超低摩擦固体润滑薄膜

中国科学院兰州化学物理研究所先进润滑与防护材料研究发展中心

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当前及今后很长时期，我国都将面临节能和减排的双重压力，降低机械运动部件摩擦磨损是实现节能减排的有效途径。兼具石墨低摩擦和金刚石高耐磨损性能的碳基薄膜，被认为是新一代固体润滑薄膜材料。近年来，国内外相关研究发现碳基固体润滑薄膜在特殊环境（如N_2、真空、微力）下具有超低摩擦行为，而我们研究团队已经实现了碳基固体润滑薄膜在大气环境下的超低摩擦这一项挑战性课题，并将具有类富勒烯纳米结构碳基固体润滑薄膜推向工业化应用。

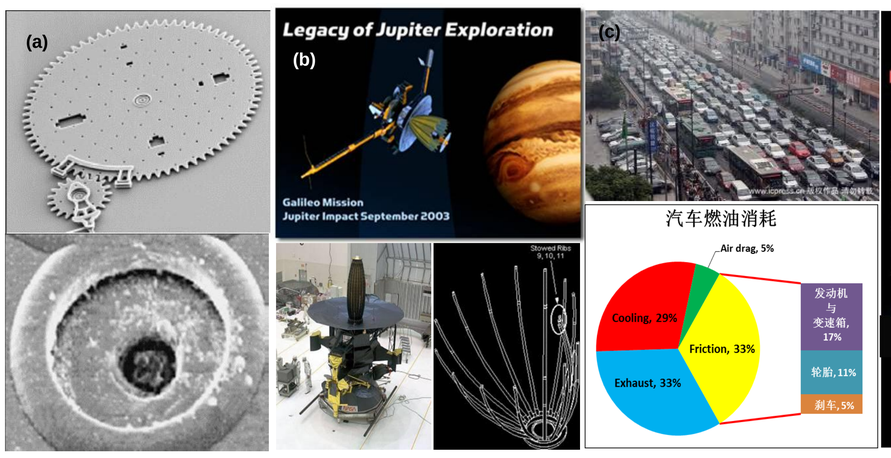

Figure 1.1 Friction in MEMS(a), spacecraft (b) and vehicles (c).

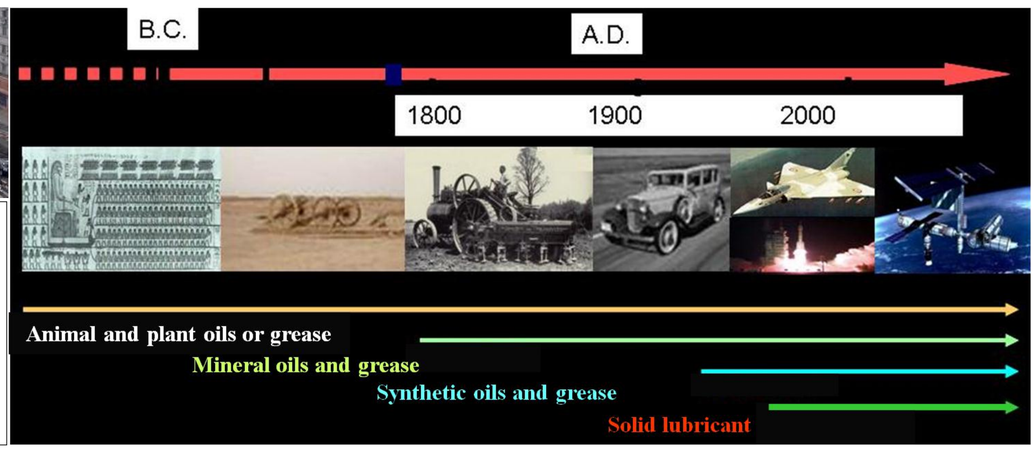

Figure 1.2 History of the development of lubrication materials.

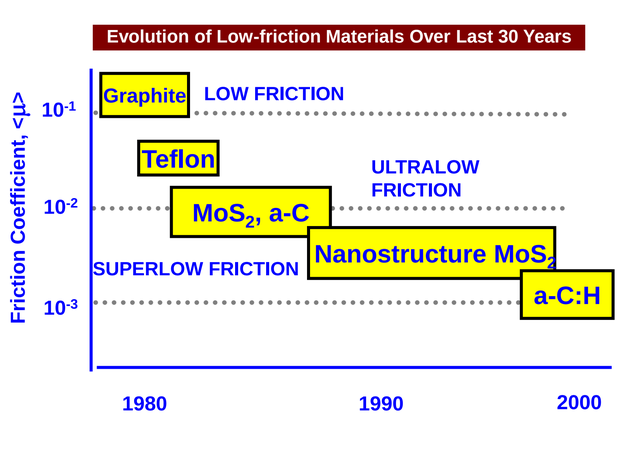

Fig. 1.3 Surf. Coat. Technol. 180-181, 76 (2004).

