

Cr₂O₃ – A Novel and Versatile Material for Nanofabrication

B. Robert Ilic,¹ Christopher H. Ray,¹ Kerry Seibein,¹ and J. Alexander Liddle¹
¹*Center for Nanoscale Science and Technology, National Institute of Standards
and Technology, 100 Bureau Drive, Gaithersburg, MD 20899*
liddle@nist.gov

The fabrication of micro- and nanoelectromechanical systems (MEMS/NEMS) and micro- and nanofluidic devices often requires the use of a sacrificial layer material to produce free-standing mechanical structures. Ideally, such a material should be easy to deposit, with controllable stress, inert with respect to interactions with any of the other materials used to build the structure, readily patterned, and removable in a way that has no effect on the other materials involved. These constraints are quite limiting, and are only satisfied by a small number of sacrificial layer materials.

In the context of devices fabricated using Si as a platform material, SiO₂ is often used as a sacrificial layer, being removable by liquid or vapor HF. This process offers almost unlimited selectivity with respect to Si, but HF is not compatible with many metals or other dielectrics. Si can act as a sacrificial material itself, with respect to SiO₂ or SiN_x, but the strong basic etchants required (tetramethyl ammonium hydroxide, or KOH, respectively) are, again, problematic with respect to many other materials, and provide good, but not unlimited selectivity.

Here we introduce Cr₂O₃ as a versatile sacrificial layer material. It can be sputter-deposited in films up to at least 1 μm thick, with low, and controllable stress (Fig. 1). It is stable up to at least 1000 °C (Fig. 3), enabling subsequent high temperature processing steps, such as the deposition of LPCVD SiN_x. It does not react measurably with other common device materials, including metals, even at high temperatures, and can therefore be used as a protective encapsulant during anneals. It can be patterned readily using a Cl₂/O₂ reactive ion etch, typically etching at approximately 100 nm per minute. This etch chemistry exhibits excellent selectivity to both SiO₂ and SiN_x, allowing either material to serve as an etch stop. In addition, Cr₂O₃ can be used as a highly-resistant hard mask for fluorine-based dry etches. Cr₂O₃ is also unaffected by most mineral acids and strong bases and can thus be used as a protective layer. Finally, once processing is complete, it can be removed using standard ceric ammonium nitrate etchants (Fig. 2). This wet etch chemistry shows almost infinite etch selectivity with respect to Si, SiO₂, SiN_x, Pt, Ti, polyimide, and most other materials. Given all these characteristics, Cr₂O₃ appears to be an ideal sacrificial layer material. We will present a detailed description of the deposition, chemical resistance, etching, and removal characteristics of this material.

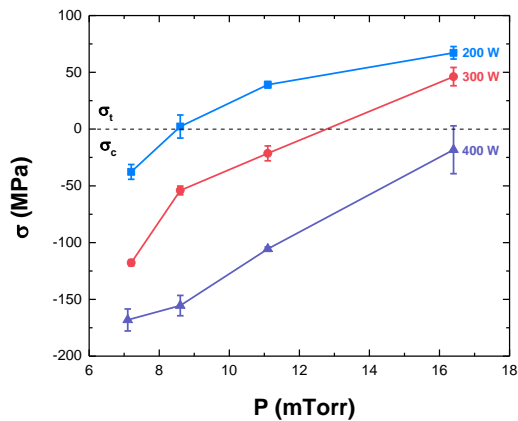


Figure 1. Thin-film stress as a function of pressure for sputter deposited Cr_2O_3 , showing the ability to access both tensile (σ_t), compressive (σ_c), and near zero stresses. The deposition rate is largely independent of pressure and is ≈ 0.06 nm/s at 200 W, ≈ 0.1 nm/s at 300 W, and ≈ 0.14 nm/s at 400 W.

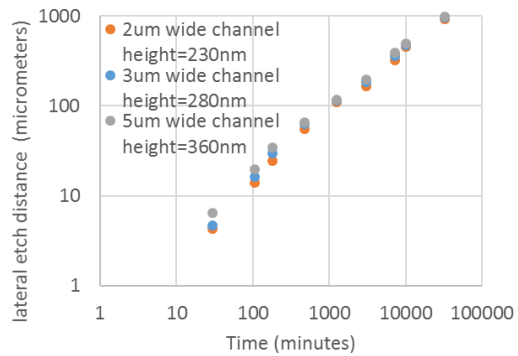


Figure 2. Lateral etch distance as a function of time for in LPCVD SiN_x microfluidic channels. Note the existence of a short incubation period before etching begins. For the distances and times tested, the etch rate rapidly becomes diffusion limited.

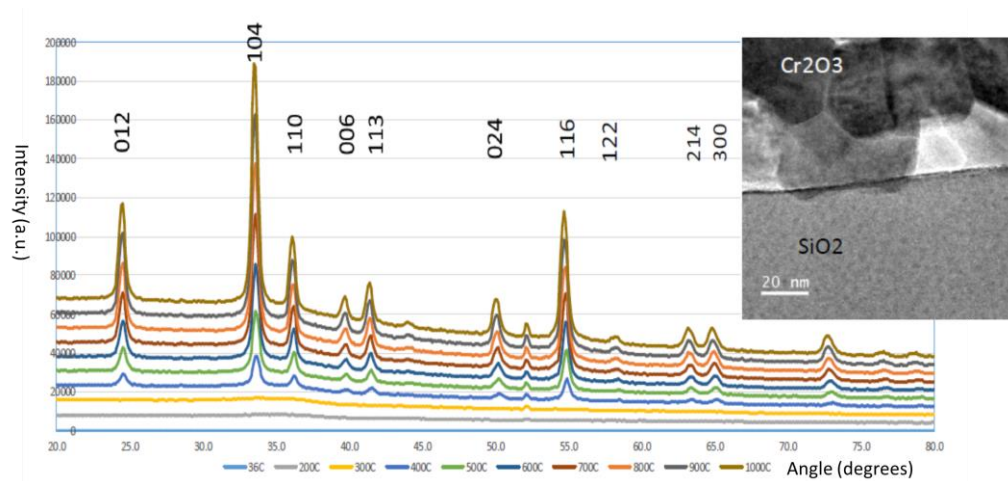


Figure 3. X-ray diffraction data from Cr_2O_3 film as a function of annealing temperature. The material begins to crystallize at 400 °C, becoming increasingly dense, crystalline and under greater tensile stress as the annealing temperature increases. The inset shows the nanocrystalline material structure after an anneal at 1000 °