China's first diamond MESFET with gigahertz frequency performance

Cut-off frequency and maximum oscillation frequency reach 1.7GHz and 2.5GHz, respectively; shorter gate lengths promise improvement.

China-based researchers have reported that country's first diamond metal-semiconductor field-effect transistors (MESFETs) with RF characteristics [Feng ZhiHong et al, Science China Technological Sciences, vol56, p957, 2013]. The team was based at four sites: Hebei Semiconductor Research Institute, Hebei University of Technology, University of Science and Technology Beijing, and Hebei Institute of Laser.

Diamond is of interest for high-power, high-frequency and high-temperature electronics due to its high breakdown field (~10MV/cm, which is 3.3x that of silicon carbide and 4x that of gallium nitride), its high thermal conductivity (~22W/cm-K, 4x SiC, 13x GaN), and its low dielectric constant (~5.7). Unfortunately, large-scale diamond manufacture is not available as yet.

The researchers used a 15mm x 15mm x 0.3mm free-standing polycrystalline film grown by arc melting. The polycrystalline grains were larger than 100μm — of the order of the size of the fabricated transistors. A p-type surface channel was created using a hydrogen plasma treatment. The treated samples had a surface channel carrier density of $10^{12}/cm^2$ and mobility $20cm^2/V\text{-}s$.

Devices were fabricated using gold masks that were patterned using lithography. Gold masking was needed to avoid damage to the hydrogen termination of the diamond surface from oxygen plasma used to remove

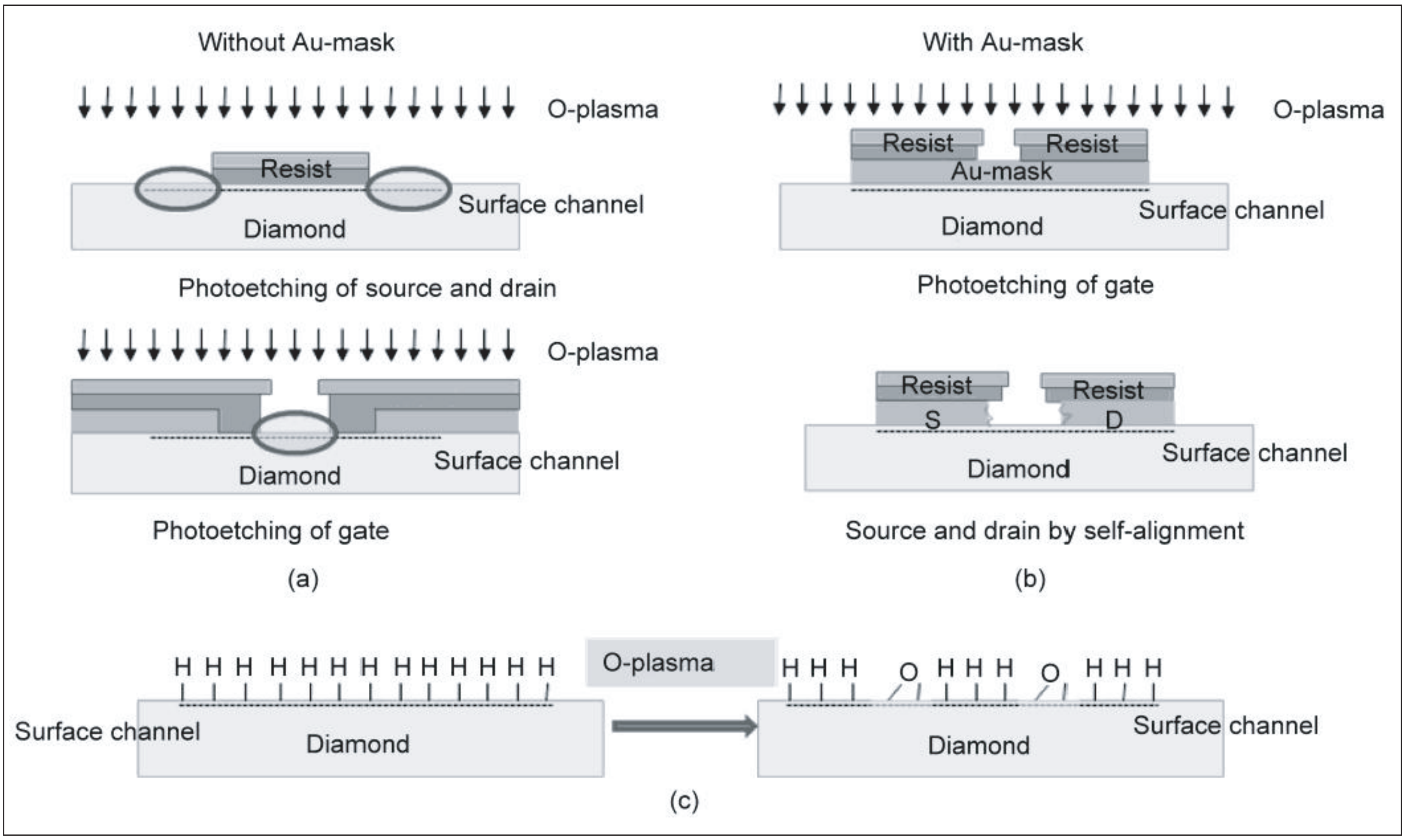

Figure 1. (a) The lithography process with (a) and without (b) Au-mask. Damaged areas are indicated by circles; (c) O-plasma on hydrogen-terminated diamond surfaces.

resist layers (Figure 1). Unannealed gold also makes a good ohmic contact with the hydrogenated diamond surface with a specific resistivity of $10^{-5}\Omega\text{-cm}^2$.

