Physico-Chemical Properties of V$_2$O$_5$ Thin Films
Obtained by Atomic Layer Deposition (ALD)

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The vanadium pentoxide (V$_2$O$_5$) is a compound of high interest having in a wide range of applications. Among them is its use as a rechargeable cathodic material in lithium batteries. There is growing interest in producing thin film lithium batteries for microelectronic applications. Vanadium pentoxide thin films have been deposited by several methods such as sol-gel, sputtering, chemical vapor deposition (CVD), electron-beam evaporation, thermal evaporation, flash evaporation and pulsed laser deposition (PLD). The investigation of other methods is an important issue since the properties of the films are depending on the deposition method.

In a previous paper (1), we have investigated the use of atomic layer deposition (ALD) to obtain vanadium pentoxide (V$_2$O$_5$) thin films. ALD technique (2) can be considered as a modification of the CVD and can be thus called “alternately pulsed CVD”. Excellent coverage and uniformity of deposition are consequently obtained.

In the present study, vanadium oxide thin films were deposited on titanium substrate at 378K from vanadyl trisopropoxide, VO(OC$_3$H$_7$)$_3$ and water precursors. Since the as-deposited thin films were amorphous, they were annealed in air between 300 and 550°C. In terms of electrochemical properties, V$_2$O$_5$ thin films exhibit a good cyclability in the potential range 3.8 to 2.9 V vs. Li$^+$/Li. X-ray diffraction patterns have shown a strong preferential orientation of the V$_2$O$_5$ nanocrystallites along the substrate surface (Fig. 1) (3). Raman microspectrometry has shown a good crystallization of the V$_2$O$_5$ thin films. Moreover, vibrational changes as lithium insertion proceeds were discussed in relation with structural data drawn from X-ray diffraction.

As a result, specific Raman fingerprints were evidenced during the formation of the successive α, ε, δ and γ Li$_x$V$_2$O$_5$ phases (0≤x≤1.8) related to the first three lithium insertions steps at 3.4, 3.2 and 2.8V vs Li/Li$^+$. (4) The AFM study showed a good film stability before and after annealing by analyzing the film roughness. The root mean square (RMS) is around 20 nm for the V$_2$O$_5$ thin films. The electrical properties of V$_2$O$_5$ films were measured by the broadband dielectric spectroscopy (BDS) in the range of 10 to 10$^{10}$Hz at temperatures varying between 200 and 300 K. The spectra have been analyzed to obtain the electronic dc-conductivity vs. lithium content.

REFERENCES

Fig.1 : XRD pattern of a V$_2$O$_5$ thin film (thickness= 800 nm) annealed at 770°C ($\lambda_{CoK\alpha}$ = 1.7890Å)