Resistivity of Nickel Silicide Thin Films

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ABSTRACT

The characterization of resistivity within thin films is paramount for proper integration into modern electronics wherein they show promise as contact materials due to their low contact resistance and high conductivity. Nickel silicide compounds often form in microelectronics at intersections between nickel and silicon, traditionally forming as a variety of intermetallic compounds including NiSi, Ni_2Si, Ni_3Si, Ni_3Si_2, and $NiSi_2$. Within this study, nickel silicide thin films ranging in thickness from 25nm to 110nm were synthesized on a silicon wafer substrate utilizing vapor deposition at a temperature of 900°C in low vacuum with pressure in the µTorr range. Analysis of synthesized films yielded a decreasing resistivity in samples with film thickness below 45nm, and for samples with film thickness above 45nm resistivity plateaued with an average resistivity of 23.35 Ω*nm.

INTRODUCTION

The increased conductivity of nickel silicide compared to other metallic compounds offers potential for integration into numerous materials and electronics including thin film transistors and CMOS low-power integrated circuits[1,2]. Nickel silicide offers advantages in that resistivity after formation is similar to Titanium disilicide or Cobalt disilicide but requires significantly less silicon during synthesis[3]. Utilizing a vapor deposition technique to synthesize films allows for precise control over film thickness as measured via a crystal growth monitor during deposition, with evaluated thicknesses ranging from 25-110nm. Precise temperature control during synthesis is essential, as temperatures in the range of 900-1200°C cause deterioration of the Silicon substrate leading to uneven film formation. The decreased resistivity of NiS thin films following high-temperature deposition has yielded results indicating that films have a resistivity of approximately 15µΩ*cm, and maintain relatively high thermal stability[4]. This experiment serves to evaluate the resistivity of nickel silicide thin films following vapor deposition at high temperature, with resistivity measured via Four-Point Probe.

METHODS

- Sample preparation was carried out by preparing 5mm x 20mm rectangles cut from 51mm diameter, 320-350µm thick Silicon wafers.
- A filament was then prepared using 0.5mm diameter nickel wire (CAS#7440-02-0) by wrapping approximately 6cm of wire around a 0.7mm diameter tantalum wire (CAS#7440-25-7), with 1cm legs.
- Both the sample and filament were attached to the sample holder as shown in Figure 1.
- The sample holder was then placed into a Kurt J. Lesker spherical vacuum chamber (Figure 2) which was sealed and pumped to low vacuum utilizing a Pfeiffer HiCube80 Eco with HiPace80 Turbo Pump.
- After reaching a vacuum speed of 9000 RPM, the electrodes were attached to the sample holder and the sample was heated to approximately 500°C.
- Following a 30-minute heating period at 500°C, the sample was flashed quickly to 1200°C for 5 seconds as measured via a Spectrodyne optical pyrometer and cooled to 500°C.
- The flashing process was repeated for a total of 3 flashes, after which the sample was set to a dosing temperature of 900°C.

METHODS cont.

- To induce dosing, current was passed through the filament via Tack Life MDCO2 power supplies until glowing in a well-lit room.
- At this point, the FTM2400 crystal growth monitor was zeroed, and the sample was dosed to the appropriate thickness.
- Following film deposition, the resistivity of each sample was analyzed via an Ossila T2001A3 Four-Point Probe with a a current of 2000µA, 0.02V increments, and 25 repeats at 256 samples per point.
- Each sample was analyzed three times via the Four-Point probe, and the average of the three samples was taken to obtain each resistivity.

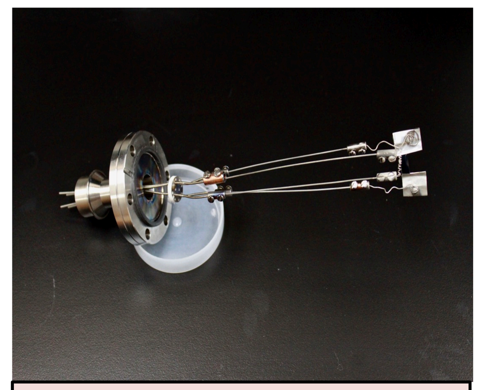


Figure 1: The above picture is of the sample holder used during sample dosing.

Figure 2: The Kurt J. Lesker Spherical Vacuum Chamber used during dosing.

