Gold Catalyzed Germanium Nanowires on Titanium

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Abstract:
Germanium nanowires have been grown successfully on titanium. The wires are single crystal, with some low angle stacking faults and other defects. Growth of nanowires on metal substrates offers reduced cost over single crystal substrates, while still offering an electrical contact to the wire core for core-shell junction structures.

Summary of Research:
Nanowires have received considerable interest as a material for photovoltaics (PV) [1-3]. In many proposed systems, the nanowire and a radial cladding on the nanowire serve as an inorganic pn junction. These nanowire PVs suffer from a variety of problems, including electrical parasitic effects, doping control, poor contacts and material quality issues related to the use of metal catalysts.

In order to achieve the highest quality material, nanowires are often grown on single crystal substrates. This allows for the possibility of epitaxial growth on matched substrates. Indeed, it has been shown that wires have preferred orientations of growth in such conditions [4].

One of the principle reasons to use nanowires for PV applications is possible cost reduction. Therefore, the need for a single crystal substrate is a significant drawback. Indeed, if such a substrate is used, one may reasonably inquire—why not simply use the substrate itself as the PV? In order to get around this problem, some groups have shown that it is possible to reuse a single crystal substrate many times over, thus reducing this cost, while preserving the integrity of the growth [5].

Others have grown wires directly on metal films, which are relatively inexpensive [6]. This second route is appealing if growth of high quality wires can be achieved.

We have used thin sheets of evaporated titanium on a silicon substrate, and grown nanowires on them. While silicon wafers are still used in this process they...
are used only to facilitate easy clean room processing. Efficient characterization of the nanowire growth requires a surface whose roughness is less than the nanowire height (several to many micrometers), and polished silicon wafers clearly fit this requirement. Other cleanroom compatible substrates meeting the roughness requirement such as fused silica could easily be substituted. The titanium film is of a great enough thickness (> 200 nm), to decouple the carrier substrate from the growth process at the top interface of the metal film.

Growth of germanium nanowires has been accomplished using both bulk grade 2 titanium sheets, and the thin film method described above. Wires grown on the thin films were characterized using both scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The wires were catalyzed by gold colloidal particles with diameters between 40 and 80 nm. Growth took place in a 1 inch quartz tube furnace at 300°C. GeH₄ was the precursor gas for the catalysis. The partial pressure of GeH₄ during the growth was between 1 and 1.5 Torr depending on the wire diameter used.

The gross morphology of wires grown with these conditions, as seen in Figure 1, is that of straight untapered wires. Each wire retains its catalyst, which is typical of the vapor-liquid-solid process (VLS). In poor quality growth, wires are not straight, so this feature indicates relatively high quality wires. This inference is borne out in TEM microscopy of these wires.

For TEM the wires were removed mechanically into solution and then deposited onto a carbon coated copper grid. From TEM micrographs, such as that in Figure 2, we observe only single crystal nanowires, exhibiting low angle detects such as crystal twinning. This verifies that it is possible to achieve fairly high quality nanowire growths on metal films.

References:

Figure 2: HM-TEM of a single 80 nm germanium nanowire removed from a titanium film showing crystal twinning.