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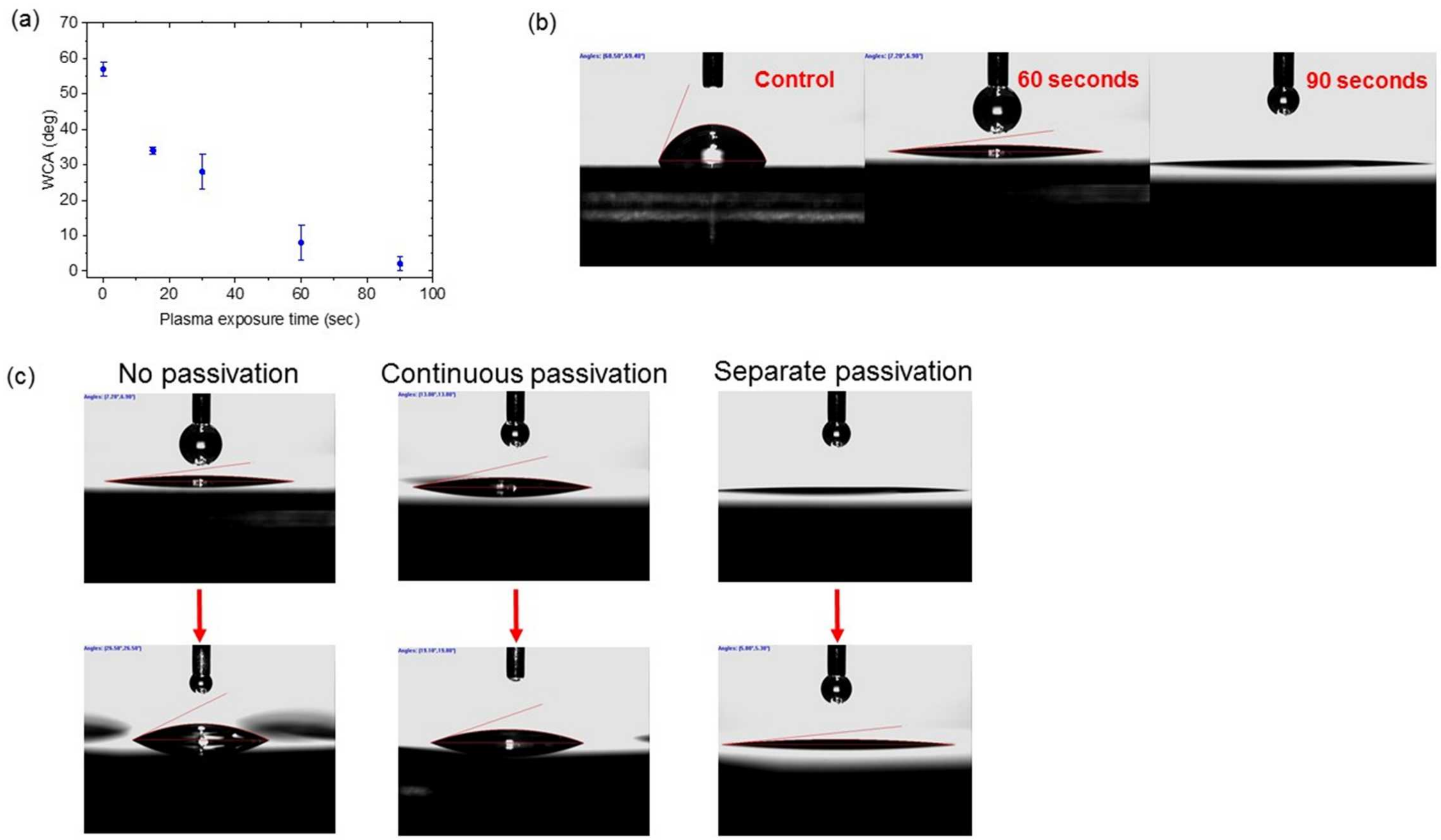
Plasma cleaning is an integral part of electronics processing used for surface decontamination, wire bonding, wafer-to-wafer interconnect formation, preparation for film growth, and many other process steps. Plasma cleaning and passivation of aluminum is of particular importance because any degree of ambient exposure results in a rapidly-forming native oxide several nanometers in thickness, potentially deteriorating the metal's electrical and mechanical properties. Careful control of this oxidized surface at the atomic scale is of paramount importance for many steps. In this work we use a flexible, high-throughput, low-damage atmospheric plasma treatment system to fully reduce oxidized aluminum surfaces and passivate against future re-oxidation. Wire bond pull tests and water contact angle (WCA) measurements were used to initially characterize the aluminum cleaning process. Aluminum wire bonds made to an untreated aluminum surface failed under a force of (10.1 ± 1.8) grams. Exposing the aluminum surface to a hydrogen-based plasma prior to wire bonding resulted in an increased bond strength, requiring a force of (13.2 ± 0.9) grams for failure. WCA measurements correlate this enhancement with native oxide removal: untreated aluminum samples show a weakly hydrophilic surface with a contact angle of (57 ± 2) degrees. Exposing the samples to the same hydrogen-based plasma reduces the WCA to (28 ± 5) degrees, suggesting the degree of oxidation is reduced. Increasing the plasma exposure time by a factor of three reduces the WCA to zero, indicating that the native oxide has been complete removed, Fig. (a) and (b). However, the WCA increases rapidly under ambient exposure. To combat this re-oxidation, nitrogen gas is added to the plasma in order to passivate broken Al-O bonds and improve process flexibility. Both mixed mode – hydrogen and nitrogen mixed gas flow - and sequential – separate hydrogen and nitrogen steps – are investigated in order to maximize the time with minimal WCA. Both show improved resistance to aluminum re-oxidation: WCA increases from 12 to 18 degrees in mixed passivation mode, while a separate passivation step shows superior resistance with a modest WCA increase from 2 to 6 degrees, Fig. (c). The cleaning and passivation mechanisms will be further characterized with x-ray photoelectron spectroscopy measurements. Extensions to aluminum nitride film growth on plasma-cleaned and passivated aluminum substrates are also underway.



Abstract Figure. (a) Water contact angle (WCA) as a function of plasma exposure time. (b) Water droplet shape evolution with increasing plasma exposure time. (c) Water droplet size before (top row) and after (bottom row) 30 minute ambient clean room exposure.