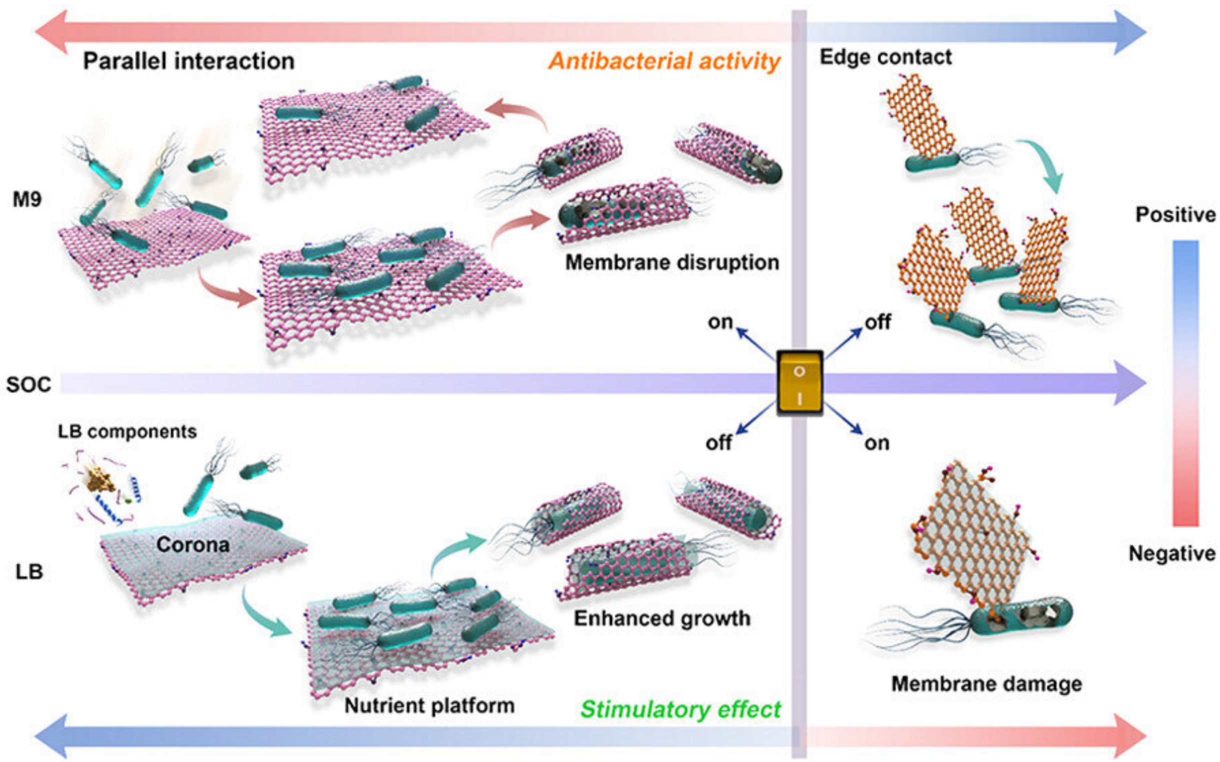
PHYS.ORG

Oxygen groups key to unlocking graphene's antimicrobial potential, say scientists

March 8 2023



As antimicrobials, graphene materials (GMs) may have advantages over traditional antibiotics due to their physical mechanisms of action which ensure less chance of development of microbial resistance. However, the fundamental question as to whether the antibacterial mechanism of GMs originates from parallel interaction or perpendicular interaction, or from a combination of these, remains poorly understood. Here, we show both experimentally and theoretically that GMs with high surface oxygen content (SOC) predominantly attach in parallel to the bacterial cell surface when in the suspension phase. The interaction mode shifts to perpendicular interaction when the SOC reaches a threshold of ~0.3 (the atomic percent of O in the total atoms). Such distinct interaction modes are highly related to the rigidity of GMs. Graphene oxide (GO) with high SOC is very flexible and thus can wrap bacteria while reduced GO (rGO) with lower SOC has higher rigidity and tends to contact bacteria with their edges. Neither mode necessarily kills bacteria. Rather, bactericidal activity depends on the interaction of GMs with surrounding biomolecules. These findings suggest that variation of SOC of GMs is a key factor driving the interaction mode with bacteria, thus helping to understand the different possible physical mechanisms leading to their antibacterial activity. Credit: *ACS Nano* (2023). DOI: 10.1021/acsnano.2c10961

The amount of surface oxygen in graphene materials is a key factor in how effective they could be in killing bacteria—a discovery which may help to design safer and more effective products to combat antimicrobial resistance.

Graphene oxide with high surface oxygen content (SOC) is very flexible and can wrap around bacteria (a parallel mode of contact), but when it has lower SOC the material has higher rigidity and tends to contact bacteria edgewise (in a perpendicular mode).

Neither mode necessarily kills bacteria, but bactericidal activity depends on how the material interacts with surrounding biomolecules. The discovery will help scientists to understand the different possible physical mechanisms leading to their antibacterial activity.

Publishing their findings in *ACS nano*, an international group of scientists from the UK, Cyprus, Austria, Finland, The Netherlands and China reveal that it is graphene oxide's different interaction modes that lead to distinct antibacterial activity—with a 'switch' occurring when surface oxygen levels reach a certain threshold.

A slight change of SOC can lead to the shift of interaction modes between parallel and perpendicular contact. "The impact of SOC on the interaction mode has been underestimated for a long time," commented Dr. Zhiling Guo, from the University of Birmingham.

Dr. Peng Zhang, from the University of Birmingham, commented, "Our research highlights that surface oxygen levels can help to evaluate the antibacterial effects of graphene materials—helping to design safer materials through clarifying the role of SOC."

As antimicrobials, graphene materials may have advantages over traditional antibiotics due to their physical mechanisms of action which ensure less chance of development of microbial resistance.

Until now, the fundamental question as to whether the antibacterial mechanism of graphene materials originates from parallel interaction or perpendicular interaction, or from a combination of these, remains poorly understood—hindering progress in developing antibacterial graphene materials and understanding their environmental safety.

Professor Iseult Lynch, from the University of Birmingham, said, "The discovery is a potential 'gamechanger' and we should be using this surface oxygen 'switch' as the determining property to define and classify graphene materials in the context of human health and environmental safety."

The UK- led international research team created a series of graphene materials with different SOCs and compared their antibacterial performance—evaluating total cell growth, biofilm formation and oxidative stress, as well as physical interactions with bacteria including through molecular simulations.

Different interaction modes lead to distinct antibacterial activity and interaction mode is highly related to the rigidity of the graphene materials which depends on the amount of surface oxygen.

The antibacterial activity of graphene materials was reported as early as 2010. The material has been used to create antibacterial fabrics for maternity garments which can prevent microbial growth on the fabric surface. Graphene-coated nonwoven fabrics have been used to produce antibacterial masks, while graphene-based membranes have been extensively studied for water treatment because of their ultrafast water transport and antifouling activity.

More information: Zhiling Guo et al, Defining the Surface Oxygen Threshold That Switches the Interaction Mode of Graphene Oxide with Bacteria, *ACS Nano* (2023). DOI: 10.1021/acsnano.2c10961

Provided by University of Birmingham