# Scalable manufacturing methods for wearable graphene based electronics

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Graphene and related materials have a number of unique properties that make them particularly interesting for light and wearable devices with a low environmental impact. Graphene is relatively easy to functionalize and can be extremely sensitive in a sensor application for a wide range of analytes. The wearable electronics area is evolving rapidly towards networks of multi-analyte sensors providing data for self-diagnosis and performance tracking as well as IoT solutions.

Graphene and other layered materials are available in dispersions suitable for deposition for example by printing or coating with many different techniques such as screen printing, flexographic printing, ink-jet, spraying etc., and these scalable methods are also compatible with a range of post-processing techniques to pattern or modify the properties of the deposited material. Thus, for printed leads using pure graphene as a conductor the conductivity of ~1 Ω/▫ can be reached for a practical thickness of < 25 µm.

Circuit integration methods have been developed for combining with printing processes in a scalable manner and thus flexible and lightweight devices can be manufactured in large area or volumes at low cost with a low environmental impact. For practical prototypes hybrid integration is required to achieve the required performance of certain components. It is also beneficial to implement certain functions as traditional packaged components or ICs from both a cost and environmental perspective. Using hybrid integration techniques functionality requiring large area and flexibility printed electronics is applied and for e.g. computing or wireless communication traditional chips will be used. Thus, flex-on-flex methods are also developed to obtain optimized hybrid integration over large devices.

Device manufacturing can utilize traditional or novel biodegradable substrates and has been demonstrated on e.g. paper, fabric and plastic on a range of thicknesses, flexibility, stretchability and biocompatibility.

Recently more focus has been on durability and washability of wearable devices, without introducing costly or un-environmental materials and processing steps. This presentation will focus on aspects of scalable production processes for wearable devices and on the applicability of graphene and related materials in such products.