IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Specialised Technologies, Including Nanotechnology (8)

Author: Dr. Santiago Jose Cartamil Bueno
SCALE Nanotech, Germany

LASER-INDUCED PROPULSION OF GRAPHENE LIGHTSAILS IN MICROGRAVITY

Abstract

Light from the Sun or a laser beam can be used to transfer momentum to matter and displace low-mass objects. Space agencies have successfully tested the solar sail technology for low-Earth orbit applications, navigation control, and Solar System exploration [1,2,3], JAXA's mission *IKAROS* [4] (2010) being the first demonstration of spacecraft with a sail contributing to its propulsion. However, the thrust from radiation pressure is too low for standalone propulsion unless we use ultrathin sails made of optically-suitable materials with low mass density yet mechanically strong and stiff to reduce issues with sail deployment and space particle bombardment [5,6].

Graphene, a one atom thick allotrope of graphite [7,8], has the ultimate low mass density with exceptional properties: large stiffness (1 TPa) and tensile strength (130 GPa) for a 20% stretchability [9]; and excellent electrical (350000 $cm^2V^{-1}s^{-1}$) [10,11] and thermal (2500 $Wm^{-1}K^{-1}$) conductivity [12]. Despite promising great material performance for lightsail material, its large optical absorption (2.3% in the visible and near infrared spectrum) [13] and low reflectivity need to be engineered if wants to be used as the lightsail interface.

In this work, we propose and experimentally study a lightsail design where graphene layers cover a holey copper grid. Such a compounded structure allows to reduce the average mass density of the sail substrate while deriving from graphene its mechanical rigidity and full-surface availability to sustain a reflective thin film. Furthermore, we made a laser setup to demonstrate the light-induced acceleration of these 2D sails in microgravity at ZARM Drop Tower (Germany). By using lasers with different wavelengths and optical powers (up to 1 W), we observe thrusts of $8 - 248$ nN, one order of magnitude higher than the theoretical calculations for a radiation pressure mechanism.

References:

[1] Friedman et al, 16th Aerospace Sciences Meeting (1978).
[2] Tsu, ARS Journal 29, 422 (1959).
[3] Johnson et al, Acta Astronautica 68, 571 (2011).
[4] Tsuda, Acta Astronautica 69, 833 (2011).
[5] Fernandez et al, Acta Astronautica 103, 204 (2014).
[6] Hoang et al, The Astrophysical Journal 1, 837 (2017).
[7] Novoselov et al, Science 306, 666 (2004).
[8] Novoselov et al, Nature Materials 3, 6 (2007).
[9] Lee et al, Science 321, 385 (2008).
[10] Novoselov et al, Nature 7065, 438 (2005).
[11] Neto et al, Reviews of modern physics 81, 109 (2009).
[12] Balandin et al, Nano Letters 3, 8 (2008).
[13] Nair et al, Science 5881, 320 (2008).