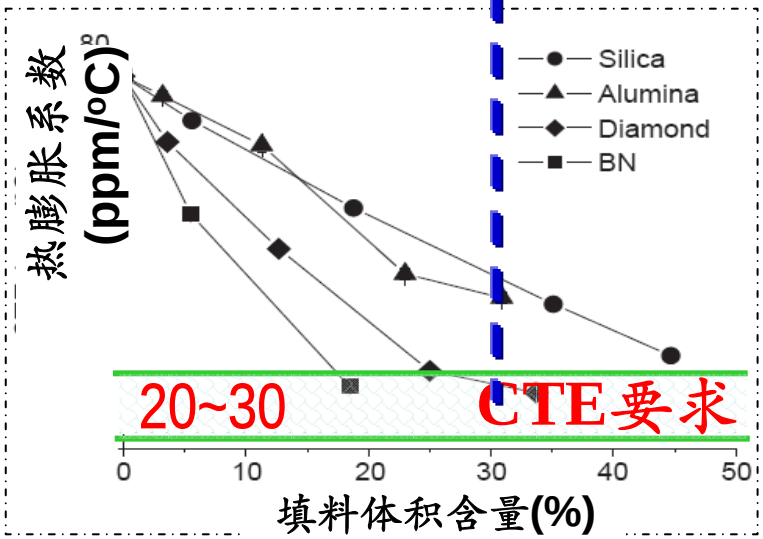

封装材料
导热差
CTE大
Underfill工艺
难成型
“黑匣子”
高性能
封装
难以满足芯片高
集成度发展需求
封装过程复杂
凭经验控制
流动：
2~5分钟
易产生
缺陷
成品率低
稳定性差
性能与失效
性能难
于预测
失效机
理复杂
Initial center
Shifted center
50 μm

环氧封装材料研究现状

添加导热无机填料是常用方法







高填充量导致体系粘度高，不能满足Underfill封装工艺

Diamond Relat Mater 14 (2005) 1647

填料热学性质

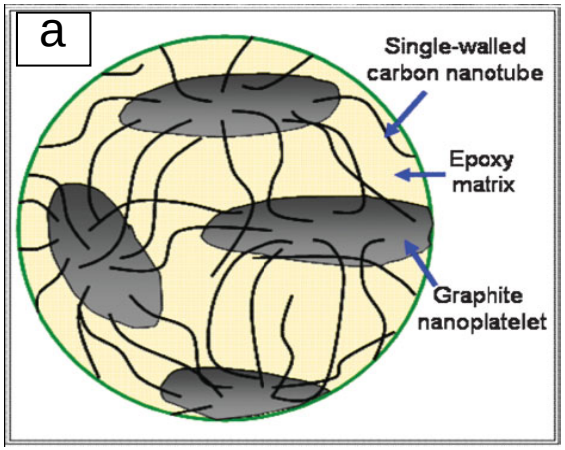
材料	热导率 W/m K	CTE ppm/°C
环氧	0.14	75.2
SiO_2	1.5	0.5
Al_2O_3	36	6.6
BN	250~300	<0.5
碳纳米管	> 3000	→0
石墨烯	> 4800	→0

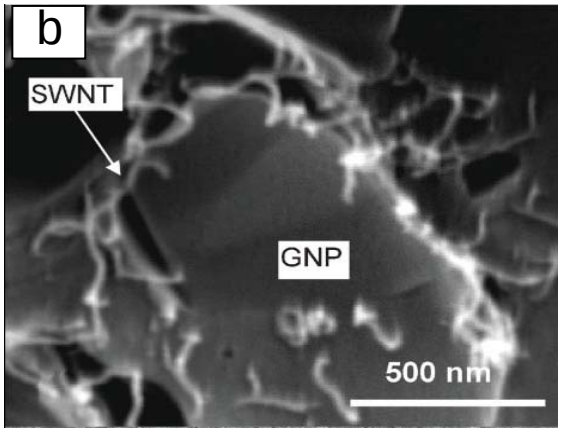
存在的问题

- 填料导电
- 复合体系粘度高
- 复合界面热阻大

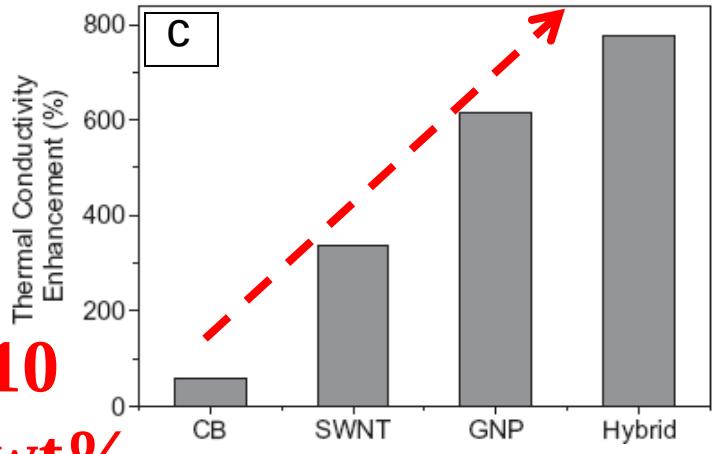
理想的电子封装用导热填料

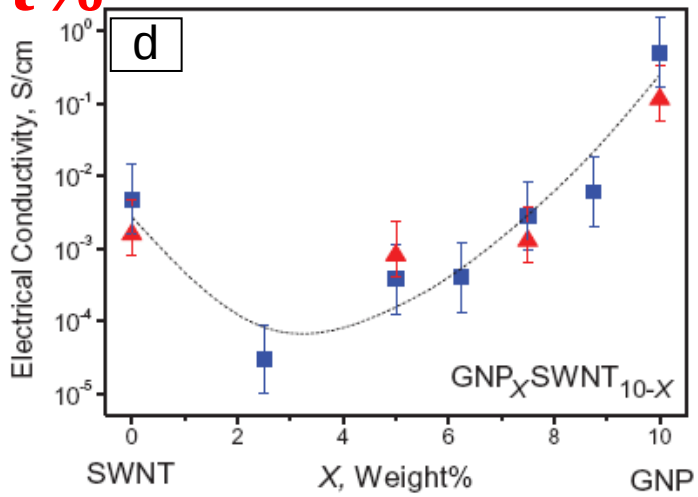
添加碳管或石墨烯等方法





10 wt%

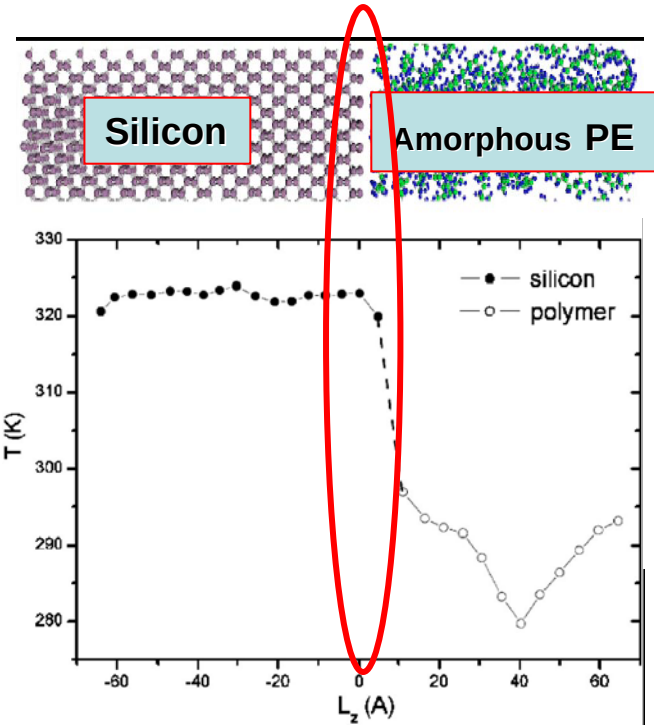




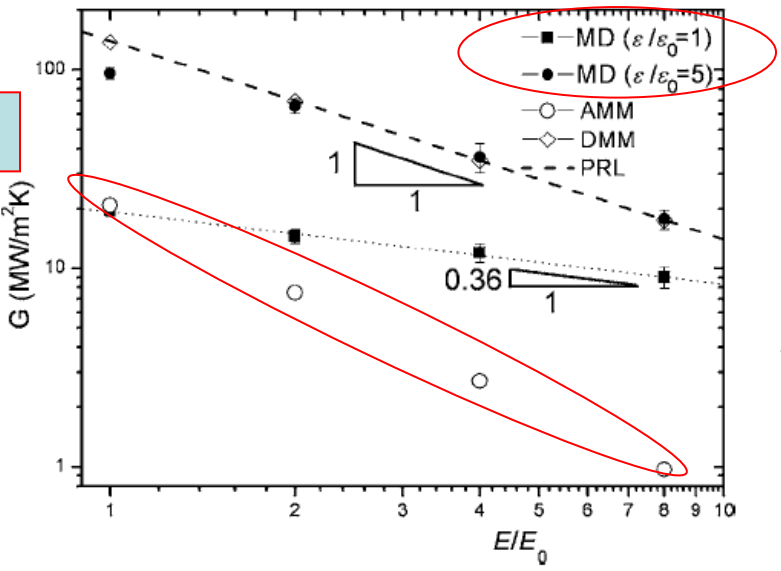
导热大幅增加
但绝缘性破坏

Advanced Materials, 2008, 20, 4740.

