

of 1–3 composite made of epoxy and PZT was cut into a strip (1.5 mm long \times 20 mm wide \times 1.4 mm thick) and glued onto the glass ball. Using a pulse generator connected to the transducer to provide an electrical pulse, a Rayleigh wave with frequency \sim 1.1 MHz was excited. The transducer was subsequently used to monitor the resulting wave propagation. Waveform measurements show that the width of the Rayleigh wave was \sim 20 mm (the width of source transducer) and support the model of diffraction-free propagation of the Rayleigh wave around a solid sphere. The single transducer generated both surface and bulk acoustic waves. Other measurements were performed in which a second transducer was placed collinear with the first and excited with opposite polarity. In these experiments, the ratio of surface-to-bulk acoustic waves was strongly enhanced.

Work is under way to calculate the beam propagation of Rayleigh waves for further comparison with experiment. According to Tsukahara, this phenomenon is probably not limited to Rayleigh waves. “We anticipate that the same mechanism of diffraction-free propagation will be applicable to other waves, such as light and quantum mechanical wave functions, given that the waves are confined to the surface of a sphere with an appropriate diameter-to-wavelength ratio.”

STEFFEN K. KALDOR

Abnormal Oxidation of TiSi_2 in Gate Stacks Found at 750–850°C

A team of researchers at the Hyundai Electronics Industries Company Ltd. has recently reported abnormal oxidation behavior of TiSi_2 sidewalls in patterned TiSi_2 /polysilicon gate stacks at temperatures above 800°C. The enhanced oxidation of the TiSi_2 film was attributed to structural aspects, as it was not observed in unpatterned gate stacks. This suggests that the gate reoxidation of TiSi_2 /polysilicon stacks has to be performed at temperatures below 750°C.

“Low-resistivity gate electrodes are often required for device performance, as silicon devices are scaled down. A common approach is to adopt a structure that is composed of a low-resistivity silicide and doped polysilicon (polycide structure),” said Dae-Gyu Park in the November issue of *Electrochemical and Solid-State Letters*. Gate reoxidation after the patterning process is necessary to increase the reliability of devices. While recent experiments on WSi_2 /polysilicon gate stacks showed oxidation of the metal instead of the silicon at low temperatures, In-Seok Yeo and his co-workers found that

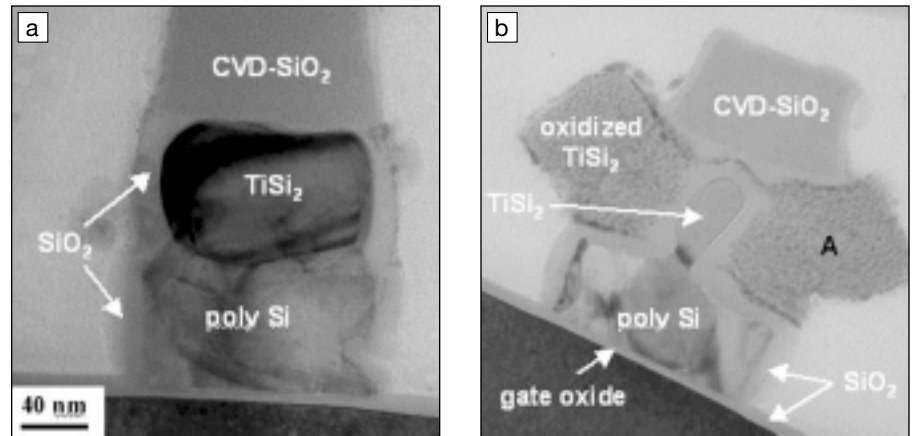


Figure 1. Transmission electron microscopy images of samples oxidized at (a) 750°C and (b) 850°C.

TiSi_2 /polysilicon gate stacks displayed abnormal oxidation behavior at high temperatures.

A 900-Å-thick film of *in situ* phosphorus-doped polysilicon was deposited on a 50-Å-thick gate oxide, followed by deposition of an 800-Å-thick film of TiSi_2 . A 20-s anneal at 850°C was performed in order to obtain the desired low-resistivity C54- TiSi_2 phase as confirmed by x-ray diffraction. The stack was patterned after deposition of a hard oxide mask layer by etching with Cl_2 and O_2 and reoxidized in a dry atmosphere at temperatures between 730°C and 850°C. Films treated at 730–750°C showed no gate line deformation, whereas the samples heated to above 800°C exhibited strong swelling of the sidewalls.

