Graphene Infused Elastomer Nanocomposites: Materials for Improving Food Packaging

Jonah de Cortie and Tyler Paplham
University of Pittsburgh Swanson School of Engineering

Introduction
The Importance of Food Packaging: Continually expanding the knowledge of what materials make the safest, most effective, and cheapest food packaging allows for the development of food production and transportation systems that are better able to address the needs of an ever-expanding population. In particular, the compound graphene is especially promising as an additive to traditional elastomers to yield graphene infused elastomer nanocomposites (GIENs). The newly synthesized compounds have promising applications in the food packaging industry due to their unique structure and desirable permeability properties.

The Food Packaging Industry Today
Properties of desirable food packaging:
- Ability to resist puncture deformation
- Slow rate of fatigue crack growth
- High tensile strength
- Low moisture and gas permeability
- Low production cost

GIEN Materials and Synthesis
- Elastomers are a specific type of polymer in which the molecular chains are “cross-linked” by smaller chains, giving them increased elasticity (Fig. 2B)
- The ultimate strength of a material depends on the elastic modulus (ability to resist tensile strain) and can be greatly improved with the incorporation of a filler such as graphene
- Graphene is a planar (two-dimensional) sheet of sp² hybridized carbon atoms arranged in a hexagonal structure (Fig. 3)
- Graphene has an elastic modulus of ~1 TPa (approx. 20.89 billion lb/ft²), five times more inelastic than steel²
- These two materials can be combined to form GIENs through two different processes: melt mixing and solution blending (Table 1)

Permeability Properties of GIENs
- The “hedge maze” like effect of Graphene in GIENs greatly reduces the gas permeability of all gases through the material
- The low permeability has different repercussions on GIEN’s applications in food packaging depending on the identity of the gas
  - In regards to H₂O
    - Low H₂O levels inside of food packaging will inhibit the growth of bacterial and fungal species that will damage the food, because of this, low H₂O permeability has the effect of increasing the shelf-life of the packaged food³
  - In regard to O₂
    - Reactive oxygen gas is what causes the oxidation of organic fruits and vegetables. This process is what eventually leads to their spoiling. Reducing the concentration of O₂ within the packaging will reduce the rate at which this reaction occurs and increase the edible lifespan of the food⁴
  - In regards to N₂
    - Nitrogen gas in highly unreactive, so a controlled atmosphere with a very high nitrogen content is ideal for maximizing the shelf life of food products. The low permeability of GIENs will allow the package to retain the gases it was packaged with longer, thus expanding the potential of controlled atmosphere packaging⁵

References

Possible Health Hazards
- A major concern of any packaging material is its tendency to “migrate”, the term for the movement of small particles that have flaked off the packaging into the food
- Conclusive data for GIENs are not currently available because the technology required to accurately measure migration, called inductively coupled plasma analysis (ICP), was not available until very recently, however early tests show relatively low migration levels⁶
- Graphene may pose a respiratory risk, as it belongs to a group of compounds called aromatics, many of which are carcinogens
- Because graphene is chemically inert, the body lack the mechanisms both to prevent GIENs from settling in the alveolar walls of the lung and to break it down once there⁷
- These results are not conclusive, and more research must be done to definitively determine risks posed by GIENs

Conclusions
- In terms of functionality, graphene infused elastomer nanocomposites are perfect for food packaging, as they provide vastly increased tensile strength and moisture impermeability that will allow food packaging to better weather the rigors of transport and storage
- However, the methods used to produce GIENs remain untested on industry scales, and in their current form are predicted to be expensive and inefficient; more importantly, valid concerns remain about the safety of using GIENs as food packaging
- If GIENs are to be phased in as a next generation food packaging, the following must occur:
  - More research needs to be done to definitively quantify health risks
  - New, cheaper methods must be developed for production, or old ones modified
  - The improvement in quality must be significant enough to capture public interest

Acknowledgements
We would like to acknowledge the two students who peer reviewed our paper as well as Calvin Hall, our co-chair, for providing advice on how to make our paper better. Additionally, we would like to acknowledge Mark Shearer for providing insights to improve our presentation and Janine Carlock for answering many questions during the writing process.