热界面热阻

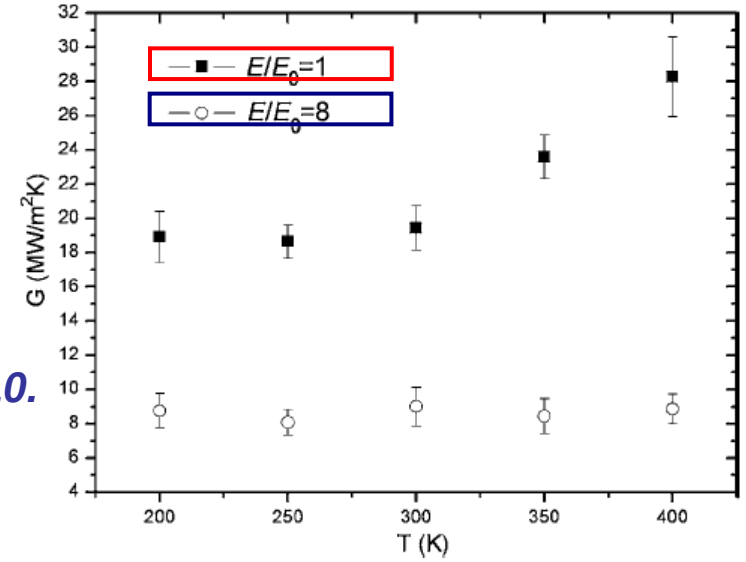


热界面热阻使得温度不连续



单晶硅/聚乙烯界面热导随硅模量**E**及单晶硅与聚乙烯间相互作用力 ε 的变化关系，E_0为硅的基准模量，ε_0为基准范德华力

Bonding Strength



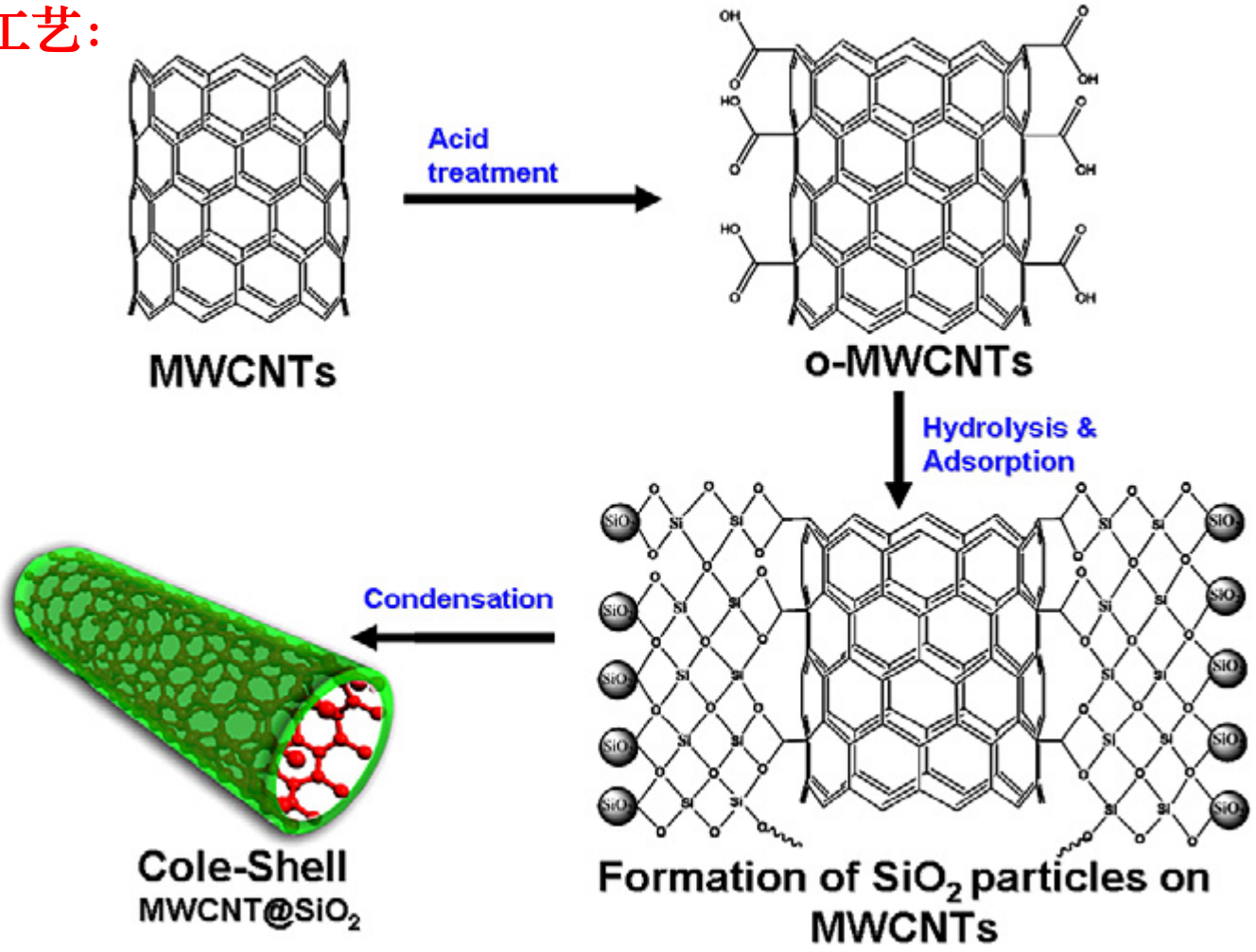
单晶硅/聚乙烯 (■)
金刚石/聚乙烯 (○)
的界面热导随温度的变化关系

Modulus Mismatch

Appl. Phys. Lett. 2007, 91,241910.
Phys. Rev.B,2009,79,104305.

体系1： 二氧化硅包覆MWCNT

Sol-Gel 工艺：

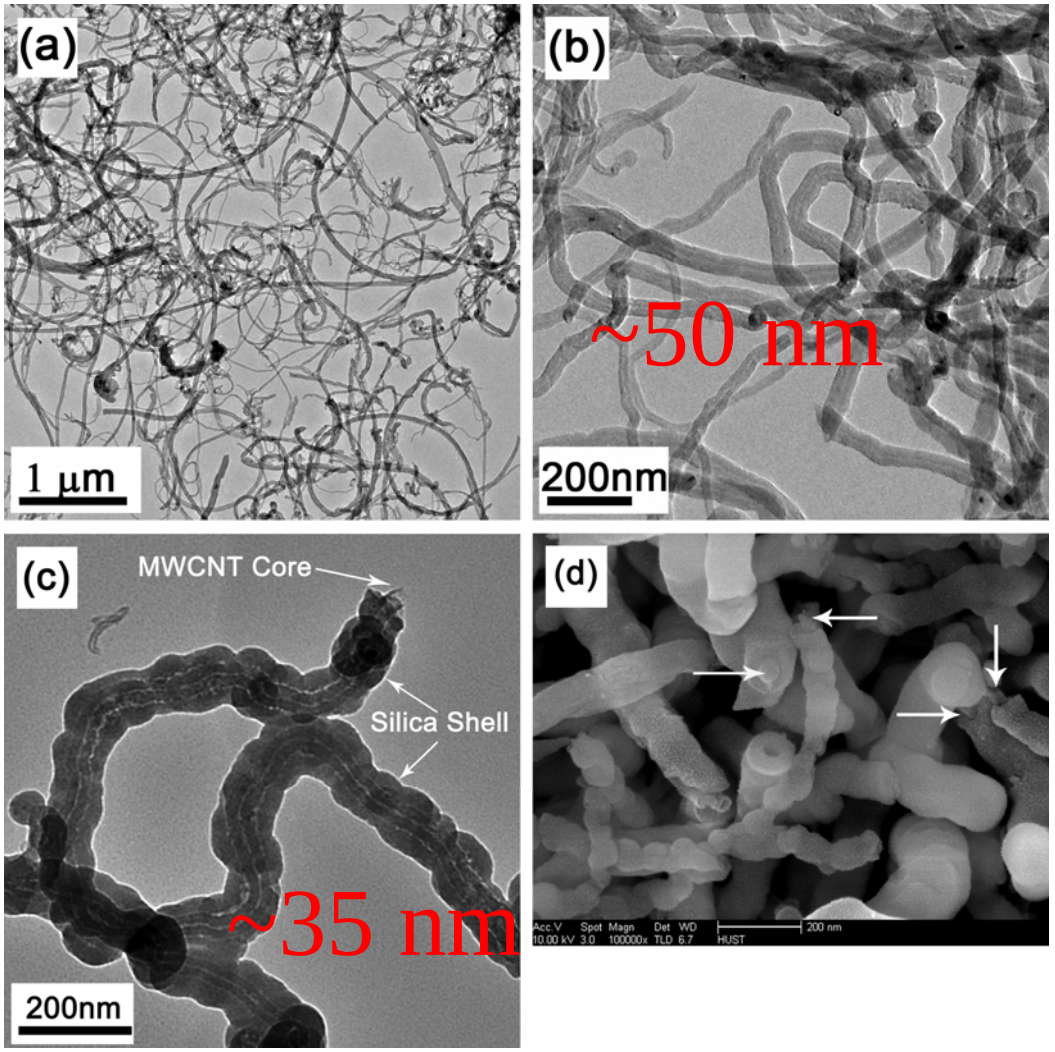


Xie X. L. et al, Carbon, 2011, 49, 495.

