Although graphene was the first proven two-dimensional (2-D) material, there are many other atomically layered materials which can be extracted/formed into 2-D structures [1]. As is the case of graphene these 2-D materials have very different physical and chemical properties from those of the bulk materials. This leads to the need to assess these materials properties by as many techniques as possible and answer questions such as: when going from 3-D to 2-D, do these materials retain their electronic character (i.e., insulator or semi-metal) and, if the materials have differing phases, which do this? The MAX-phases are an interesting group of such materials, their name derives from there structure being a combination of a transition metal M, an element from the A section of the periodic table and X which is either Carbon or Nitrogen. The phases represent but another class of natural nano-laminated materials encompassing characteristics of metals and ceramics with unique combination of chemical, physical and electrical properties [2]. Utilising a unique layer-by-layer magnetron deposition technique the synthesis temperature was recently significantly reduced to allow the thin film creation of MAX phases on common engineering substrates [3].

Here we present the evidence, for the first time, that one of the MAX-phases, Cr$_2$AlC, can be successfully deposited onto suspended graphene (directly on the TEM grid) at 500 and 600 °C. The graphene membranes have survived deposition as evidenced by microscopic and spectroscopic measurements. The deposited phase formed a nano-crystalline thin layer with island-like morphology on the graphene surface as shown in Fig. 1. The structure, growth orientation, thickness and composition of those nano-structures were revealed via atomic resolution phase contrast (BF) and high angle annular dark field imaging (HAADF), and energy dispersive X-Ray spectroscopy (EDXS). We show that the nano-structures are observed in different epitaxially arranged orientations leading to different structural appearances. In addition to that, based on spectroscopic measurements, the nano-structures with different orientations are rich either in Cr or Al (see Fig.2).

Fig. 1: BF images of the CrAlC nanostructures deposited on graphene at 600 °C. a) an overview, b) a closer look to (a), (c)&(d) show the thin film morphology and the two prevalent epitaxial orientation of the nano-crystallites.

Fig. 2: a) HAADF image of CrAlC nanostructures before taking EDX maps on the region highlighted by yellow rectangular, b) Cr map, c) Al map, d) combination of Cr, Al and C maps, e) combination of HAADF image and Cr, Al and C maps, f) EDXS results.