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Tin Whiskers – A Recurring Industrial Problem Examined With Electron Microscopy

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Tin whisker growth has been shown to cause catastrophic failures in many systems. Galaxy VII, IV, and Solidaridad 1 (launched from 1992-1993) are examples of complete satellite losses due to tin whisker induced short circuits on electromagnetic relays (failed 1998-2000). Several other satellites have suffered partial losses due to similar failures of the satellite control processor and it is estimated that there are at least 30 satellites with tin plated relays currently in orbit. Understanding the mechanism for tin whisker formation and ways to avoid them has obvious relevance. Several growth mechanisms have been proposed [e.g., 1-3]. Some involve dislocation-mediated processes whilst others require compressive stresses (micro and macro) as a precursor to growth. One of the difficulties in determining the exact growth mechanism is the problem encountered in forming electron transparent samples of the whiskers.

Tin whiskers were formed directly on electron transparent foils of Muntz metal coated with a thin layer of sputter-deposited tin. Whiskers were observed to form after the samples had been stored at room temperature. Growth rates were increased if the samples were held in an oven at 50°C. Bulk samples were prepared in a similar way by depositing thicker tin layers onto larger brass substrates. Judicious choice of the pressure in the sputtering chamber allowed samples to be prepared where the macroscopic stress in the film was tensile, compressive, or neutral.

Figure 1a shows a FEG-SEM image of the base of a Sn whisker. The grooves or striations observed along its length can be seen to be the result of nucleation occurring on several tin grains. Inter- and intra-granular porosity in the tin film results in the grooves, which continue along the whisker length. This observation shows how whiskers with hollow centers might be formed, something that other studies have found difficult to explain. When a whisker nucleates and grows from a single tin grain with no intragranular porosity the whisker will not have grooved surfaces, Figure 1b. Figure 1c is a TEM image of a Sn whisker growing over the hole in a thin foil. The whisker is electron transparent and when such whiskers were found it was possible to examine their structure. If the nucleation site was close to the edge of the hole then this region of the whisker could also be examined as shown in Figure 1d. The whiskers were found to be monocrystalline, single phase, and contain no extended defects. The absence of dislocations implies that dislocation-mediated growth models are not applicable in this case. Diffraction patterns obtained from the whisker base indicate intermetallic formation that causes a biaxial stress in the tin film. It is suggested that compressive microstresses coupled with diffusion lead to formation of whiskers. The use of appropriate buffer layers may prevent their nucleation [4].

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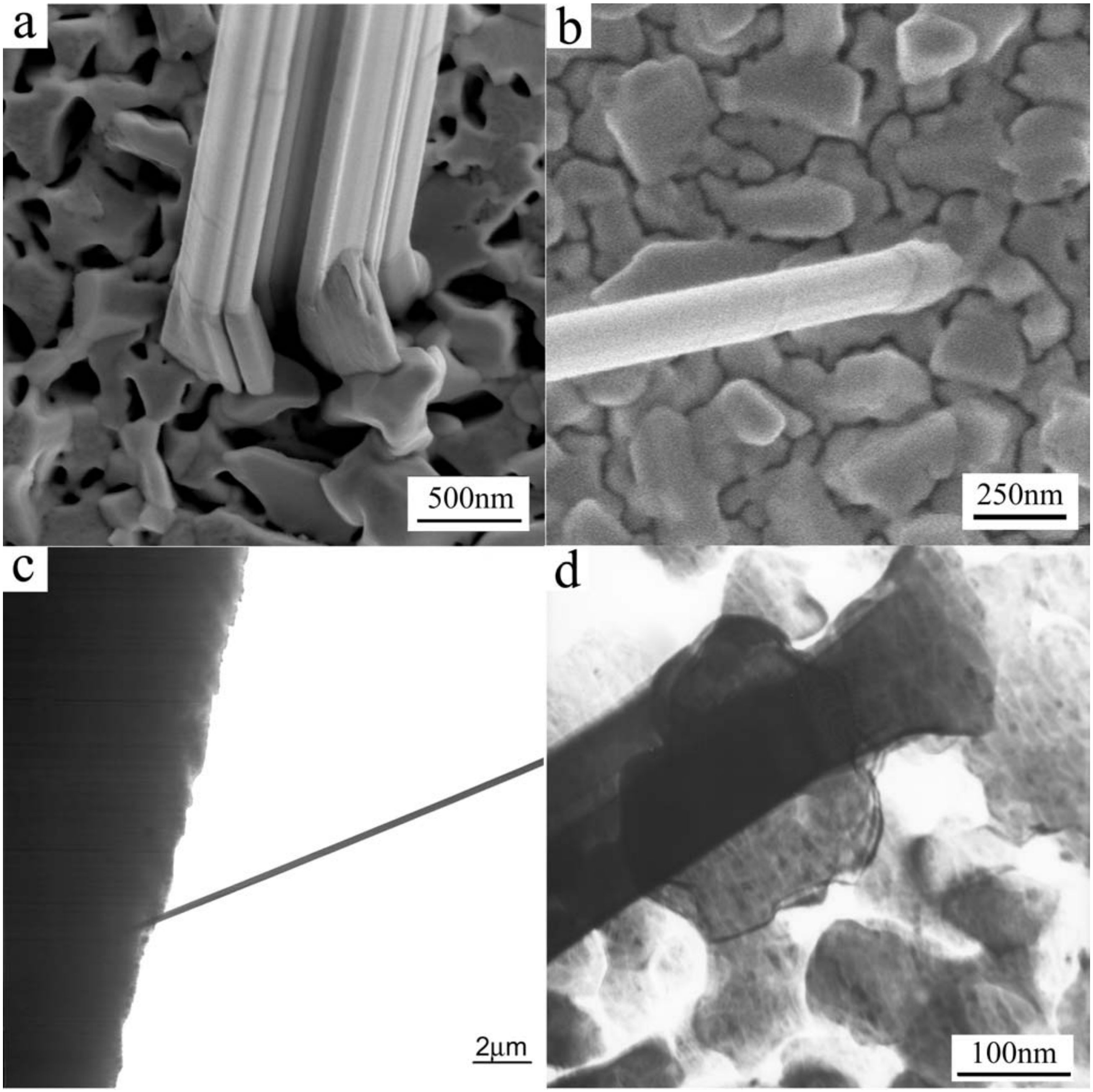

Figure 1 (a) SEM image of a tin whisker nucleating from several grains. (b) SEM image of a tin whisker nucleating from a single grain. (c) Low magnification TEM image of a tin whisker extending over the hole in a foil. (d) Image of the base of an electron transparent whisker.

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