二氧化硅包覆MWCNT形貌

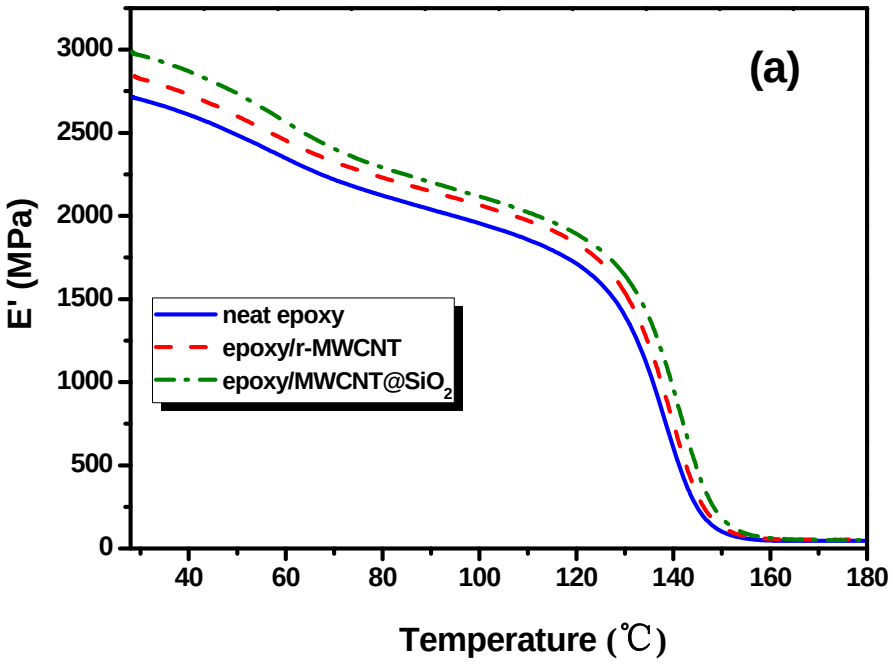
r-MWCNTs (a,b)

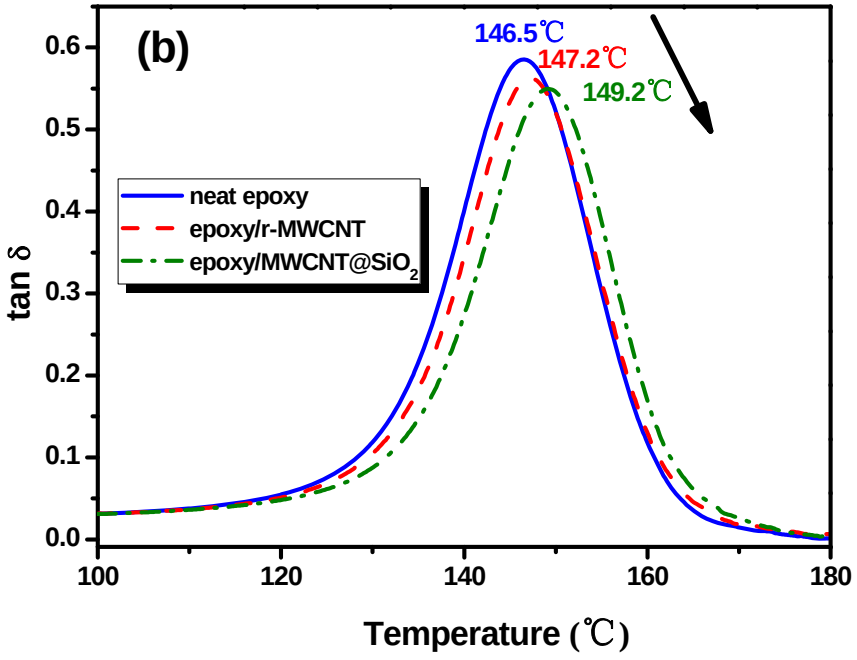
MWCNT@SiO_2 (c, d)



Xie X. L. et al, Carbon, 2011, 49, 495.

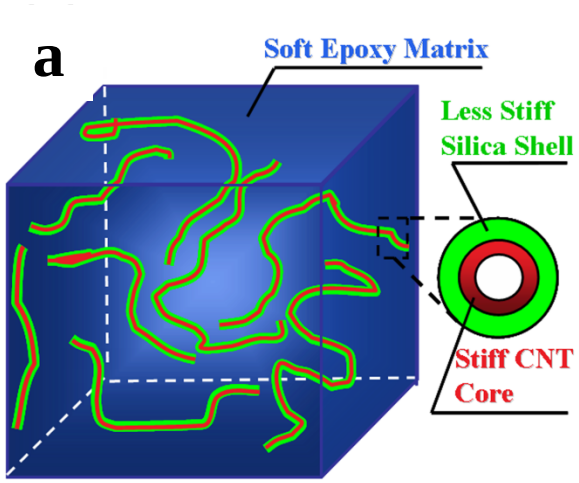
环氧树脂/MWCNT@SiO_2复合材料的DMA分析

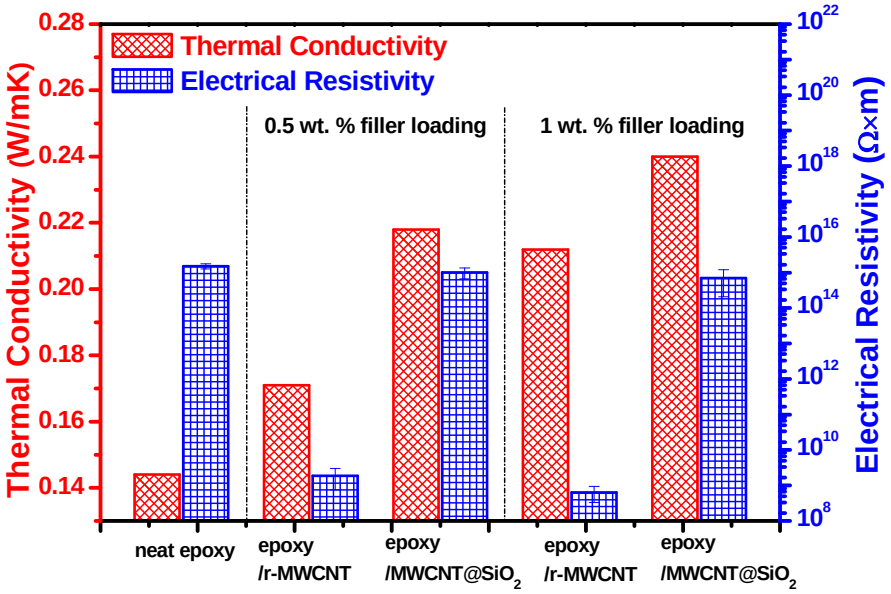


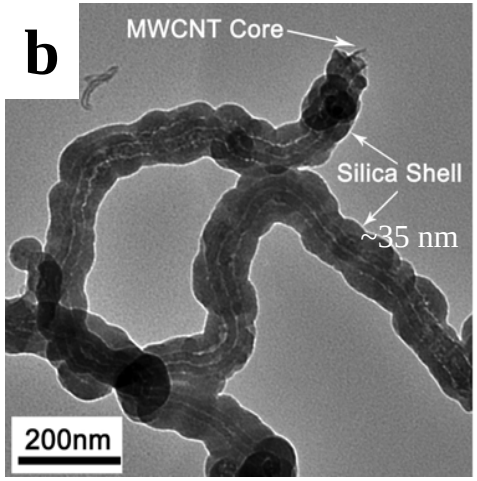


Xie X. L. et al, Carbon, 2011, 49, 495.

$E_{环氧}$:3 GPa　　E_{SiO2}: ~70 GPa　　E_{CNT}: 0.6-1 TPa







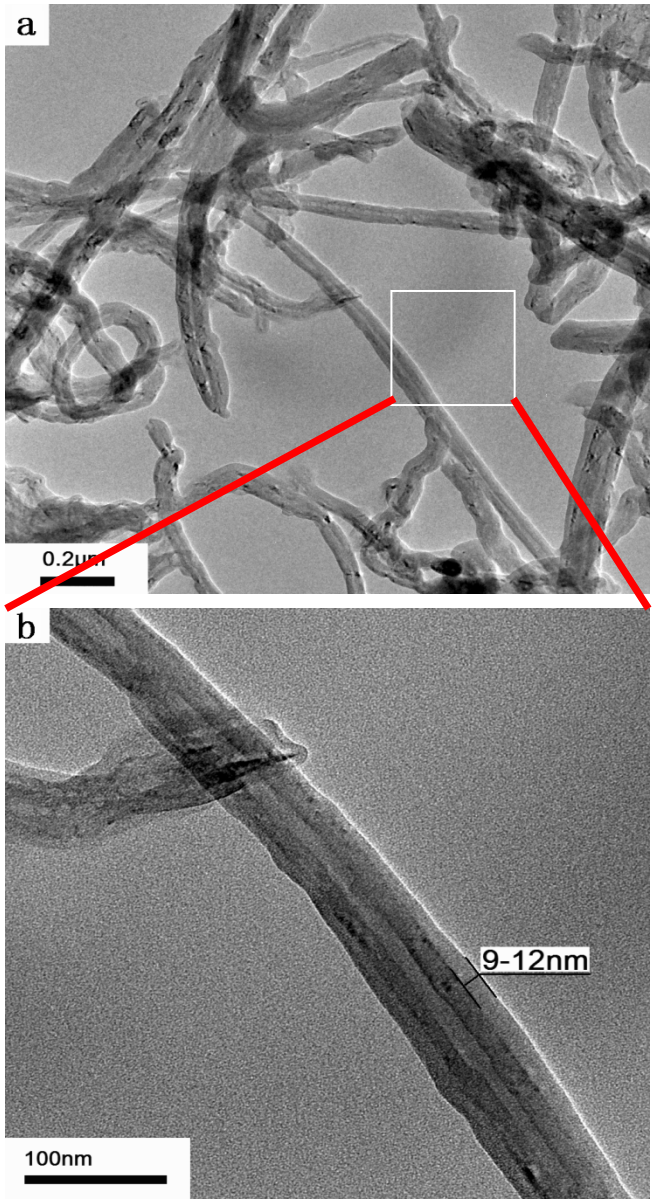
在多壁碳纳米管表面包覆二氧化硅，不仅赋予电绝缘性，还克服碳纳米管与聚合物基体的模量失配，促进界面声子共振耦合，显著提高了导热性能，克服了导热与电绝缘的矛盾