“We were surprised when we observed the severe deformation of the gate sidewalls after oxidation at 800 or 850°C,” said Se-Aug Jang. “From the reported oxidation behavior of other silicide/polysilicon structures, we expected to see abnormal oxides at low temperatures as well. However, the results were perfectly opposite. It was even more interesting that the unpatterned TiSi_2 /polysilicon stacks did not show the abnormal oxidation even at high temperatures at all.”

The group carried out transmission electron microscopy (TEM) studies to gain a detailed understanding of the oxidation process. While the films annealed at low temperatures showed two adjacent layers of polysilicon and TiSi_2 surrounded by a layer of SiO_2 (see Figure 1a), four different regions were observed for the high-temperature samples. The TiSi_2 film appeared to have shrunk considerably and was surrounded and separated from the polysilicon by SiO_2 . Furthermore, regions of a composite were found to

extrude from the original sidewall positions (see Figure 1b). This composite, marked “A” in Figure 1b, consisted of nanocrystalline TiO_2 in an amorphous SiO_2 matrix, which was identified from a high-resolution TEM study.

“We believe that this phenomenon is related to the simultaneous exposure of TiSi_2 and polysilicon to the oxidant, as we did not observe it in unpatterned films,” said Yeo. “We have ruled out any effects from polysilicon film thickness as well as etching damage, and we will conduct further studies that will hopefully help to clarify the mechanism.”

CORA LIND

Si/TiN Nanocomposites Exhibit Stable Capacities as Anode Material for Li-Ion Batteries

Research efforts have been directed toward the development of alternative anode materials for Li-ion batteries to achieve higher capacities than possible with traditional graphite anodes. Many projects have focused on intermetallic compounds containing lithium because of their high gravimetric/volumetric capacities. However, lithium alloys present problems, due to a large volume change during charge/discharge that results in a cracking of the anodes and loss of capacity during cycling. To avoid this problem, composite microstructures of a finely dispersed interconnected active phase in an inactive host structure have been explored. In the November issue of *Electrochemical and Solid-State Letters*, researchers from Carnegie Mellon University (CMU) and Blomgren Consulting Services Ltd. have reported that their composites, which consist of fine Si particles in a TiN matrix, exhibited stable capacities of \sim 300 mAh/g and good capacity retention.

P.N. Kumta, professor of materials science and engineering at CMU, said, "We chose TiN because of its electrical conductivity and mechanical strength, combined with electrochemical inertness to Li and chemical inertness to both Li and Si. It seemed to be a very promising material, but of course we first had to find a suitable synthesis process for composites." His group explored high-energy mechanical milling of Si and TiN, as this technique can generate amorphous, metastable, and nanophase structures.

Preliminary experiments showed that a 1:2 molar ratio of Si:TiN exhibited the best electrochemical properties. X-ray diffraction in combination with energy-dispersive x-ray analysis demonstrated that the composites consisted of nanocrystalline TiN with amorphous Si nanoparticles homogeneously distributed throughout the matrix after as little as 6 h of milling time. Increased milling times led to a decrease in the initial capacity of the composites.

"We are not sure yet what causes this

decrease," said Il-seok Kim of CMU. "It could be because the Si nanoparticles are embedded or enclosed by TiN during milling, which would prevent their reaction with Li."

Composites obtained after milling for 12 h exhibited stable capacities of 300 mAh/g, indicating that a large fraction of Si is inactive (~44%). Although the gravimetric capacity is lower than that of conventional carbon, this value corresponds to a 30% higher volumetric capacity, reflecting the promising nature of the composites. Cycling data showed an irreversible capacity loss (~30%) during the first cycle.

"We are still trying to understand the exact reason for this loss. It could be due to the formation of a Li-containing passivation layer or surface oxidation," said G.E. Blomgren. No cracks were present on the electrode surfaces after 30 cycles, and no changes in morphology were observed, indicating good microstructural stability.

Kumta said, "We have shown that Si/TiN nanocomposites are promising candidates as anodes for Li-ion batteries.

But there is still a lot of optimization that needs to be done. We are currently working on detailed structural and electrochemical studies."

CORA LIND

Scanning Tunneling Microscope Imaging of Cu on Cu(111) Yields Estimates of Surface-Mediated Interaction Potentials

A quantitative study of the long-range interaction between single copper adatoms on Cu(111) reveals significant changes in the growth of Cu/Cu(111) at low temperatures. As reported in the October 2 issue of *Physical Review Letters*, an international research team from Berlin University and the Paul Drude Institute for Solid-State Electronics in Berlin, Germany, and Chalmers University of Technology and Göteborg University in Sweden have experimented with a long-range interaction mediated by a two-dimensional nearly free electron gas. Their experiments were performed with a scanning tunneling microscope (STM) operated at low temper-

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