科学与技术问题：

- 碳基薄膜结构与低摩擦的相关性规律
- 类富勒烯结构碳基固体润滑薄膜超低摩擦机制
- 大气环境下低摩擦碳基固体润滑薄膜的可控制备方法

创新性成果：

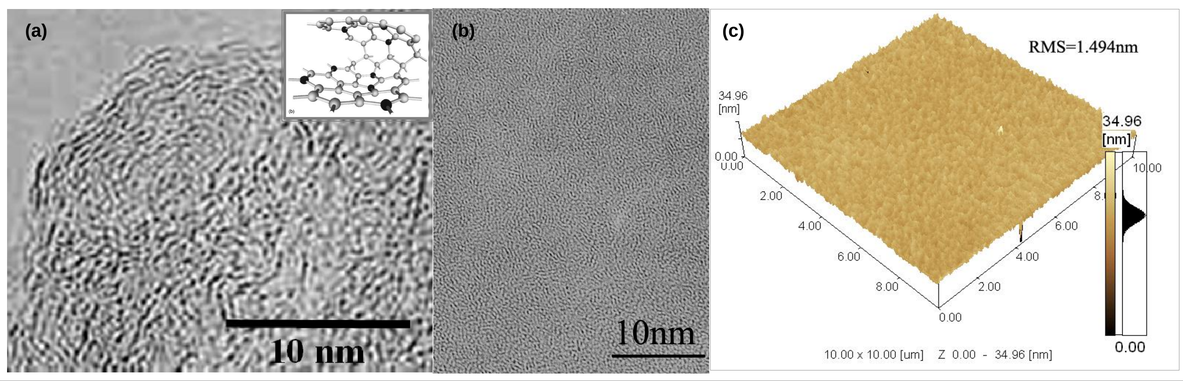

Figure 2 HRTEM and AFM images of the fullerene-like hydrogenated carbon films (FL–C:H).

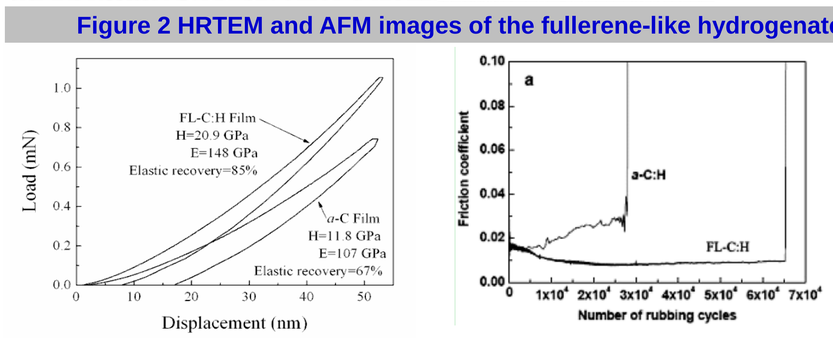

Figure 3 Load–displacement curves of the FL–C:H and the amorphous carbon film (a-C).

Figure 4 Tribological tests on the a-C:H and FL–C:H : (a) the friction coefficient as a function of time; (b) the worn surfaces of an Si_3N_4 ball against the films.

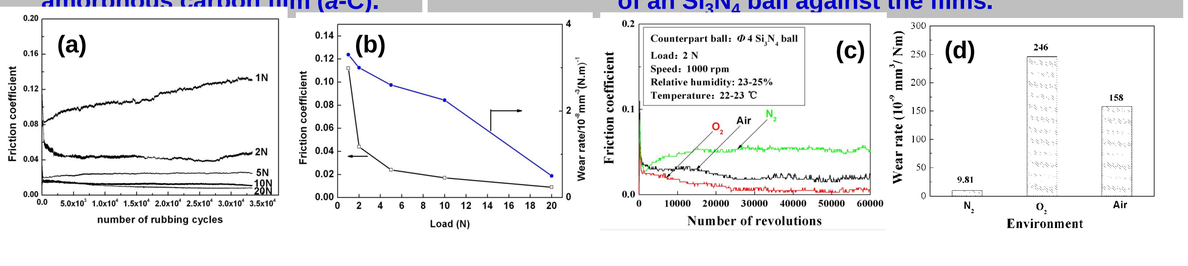

Figure 5 Friction and wear behaviors of FL–C:H film at different load in air (a and b) and at different environment (c and d) in same load.