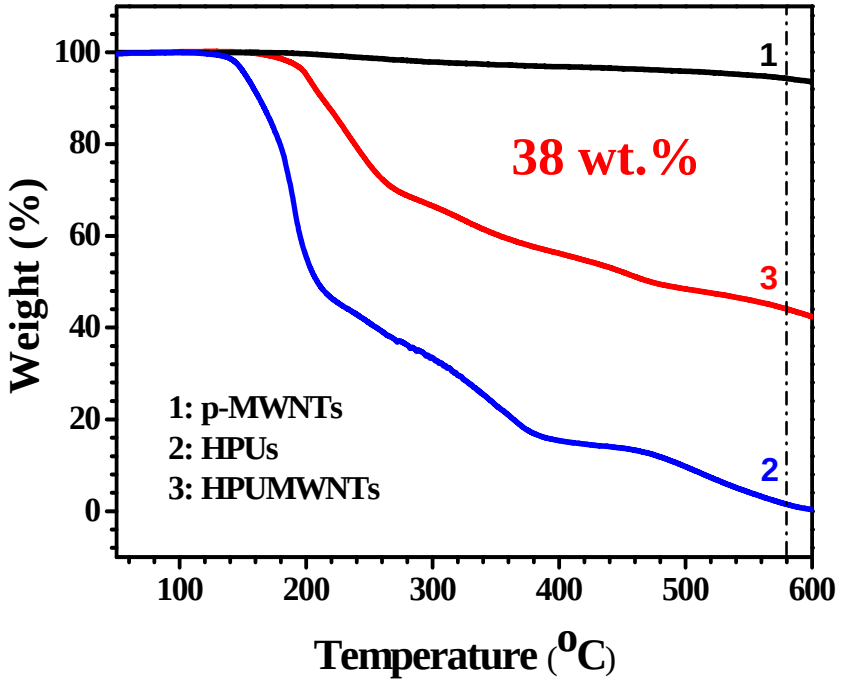
解孝林等, 中国发明专利ZL200910062796.2

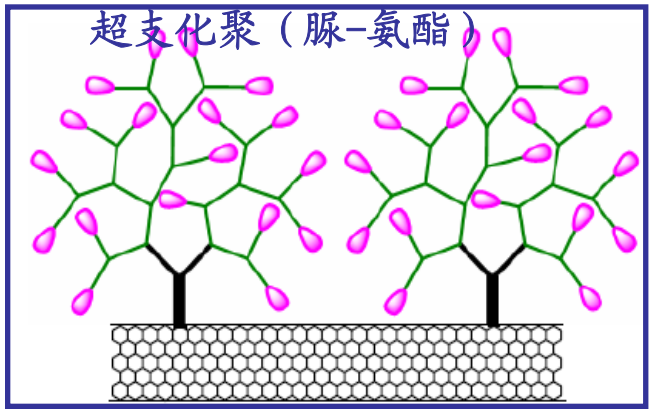
Xie XL*, *et al. Carbon* 2011, 49: 495

Xie XL*, *et al. J. Mater. Sci.* 2009, 44: 4539

体系二：超支化聚(脲-氨酯)-g-MWNTs





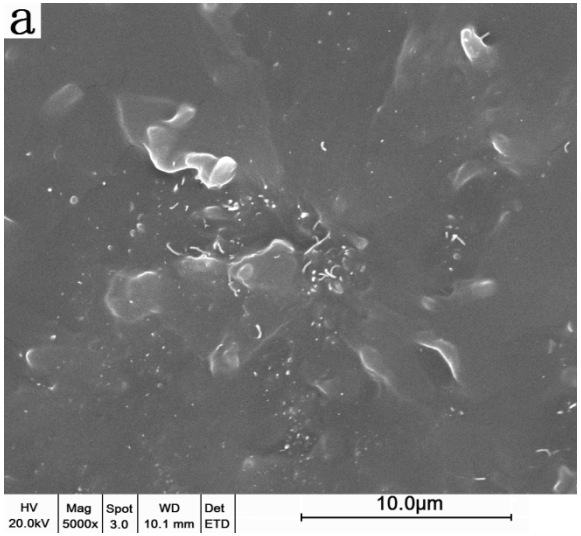


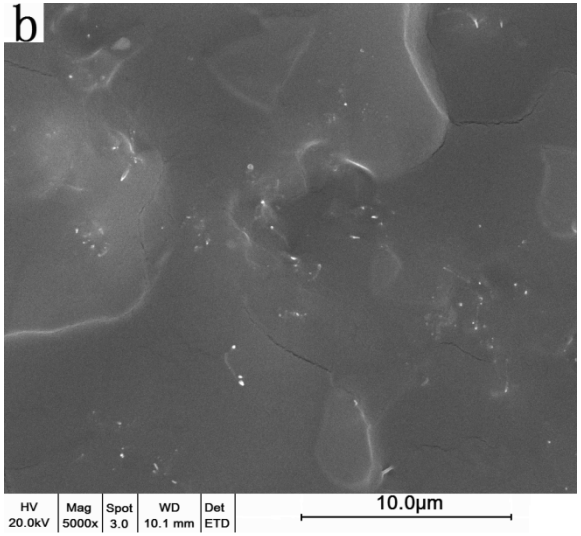
Xie Xiaolin, et al, Macromolecules 2007, 40: 5858*

