Large-scale growth and properties of lamellar vanadium sulphide

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Transition metal dichalcogenides (TMDs) in their 2D forms have recently emerged as candidates for the realization of original devices in a context of diversification of functionalities on silicon. These lamellar materials, structurally similar to graphene, exhibit a great diversity of electrical behaviours, from insulator to metal going through semiconductor, as well as many other exciting physical properties (piezoelectricity and photoluminescence for MoS_2 and WS_2, ferromagnetism, etc...). The interest of the scientific community for this family of materials is growing, mainly for the most famous of them: MoS_2 and WS_2. These two well-known 2D films are relatively easy to grow and stabilise since both alloys compositions are well identified over wide temperature ranges [1]. Among TMD family, vanadium sulphide alloys remain little studied due to the difficulty in stabilising a given composition such as VS_2, and to the inherent reaction of vanadium in air resulting on the oxidation of the sulphide surface. There are very limited publications reporting the synthesis of VS_2, and generally, the produced 2D material is in the form of flakes [2]. The synthesis of VS_2 and the development of a stable growth method on large scale is a challenge.

In this work, by following a known chemical route to grow VO_2 using Atomic Layer Deposition (ALD) at low temperature [2], we succeed in the synthesis of a vanadium sulphide alloy on Silicon 300mm diameter. We will describe the process development starting from chemical precursor's choice to the first film synthesis. We will emphasize the possibility to grow a well uniform film of amorphous vanadium thiolate $V_xC_yS_z$ at nanoscale and low temperature (below 200°C). The composition and air reactivity of the film is assessed using quasi-in-situ X-ray Photoelectron Spectroscopy (XPS), which provides an analysis of the bond states without air break. We observe that the thiolate film is quite stable in air through the formation of a surface passivated oxide. During an additional thermal treatment at 950°C in a sulphur ambient, a lamellar structure related to VS_2 hexagonal phase is obtained and visible in Figure 1. Although, the structure is close to the reported XRD data on crystalline VS_2, the extracted composition is clearly sulphur deficient near the composition of V_7S_8. Finally, we will present some of the electrical properties of the material; in particular, we demonstrate material transparency and conductivity at the nanometre scale in Figure 2, and show a p-like behaviour with a workfunction greater than 4.8eV, which makes it suitable for p-contact on silicon.

