ACTIVATION AND GAS SORPTION OF Y-BASED GETTER FILMS FOR WAFER-LEVEL VACUUM PACKAGING OF MICROSENSORS

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Getter films are reactive metallic films able to trap gases after thermal activation in vacuum. They are used in large Ultra High Vacuum (UHV) facilities to reduce both background pressure and electron or photon stimulated desorption. They are also commonly integrated in vacuum packages of resonant, thermal and infrared micro/nano sensors to get high performances owing to the suppression of air damping and thermal losses. The goal is to reach an internal pressure in the package microcavity (≤1µl) lower than 10^{-1}-1 Pa during device lifetime (≥10 years) with a low thermal budget. Thermal activation of getter films aims to promote the diffusion in the film bulk of the passivating molecules, notably oxygen, adsorbed at the surface during air exposure after film deposition. This is required to expose the reactive metals of the getter film at the surface. In this workshop, we will review our recent results [1-4] on activation as well as on oxygen and hydrogen sorption of new (co-)evaporated getter films based on yttrium. This includes Y single film and Y-Al, YV, YVAl, YZr, YZrAl and YTi alloys of variable compositions. We investigated Y as a new getter element because of its very high oxygen and hydrogen diffusion lengths, its high reactivity with oxygen and its ability to irreversibly trap hydrogen owing to the easy formation of stable YH_2 hydride.

Contrary to UHV applications, in a wafer-level vacuum package, activation and gas sorption phases cannot be clearly separated because the vacuum level during activation is not sufficiently low [5]. Consequently, surface analysis techniques mainly used for the investigation of getter film activation in published works are not sufficient. In our works, we used ex-situ and in-situ resistivity and Ion Beam Analysis techniques to get information on both surface and bulk phenomena involved during activation and sorption. We notably developed in-situ measurements of resistivity and oF in-depth film composition by Nuclear Reaction analysis (NRA) as function of temperature and controlled gaseous atmosphere. We will present results obtained by these techniques and by composition in-depth profiles achieved by combining RBS (Rutherford Backscattering), NRA and ERDA (Elastic Recoil Detection analysis). Scanning Electron Microscopy, Atomic Force Microscopy and X-Ray Diffraction (XRD) were also largely used to get information on films surface morphology and microstructure variations.

All deposited 200-400 nm thick getter films on silicon have a low lateral grain size in the 5-30 nm range suitable for gas sorption. Experiments on single Y films showed that single Y films are not stable in air and contain hydrogen after air exposure and that activation temperature is about 250°C. After furnace annealing the in-depth hydrogen profile in the Y film is inverted (lower concentration at the Y film surface) with an unexpected large diffusion of hydrogen in the silicon substrate. Formation of an in-depth Y oxide diffusion barrier and reduction of the silicon native oxide might explain these results.In situ sheet resistance measurement show that lower resistivity YH_2 begins to form at 300°C after 1400 s exposure to 10^{-1} Pa of hydrogen. YH_2 formation at 300-350°C with a low partial pressure of H_2 was confirmed by sheet resistance, ERDA and XRD analyses.

Instead, Y-based alloys are much more stable, have a low initial hydrogen content and are thus more suitable as getter films. The most efficient alloys for oxygen sorption (Y-Ti and Y-V-Al) show the lowest hydrogen/metal ratio after annealing. Y-based getter film alloys containing zirconium and aluminium exhibit the largest ability for hydrogen sorption. In situ and quasi real time NRA analyses of oxygen depth profile in various Y-based getter alloys during a temperature ramp of 5°C/min and $3x10^{-4}$ Pa air pressure demonstrated the occurrence of several activation phases and that $Y_{43}V_{57}$ film has the lowest activation temperature onset (<250°C) while $Y_{44}Zr_{47}Al_8$ films has the highest one. Integration of Y-based getter alloys in real MEMS wafer-level vacuum packages is in progress to compare with thin nanocrystalline co-evaporated $Zr_{85}V_{15}$ films activated at 300°C that were fund close but not fully suitable as a getter film for vacuum packaging of the most demanding MEMS [6].

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