Xie X. L. , et al, Macromol. Rapid Comm. 2006, 27: 1695*

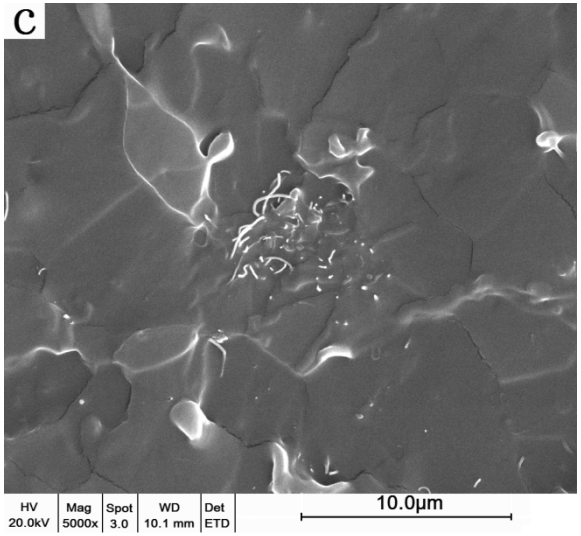
PU/HPU-MWNTs复合材料的断面形貌

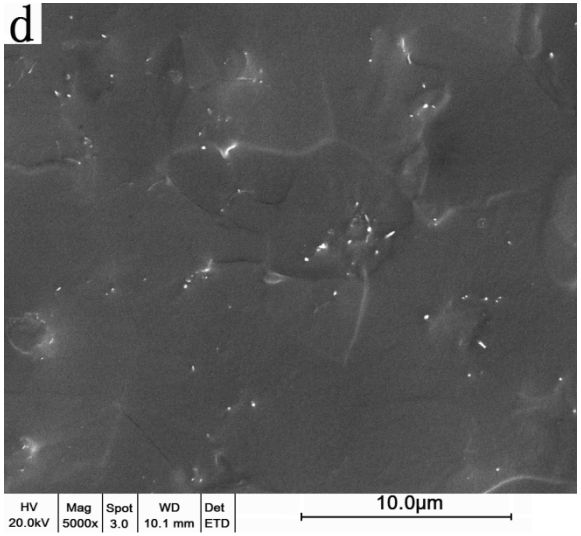
0.5 wt%

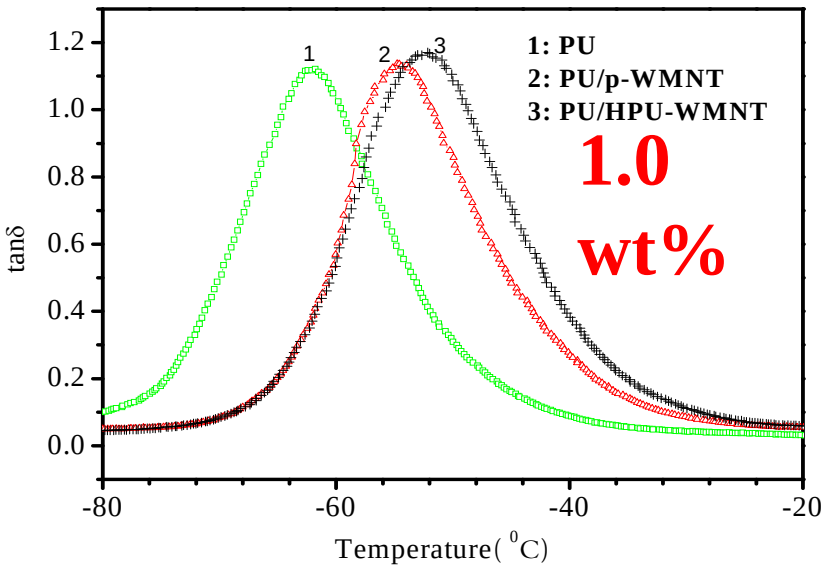


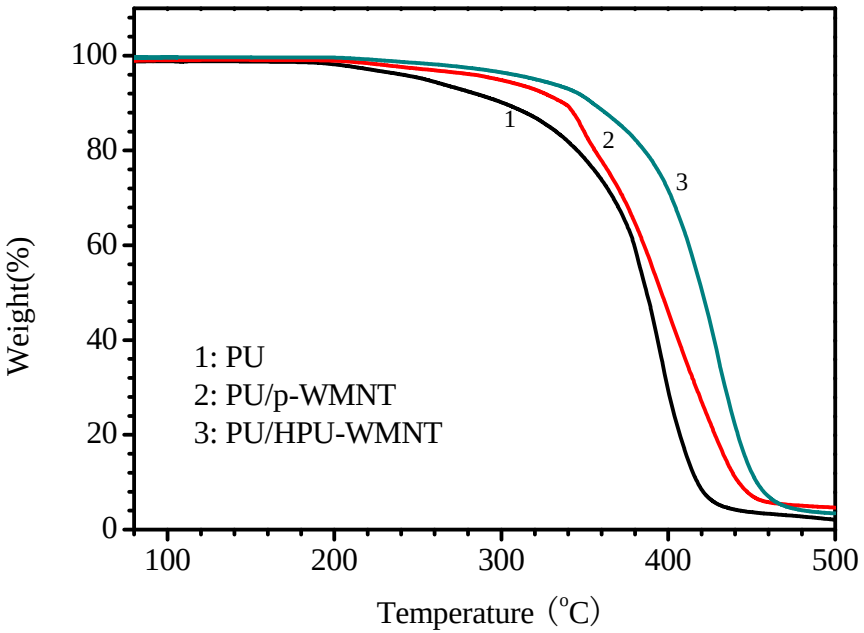


1.0 wt%



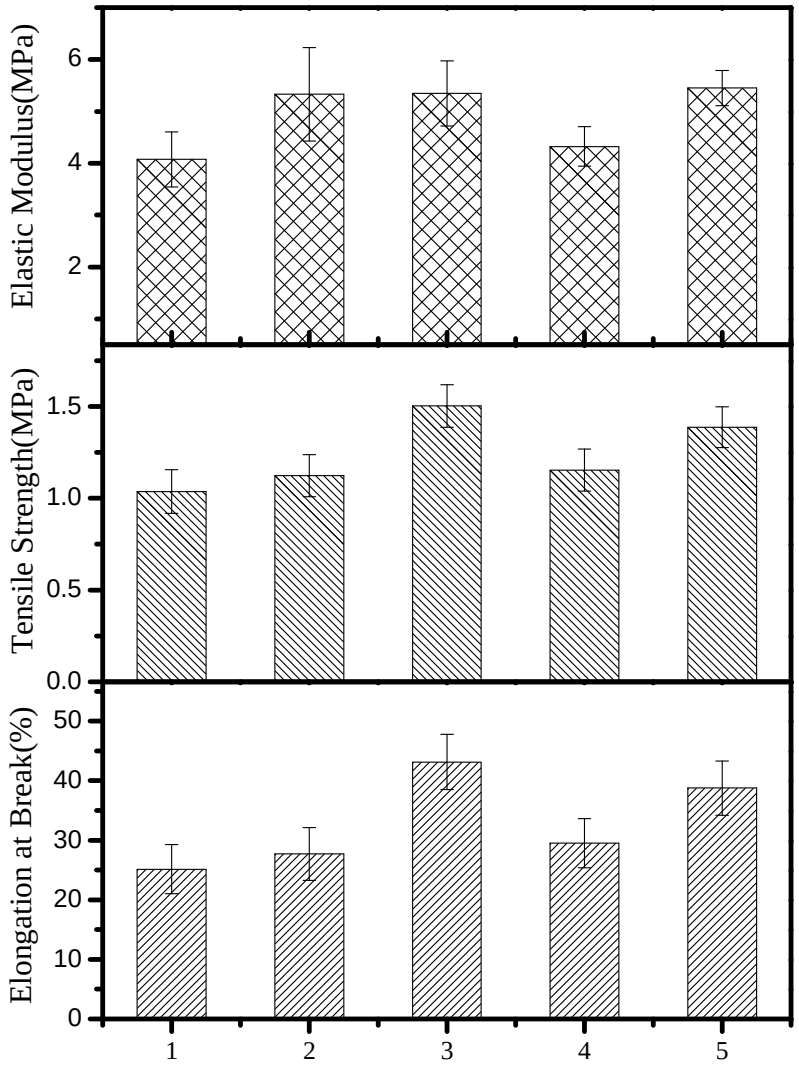






Samples	T_g (℃)	$T_{5\%}$ (℃)	T_{max} (℃)
Neat PU	-61.9	254.4	395.7
PU/p-MWNT (1%)	-54.7	298.0	403.9
PU/HPU-MWNT (1%)	-52.1	320.6	430.2

PU/HPU-MWNTs 的热行为分析



1: neat PU;

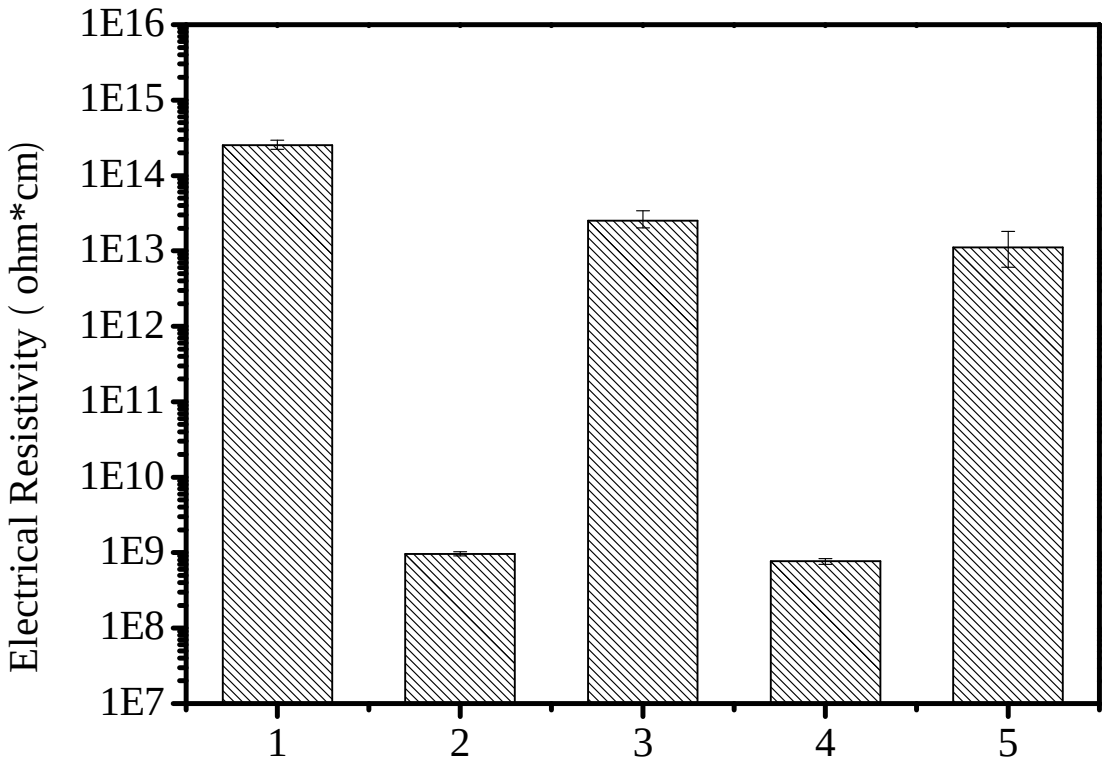
2: PU/p-MWNT (0.5 wt%);

3: PU/HPU-MWNT(0.5 wt%);

4: PU/p-MWNT (1 wt%);

5: PU/HPUs-MWNT (1 wt%)]

PU/HPU-MWNTs 的力学性能

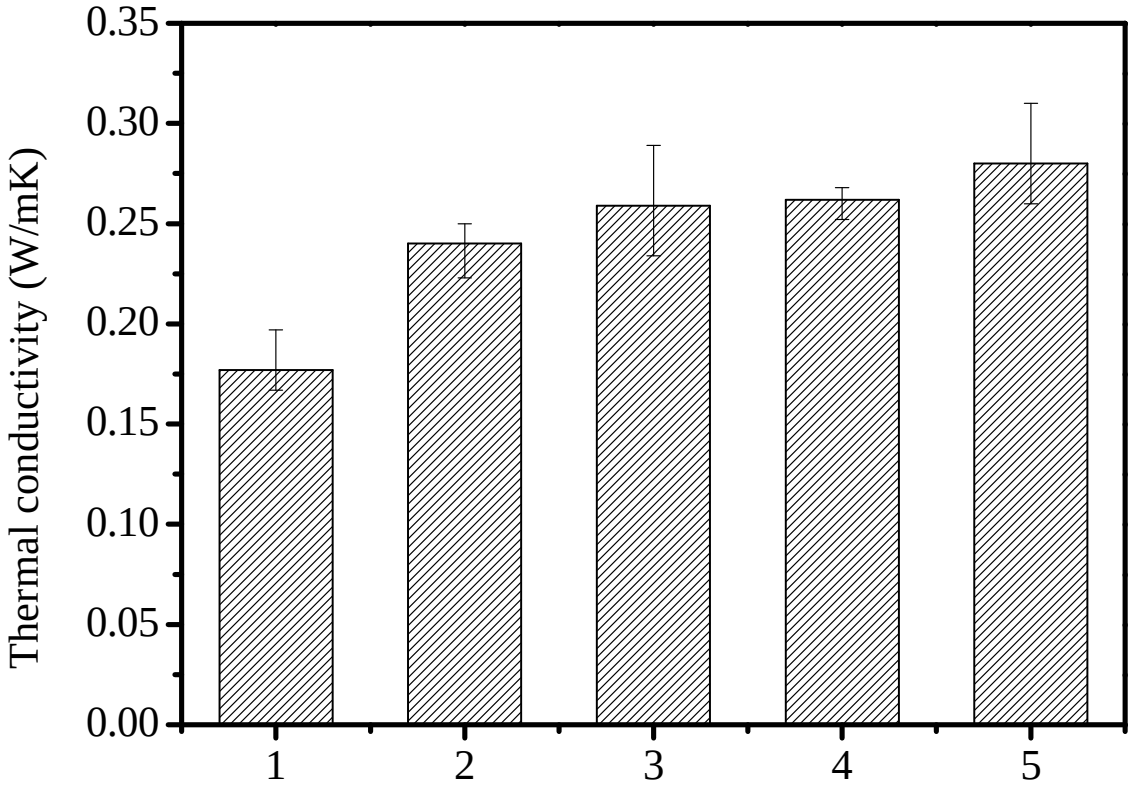


1: neat PU; 2: PU/p-MWNT (0.5 wt%);