The devices were isolated using an oxygen plasma mesa etch. A selective etch of the gold with potassium iodide created the source and drain electrode regions. The 2µm Schottky gate was made from aluminium. The gate width was 2x100µm.

The maximum drain current density was increased to 204mA/mm when using gold masking, compared with 22mA/mm without gold masking. The maximum drain current density of 204mA/mm was achieved with a negatively biased gate of –6V. The maximum transconductance was 20mS/mm at –1.5V gate, and the off-state breakdown voltage was –47V.

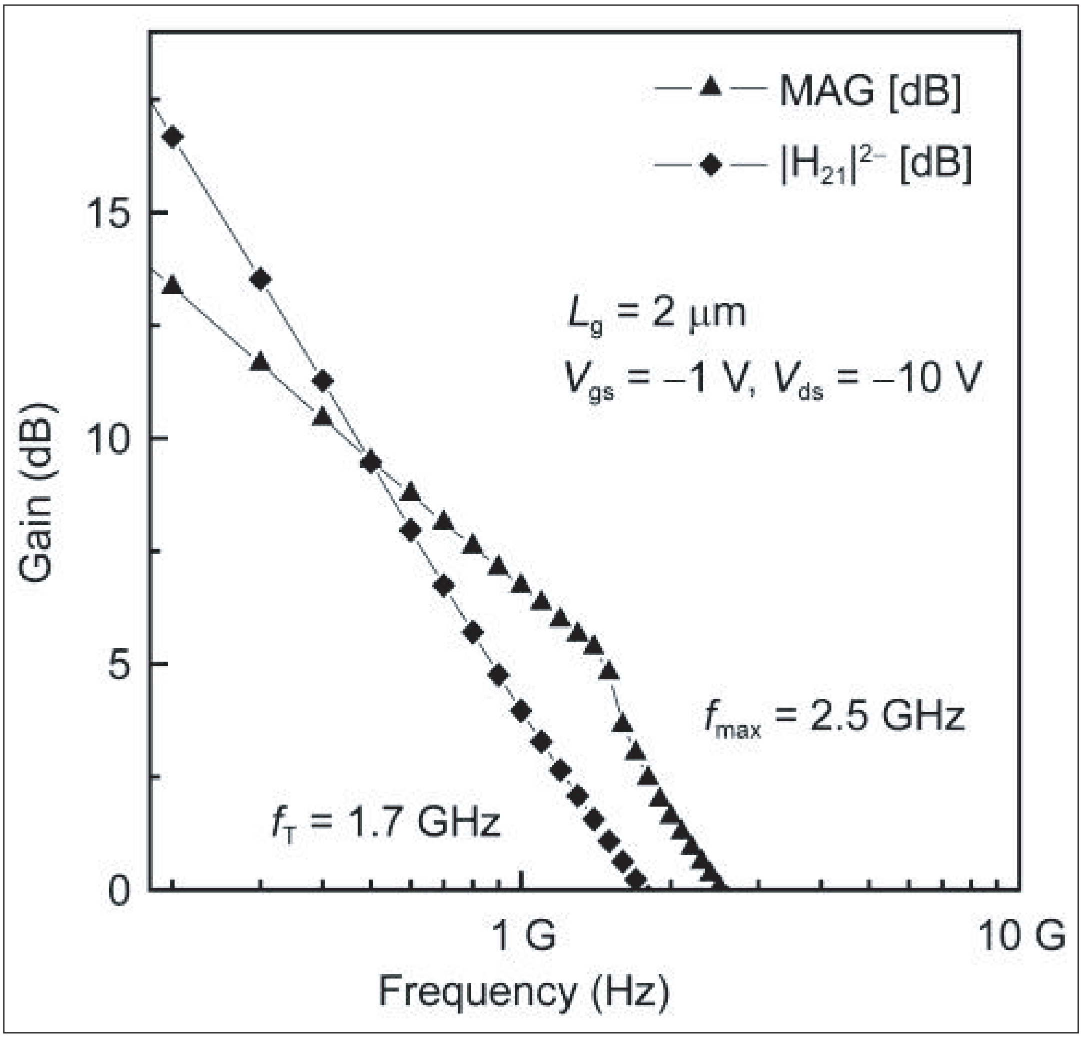

Figure 2. DC and pulsed current–voltage (I–V) performances of HEMT (a) and FP-MIS HEMT (b).

The extrinsic cut-off and maximum oscillation frequencies were 1.7GHz and 2.5GHz, respectively (Figure 2). The researchers believe that these values can be improved with shorter gate lengths. Outside of China, diamond MESFETs with frequency performance values of tens of gigahertz have been fabricated.

The frequency response was lower than expected. This could be attributed to the effects of the grain boundaries and problems with crystal quality inside the grains. ■

http://link.springer.com/article/10.1007/s11431-013-5163-z

Author: Mike Cooke