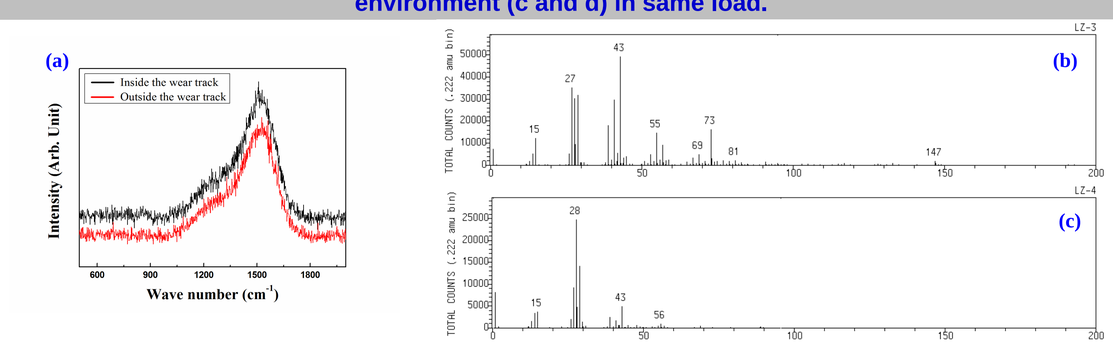

Figure 6 Raman spectra and ToF-SIMS signals collected inside and outside wear track of the H-FLC films (20 N, in air).

◆ 率先设计制备了在空气环境中具有低摩擦特性类富勒烯结构含氢固体润滑碳薄膜。

◆ 揭示了类富勒烯弯曲结构超高弹性结构因素和表面摩擦诱导重构界面因素摩擦机制。

奖励情况：

◆ 固体润滑薄膜结构与超低摩擦，**2010**年甘肃省自然科学二等奖

碳基固体润滑薄膜的工业化应用：

工艺过程

检测清洗

↓

工装设计

↓

薄膜沉积

↓

冷却取出

Figure 7 United Laboratory of Auto-Tribology, experimental facility and related products.

薄膜性能

硬度：**15-25GPa**

结合力：**>60N, HF1**

摩擦系数：**≤0.05**

磨损率：$10^{-19}m^3/Nm$

粗糙度：**≤1.5nm**

厚度：**~1μm**

节能：**≥2%(台架)**

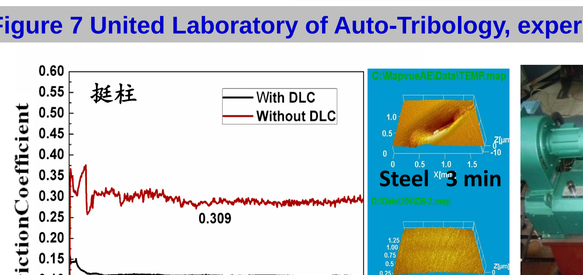

Figure 8 Tribological tests of tappets with and without DLC film.

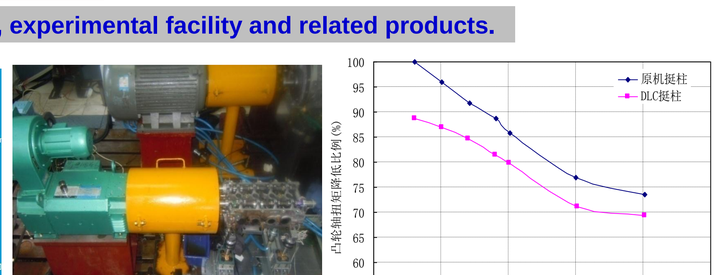

Figure 9 Platform experiments of tappets with and without DLC film.

◆ 发展了具有自主知识产权超低摩擦碳基固体润滑薄膜工艺及成套设备

◆ 解决了高功率先进汽车发动机高压共轨喷油系统和配气系统的摩擦磨损技术瓶颈问题。

奖励情况：

◆ 强韧与润滑一体化碳基薄膜关键技术与工程应用。**2015**年甘肃省技术发明一等奖