3: PU/HPU-MWNT(0.5 wt%); 4: PU/p-MWNT (1 wt%);

5: PU/HPUs-MWNT (1 wt%)]

PU/HPU-MWNTs 的电学性能

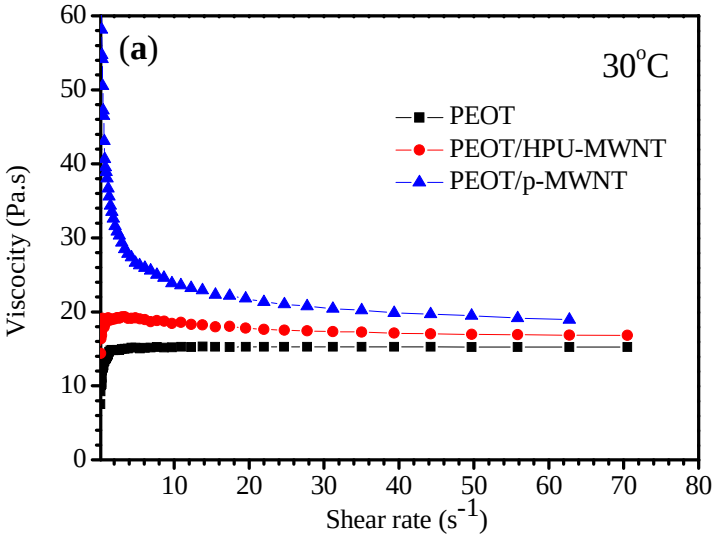


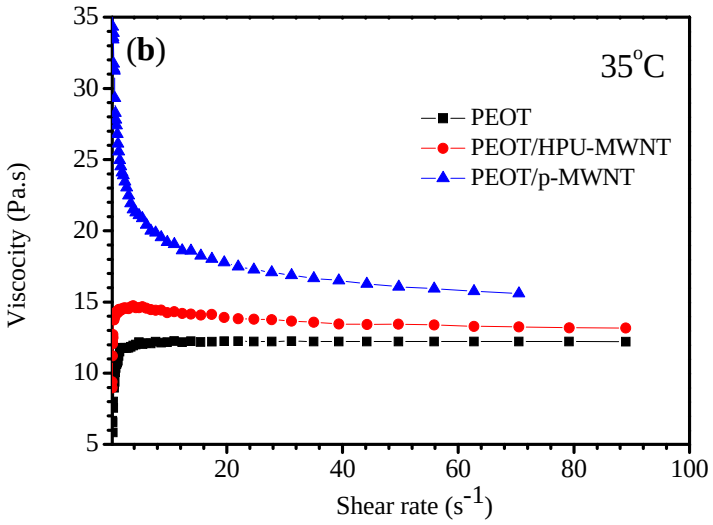
1: neat PU;
2: PU/p-MWNT (0.5 wt%);
3: PU/HPU-MWNT(0.5 wt%);
4: PU/p-MWNT (1 wt%);
5: PU/HPUs-MWNT (1 wt%)]

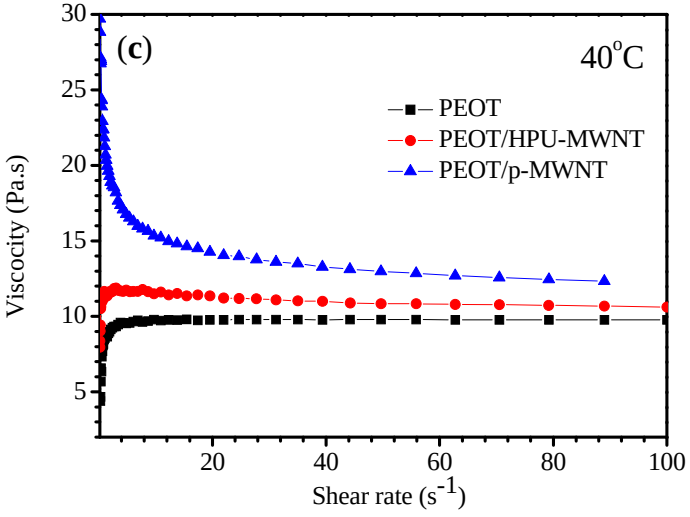
解孝林等， 一种电绝缘导热聚氨酯复合材料及其制备方法.*中国专利*（申请号200910273311.4）

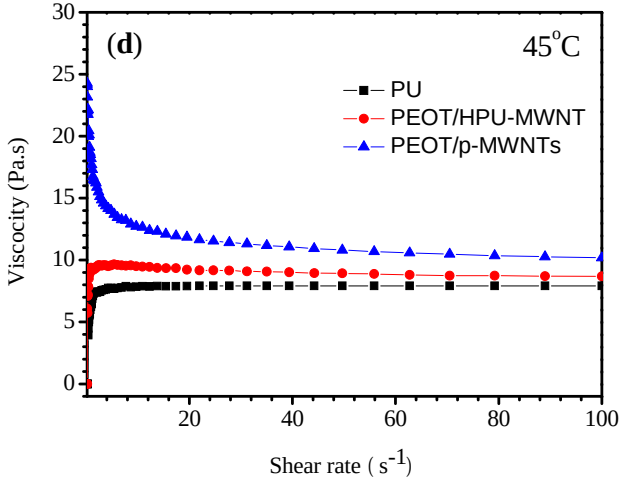
Xie X. L. *, *et al*, Enhanced properties of polyurethane/MWNT nanocomposites by surface grafting modification of hyperbranched poly(urea-urethane) on MWNTs . *Compos. B*, 2011, 42(8): 2111-2116.

