

# Graphene from Steel

By Tata Steel Europe | Category: Dare to Try

Graphene is a single layer of carbon with unique properties. Typically, graphene is produced by disintegrating graphite (dirty process) and by gas phase deposition (CVD) on a catalytic substrate like Cu or Ni. CVD requires external sources of carbon, which are flammable gases that produce toxic by-products / waste. Hence, an innovative and elegant process was invented which avoids complexity with CVD. A high-quality graphene was grown on steel surface from an atomic carbon available within the steel subsurface and therefore not altering the specific steel structure. Graphene offers a superb corrosion protection to steel owing to its unique impermeability to gases / liquids. Moreover, the "graphenated" steel will own a superior conductivity of graphene. However, this invention results in a patchy coverage, and needs further development.



## The Context

There is a great demand for methods and materials that inhibit corrosion and lengthen the life cycle of steel, since the potential safety risks and annual cost of corrosion in 2016 was USD 2.5 Tr. The protection should behave as a diffusion barrier for environmental oxygen, water and corrosive ions. The coatings often need specific characteristics: certain levels of hardness and elasticity and electrical & thermal conductivity to cope with the steel applications. Graphene is basically a single carbon layer and possesses excellent mechanical & thermal stability, low chemical reactivity, impermeability to gases / liquids and high transparency. These properties make graphene a unique material for functional coatings offering a sustainable future for steel.

## Potential Impact of the Innovation

revenue impact

**\$24.84 bn**



## The Innovation

The technology developed in this invention produces graphene films directly onto low carbon and high strength steels using the atomic carbon available in the steel subsurface by simply vacuum annealing at reasonable temperatures for high strength steel cycle. Graphene films produced by this process offer oxidation barrier protection to steel surface and future corrosion resistance to steel. This process is unique, versatile, and non-hazardous. Moreover, it can be easily adaptable to commercial lines, since steel subsurface itself serves as a precursor, and steel surface acts as a catalyst for graphene growth. The potential is enormous, as it can overperform not only gas phase process, but also other coating processes such as HDG, PVD and electrolysis. In-situ TEM and XPS experiments have confirmed a graphene film growth on steel, but have revealed a patchy graphene growth on pristine steel surfaces of various other grades. The biggest challenge still remains to obtain complete graphene film coverage on the steel surface.



## Overcoming Challenges

The key challenge was to grow graphene directly on steel surface. Traditional routes of graphene deposition are complex, and require an external source of carbon, Cu or Ni catalyst layer, chemical etch and a lengthy transfer process. We have investigated whether iron could be a natural catalyst for graphene growth and explored the option of steel being a source of carbon for the graphene growth. The efforts resulted in high quality graphene films grown on steel surfaces without the need of external catalyst layer (Cu or Ni) and external feedstock of carbon (acetylene). Unprecedented in world practice, the company succeeded to grow the graphene (about 50 micrometers large) domains homogeneously dispersed across the steel surfaces using this unique process of simple annealing and extracting atomic carbon from the steel subsurface.