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From liquid metal core to two dimensional semiconducting skin

Different deposition methods, either chemical or physical based, for two dimensional planar crystals have been devised [1-6]. However, the high quality, large scale and consistent deposition of these materials remain as significant challenges. We introduce a novel approach for depositing large scale two dimensional (2D) post transition metal chalcogenide compounds using the self-limiting metal oxide layer of the metal precursor in liquid form.

Ga, In and Sn, which are the post transition metals, have low melting points. In an oxygen containing atmosphere, these metals quickly form an atomically thin (~0.7 nm) self-limiting oxide layer [4]. The presence of this protective oxide layer increases the wettability of post transition liquid metals on oxygen terminated substrates by providing large van der Waals forces between the two surfaces [7]. After placing this liquid metal with its self-limiting oxide layer on a substrate, the coating is exfoliated due to the large van der Waals forces onto its surface oxide. Using this phenomenon, we establish a process that uses low melting point Ga (29.7°C) to deposit wafer scale printable 2D gallium sulphide from its exfoliated oxide. In this process, the oxide skin of Ga is exclusively placed onto a substrate. This oxide layer is then sulfurised via a specifically designed low temperature procedure to produce large area bilayer (~1.4 nm) 2D gallium sulphide. Controlling the surface chemistry of the substrate allows for selective patterning [7]. It will also be shown that this method can be extended to 2D indium and tin oxides and sulphides. This facile printing method is suitable for large scale fabrication of 2D post deposition sulphide based devices, overcoming one of the major impediments of the fabrication of devices based on these 2D materials.

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Figures

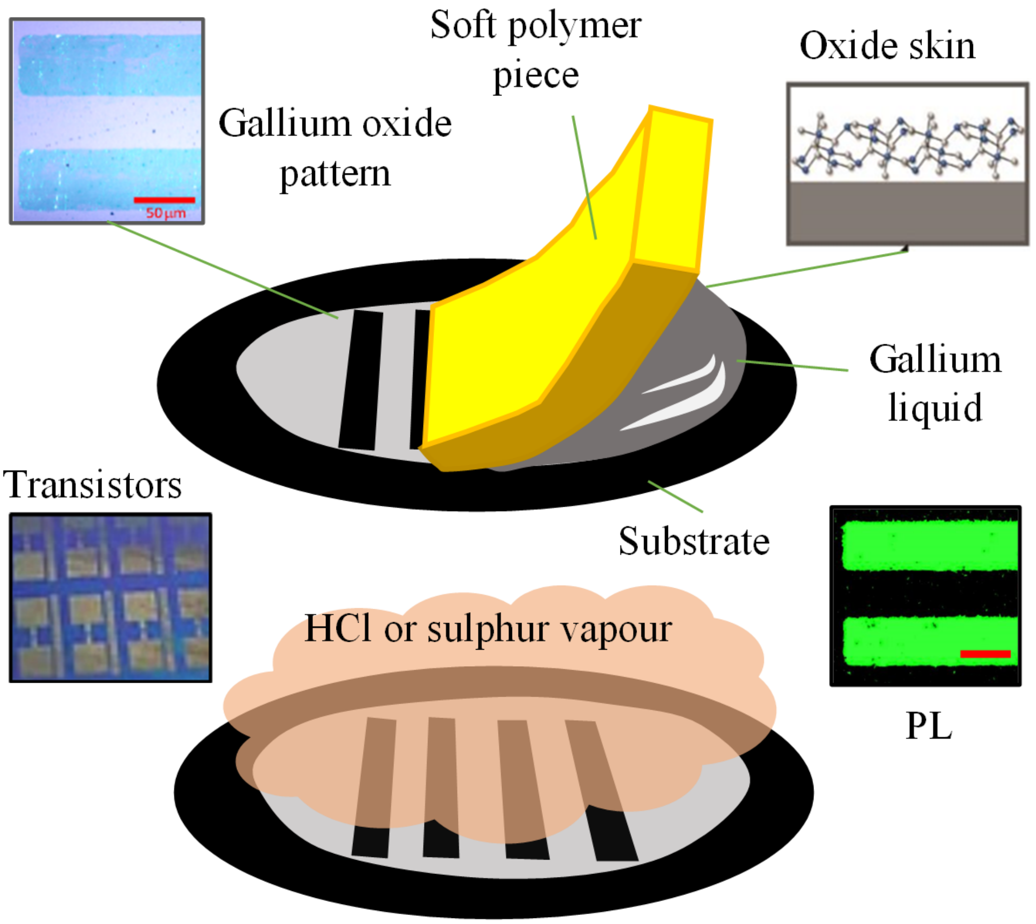

Figure 1: The demonstration of the fabrication process of 2D gallium oxide from gallium liquid metal and transformation of this material to lower bandgap semiconducting 2D gallium sulphide