PU/HPU-MWNTs 的导热性能



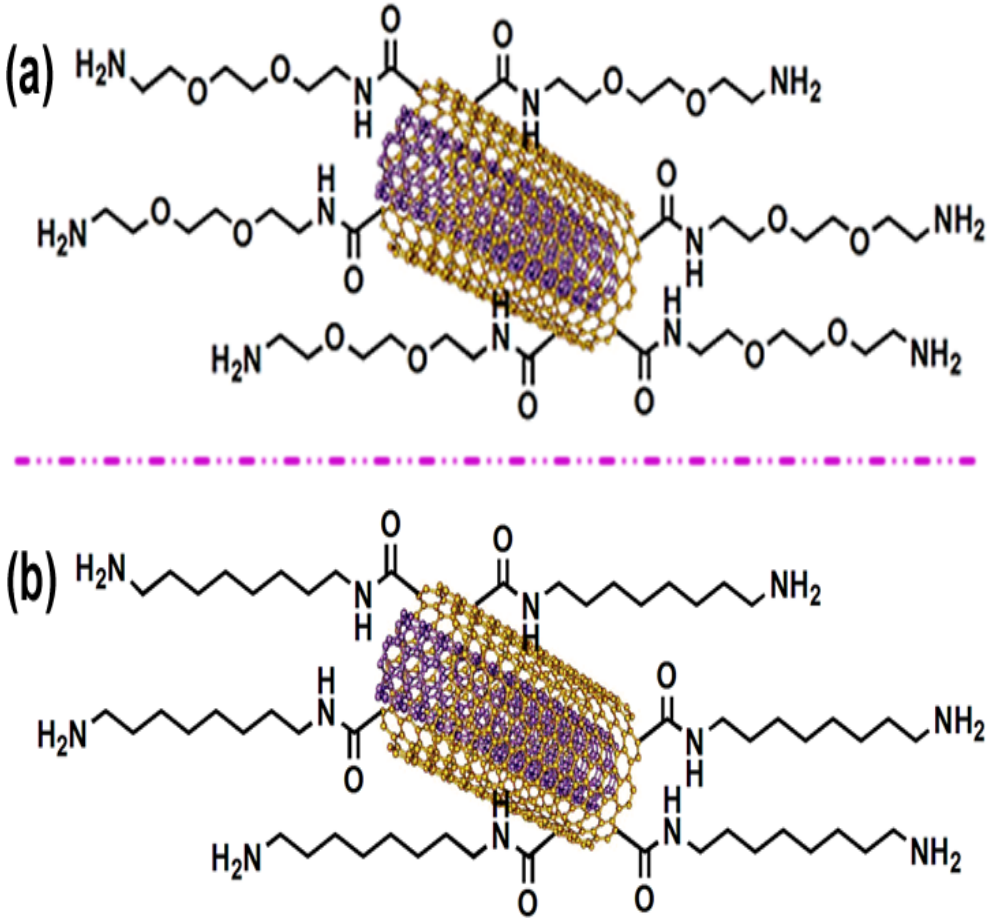


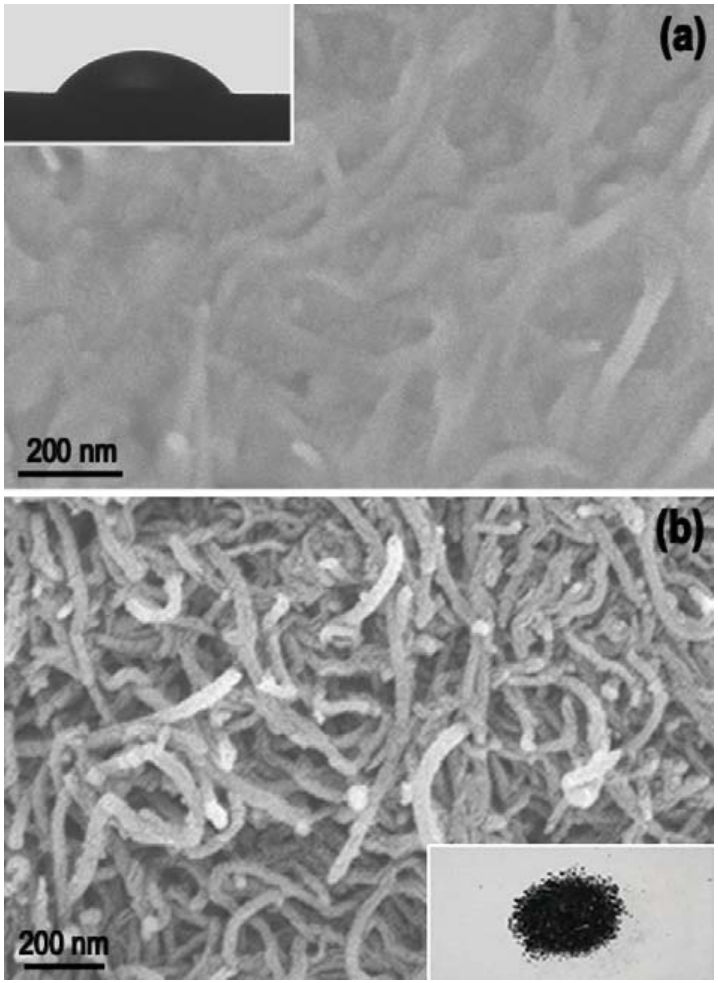




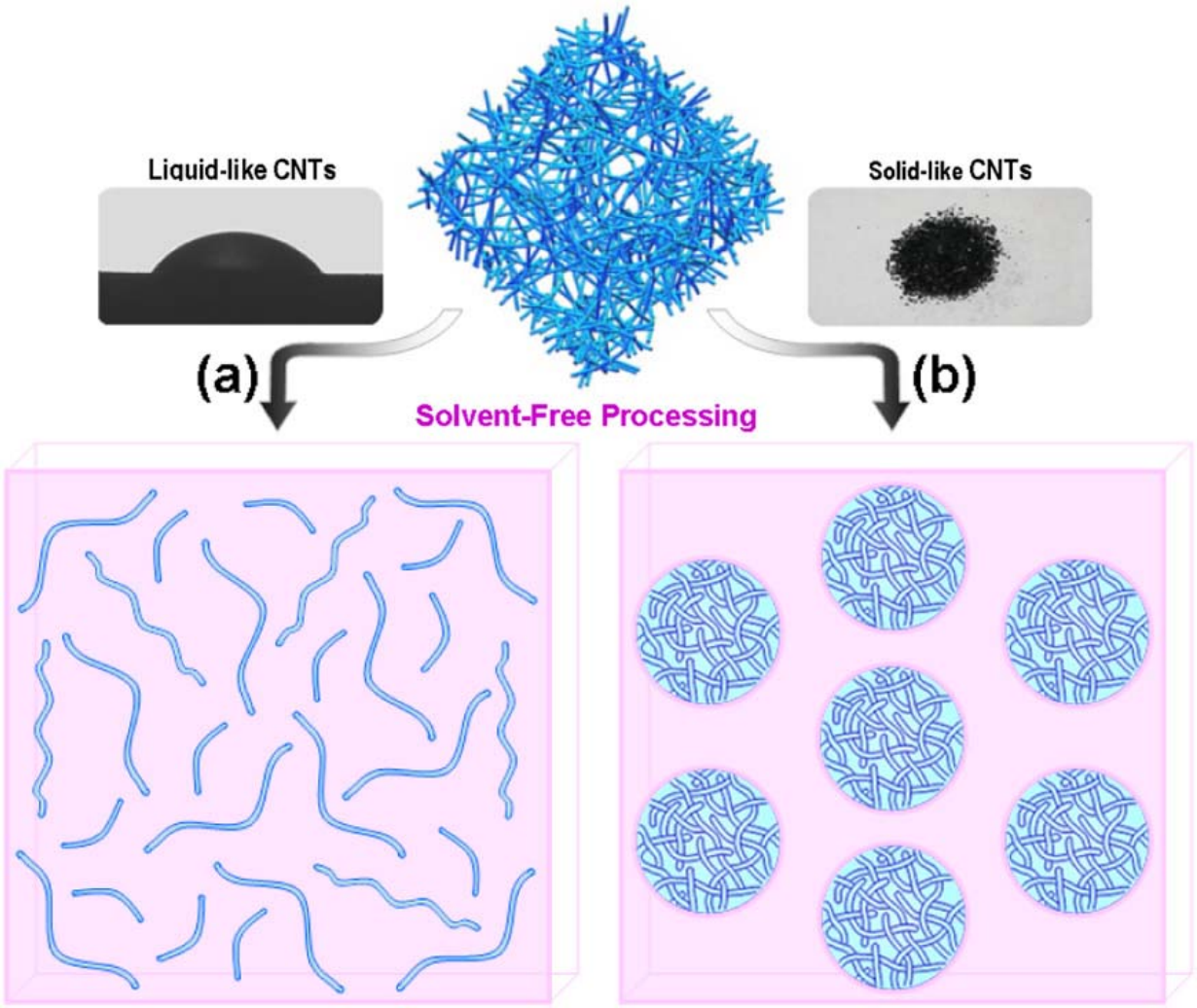
PU/HPU-MWNTs 预聚物的流变性质

体系三：类流体碳管





Xie Xiaolin, et al, Nanotechnology 2012, 23, 225701



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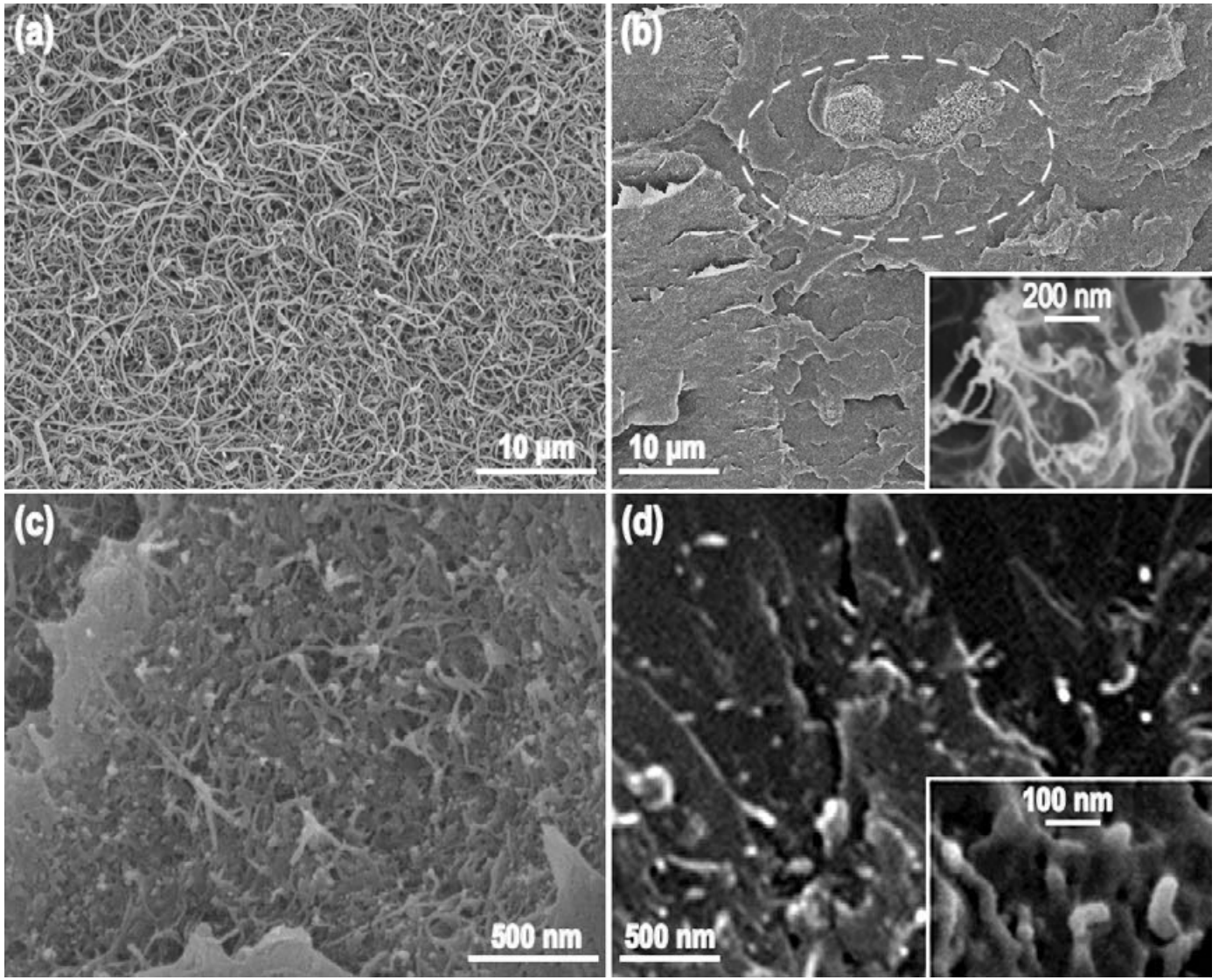
类流体碳管/环氧复合材料SEM图



