Reaching beyond Diamond to Sapphire, a 7 eV Semiconductor

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We report Si-doped α-(Al*x*Ga1–*x*)2O3 with the sapphire structure and a bandgap exceeding 7 eV synthesized by suboxide MBE (*S*-MBE). In *S*-MBE, pre-oxidized molecular beams of the constituents, i.e., Ga2O and SiO for the growth of Si-doped α-(Al*x*Ga1–*x*)2O3, are supplied. Providing a suboxide molecular beam bypasses the rate-limiting first step of the two-step reaction mechanism involved in the growth of α-Ga2O3 by conventional MBE. As a result,

growth rates exceeding 1 μm/h for α-(Al*x*Ga1–*x*)2O3 by *S*-MBE are readily achieved on (101$0)

sapphire substrates, resulting in films with high structural perfection and smooth surfaces. To get electrical conductivity in the Si-doped α-(Al*x*Ga1–*x*)2O3 layers, we find it necessary to deposit two layers. First a relaxed α-(Al*x*Ga1–*x*)2O3 buffer layer is grown at high substrate

temperature (*T*sub) on a (101$0) sapphire substrate. This is followed by an Si-doped α-(Al*x*Ga1-*x*)2O3 overlayer that is commensurately strained to the underlayer and grown at low

*T*sub. Only overlayers grown at low *T*sub are found to exhibit conductivity. While conductive films have been achieved at growth rates as high as 4.2 µm/h, typical rates for the doped layers

are around 0.6 µm/h. The growth window for conductive Si-doped 𝘢-Ga2O3 (*x*=0) films is approximately *T*sub = 425–525 °C; at higher *x* the growth window for conductive Si-doped α-(Al*x*Ga1–*x*)2O3 films narrows to approximately *T*sub = 470–500 °C. In these bilayer structures we observe room-temperature mobilities as high as 90 cm2/(V·s) for α-Ga2O3. The α-(Al*x*Ga1-*x*)2O3 films conduct for *x* as high as 0.58, corresponding to a bandgap of 7.01 eV. This makes α-(Al*x*Ga1–*x*)2O3 the highest bandgap semiconductor known. Conductivities at room temperature greatly exceeding all prior reports on α-(Al*x*Ga1–*x*)2O3 films are achieved at high *x*.

\*This work was performed in collaboration with the coauthors listed in the references below.

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