LOW-TEMPERATURE CONTACTS FOR ATOMICALLY PRECISE DELTA-DOPED SILICON MICROELECTRONICS

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As Moore's law comes to an end, it is time to explore ways of manufacturing smaller, high-speed devices. Atomically precise manufacturing provides a path to assemble devices with atomic-level precision, which can be employed in high-performance areas like quantum computers, space technology, electronic warfare, and super-sensitive sensors. Scanning tunneling microscope (STM) based Hydrogen Depassivation Lithography (HDL) allows desorption of hydrogen atoms from the surface in atomically precise patterns [1]. This technology opens the door for a plethora of opportunities to conceive new atomically precise devices[2].

Accurate delta doping at desired locations is possible using HDL coupled with STM instrumentation. Since the doping distribution vertical to the doping plane appears as a delta function, it is called delta doping [3]. Bipolar junction transistors made with small bases using delta-doped semiconductors are expected to exhibit better characteristics such as lower 1/f noise, well-matched differential pairs, better gain-bandwidth products, and improved radiation hardness behavior. In addition, the very high densities in the delta-doped areas circumvents freeze-out at low temperatures, making them suitable candidates for quantum computers and space applications. On the other hand, it is challenging to achieve good electrical contacts to delta-doped semiconductors because of misalignment problems in small-area contact regions, high-temperature processing during metal contact formation can cause diffusion of dopants, and other undesirable effects influencing the behavior of the undoped epitaxial silicon cap layer used to protect the delta-doped layer.

Under a STTR Phase II program,* research is being carried out to develop bipolar delta-doped devices both by direct electrical contact to delta-doped layers and by the use of traditional implanted layers that have delta-doped layers formed on top. This investigation shows how Pd in the form of palladium silicide [4] and as a metal can be used to make electrical contact to delta-doped regions and implanted regions, both *p*-type (boron) and *n*-type (phosphorous). Electrical measurements are made to demonstrate the quality of the electrical contacts. These measurements explore the effects of annealing conditions on the I-V characteristics of the electrical contacts as well as the temperature dependences of the I-V behavior from 5 K to 295 K.

Figure 1 shows the metallization layer to allow external contacts to test the devices and higher magnification details of the vias and contacts to the delta-doped devices. Figure 2 is an example of an I-V plot demonstrating electrical contact to *n*-type and *p*-type implants.

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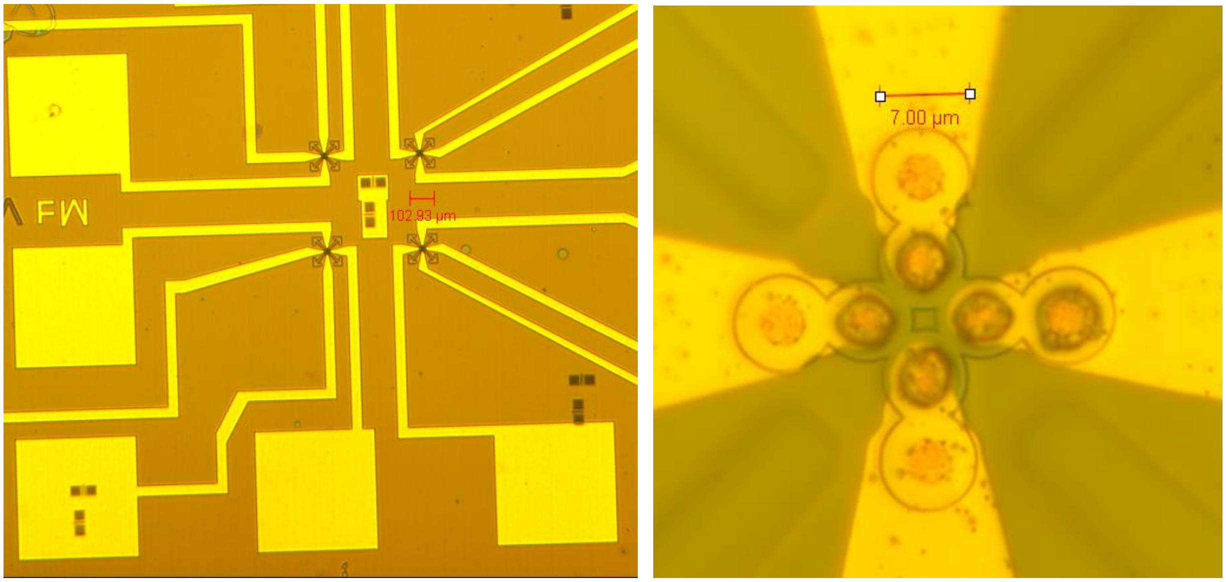

Fig 1: Optical microscopy image of the Ti/Au contact pads with Pd as contact metal with a magnified image showing the contact openings on the right

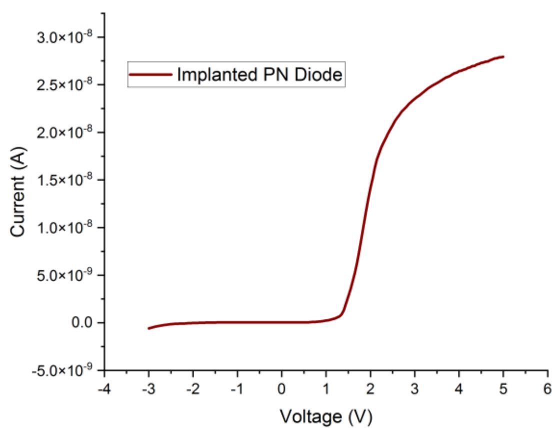

Fig 2: Plot showing the I-V characteristics of *p-n* diode with implanted boron and phosphorous dopants

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