0.5 wt%

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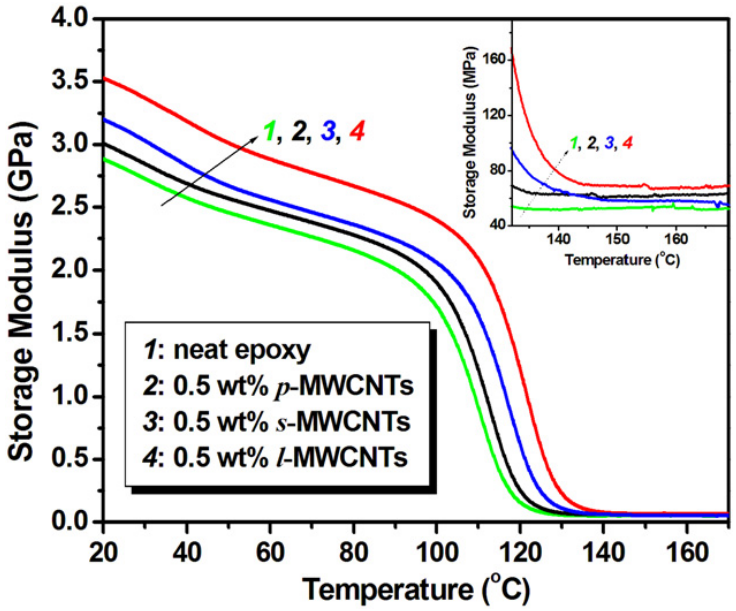
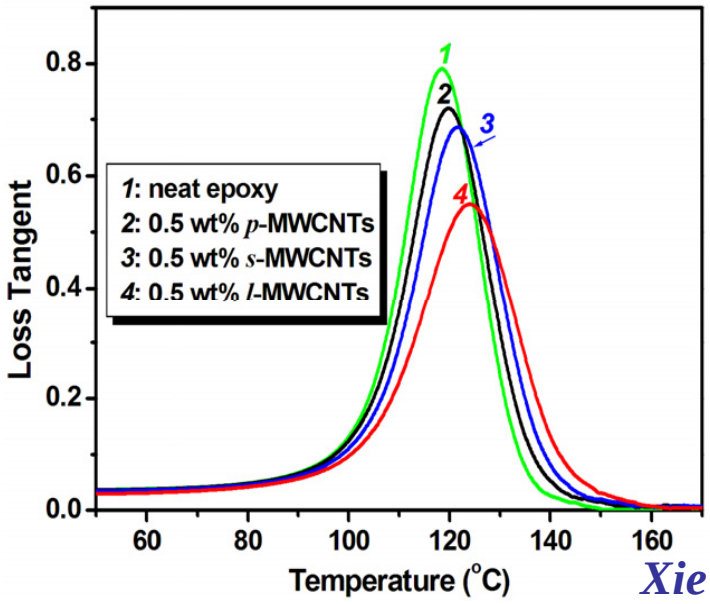
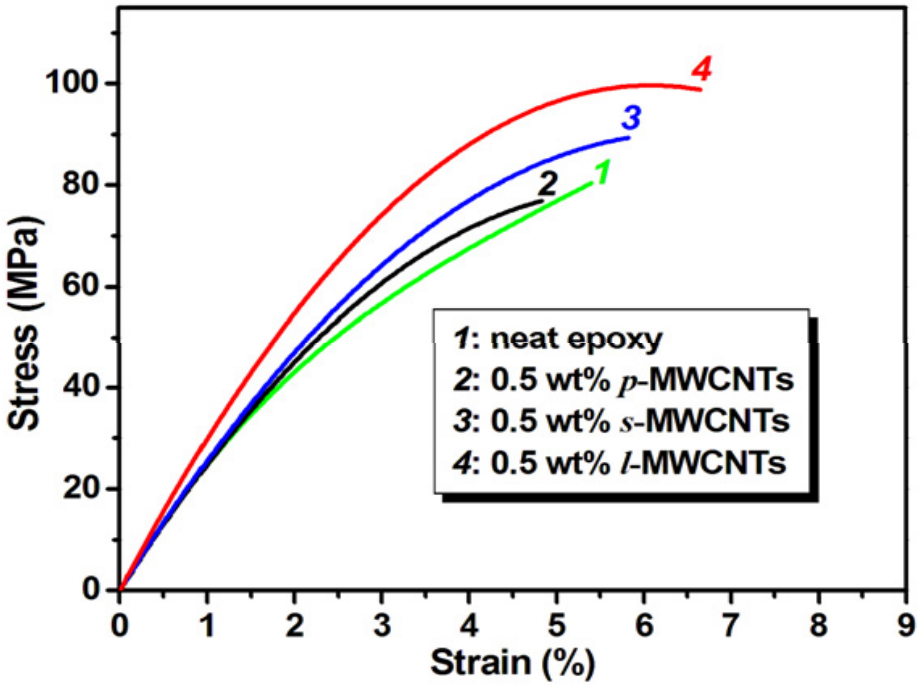
类流体碳管/环氧复合材料性能







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导热性纳米粒子类流体化设计

固态

改性

类流体
可流动
易加工

降低CTE
提高T_g

导热内核

碳纳米管
/石墨烯

有机修饰
降低粘度
促进分散

环氧交联
加速固化
增强界面

纳米层SiO_2构
筑模量过渡层

减小填料与环
氧间模量失配

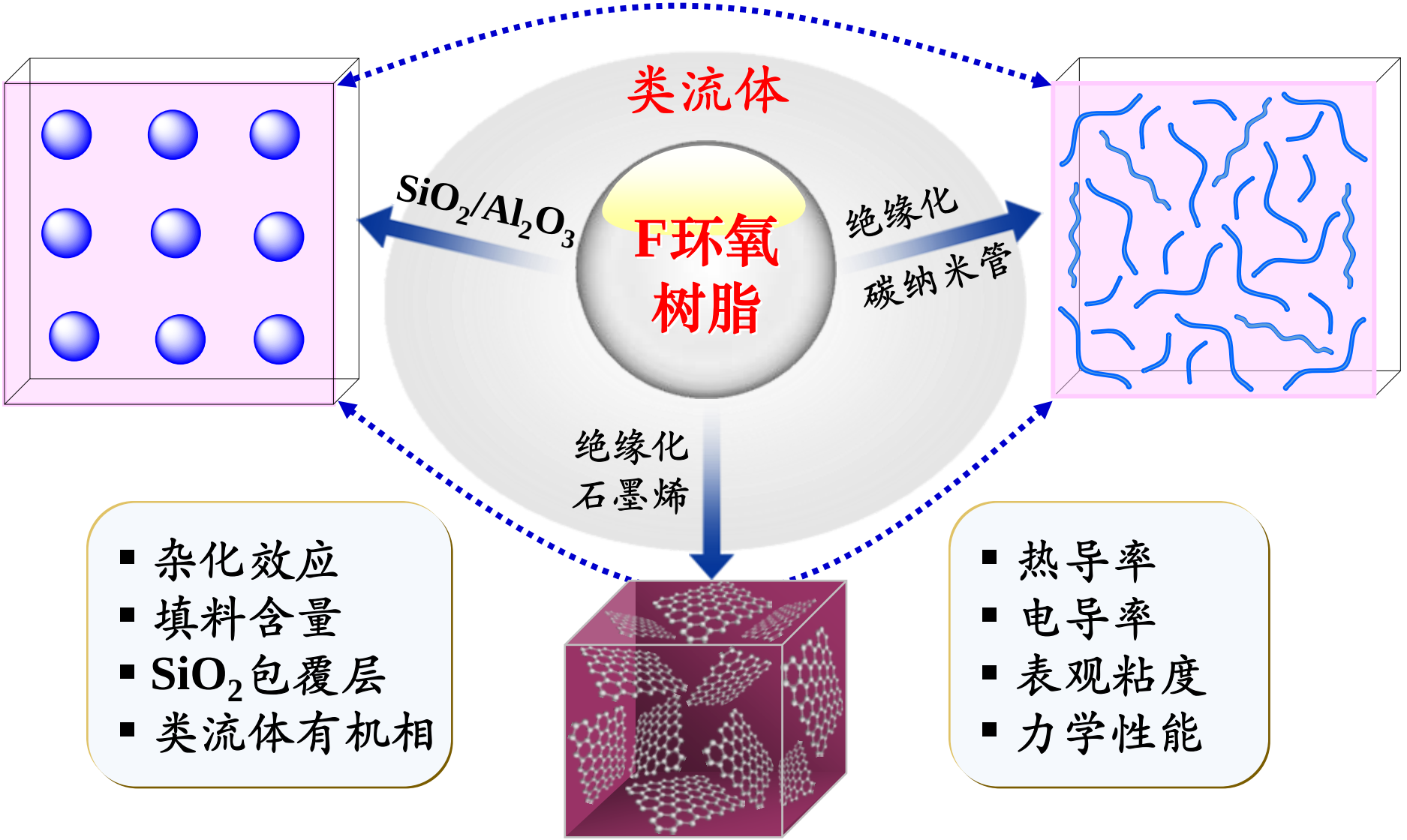
绝缘包覆

促进界面
声子共振耦合
→ 提高热导

环氧树脂复合材料制备

杂化效应是调控界面模量匹配、增强界面作用，减小界面热阻。

多元杂化



- 杂化效应
- 填料含量
- SiO_2包覆层
- 类流体有机相

- 热导率
- 电导率
- 表观粘度
- 力学性能

致谢

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科技部

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华中科技大学

欢迎访问我校，谢谢！

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