References

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Figures

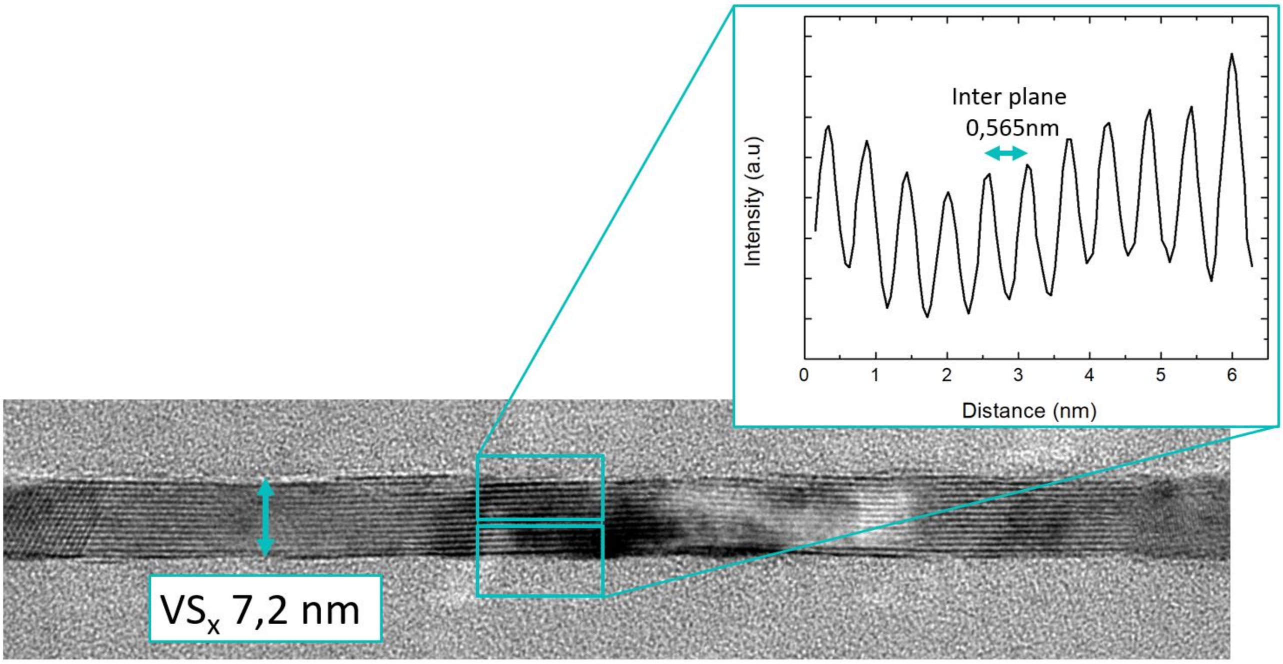

Figure 1: XTEM micrograph of 7.2nm thick $VS_{x\sim1.2}$ deposited by ALD on thick SiO_2 and annealed at 950°C. In inset, an inter plane distance of 0.565nm is extracted.

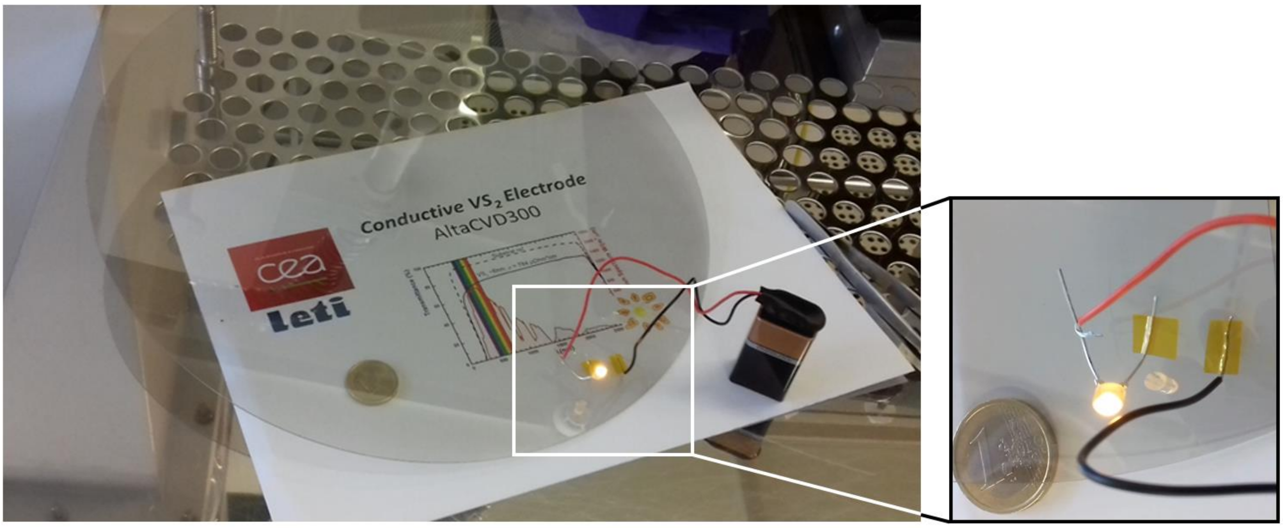

Figure 2: 6nm thick vanadium sulphide deposited on 300mm borosilicate transparent wafer. In inset, the film conductivity is low enough to insure current flow within film thickness between the kapton tape contacts, induces light emitting of a simple diode.

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