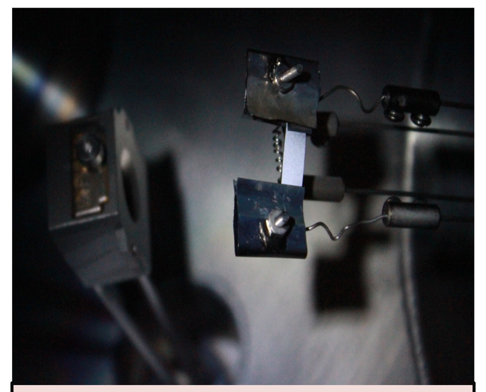
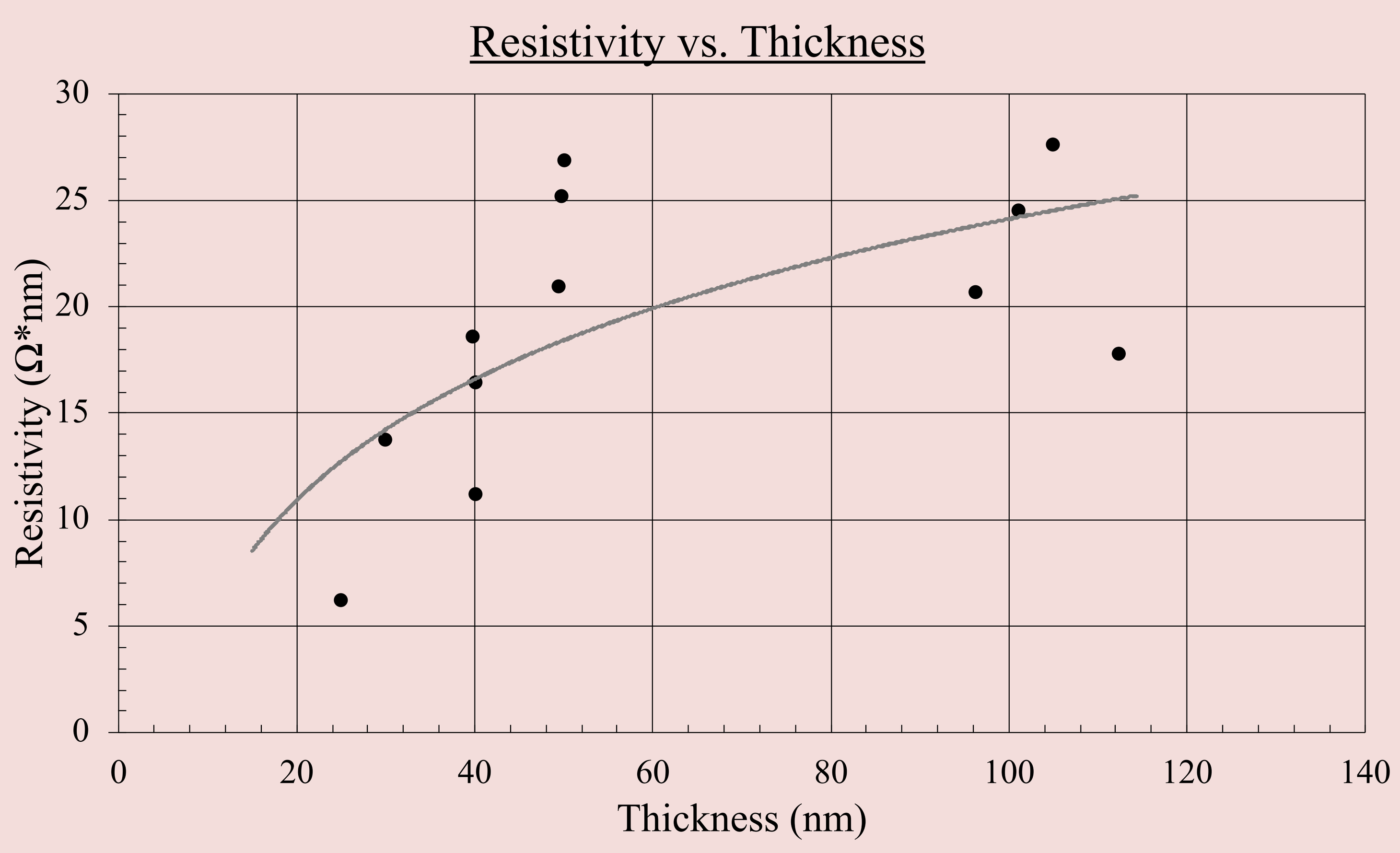


Figure 3: Placement of the sample and filament within the chamber with XTL Monitor in rear.

RESULTS/DISCUSSION

Analysis of sample resistivity after synthesis yielded several surprising and unexpected trends. In theory, as film thickness increases, the resistivity should decrease as increased thickness allows more space for charge carriers to move throughout the material un-hindered. Resistivity within a material is traditionally the result of microstructure imperfections combined with interactions between charge carriers and other particles such as phonons. However, this trend was not observed within the thin films, as resistivity tended to decrease in thinner films compared to thicker films. A notable leveling-off of resistivity occurred in samples with thickness greater than 45nm, as resistivity remained fairly constant from 45-110nm with an average value of 23.35 Ω*nm. Shown below in Figure 1 are the results from resistivity analysis of all samples, with the gray trendline highlighting the aforementioned trend.



RESULTS/DISCUSSION cont.

The unexpected trends in resistivity are attributable to several possible causes, with the uneven/incomplete film formation being most likely. This incomplete or uneven film formation is more likely to be seen in thinner samples and could possibly result in one or more probing electrodes contacting an uncoated surface resulting in a significantly reduced measured resistance more comparable to that of the Silicon substrate than of the film itself. Further research would most likely involve sample characterization via scanning electron microscopy or scanning tunneling microscopy with SEM allowing for determination of the uniformity of the thin film, and STM allowing for more precise determination of sample composition.

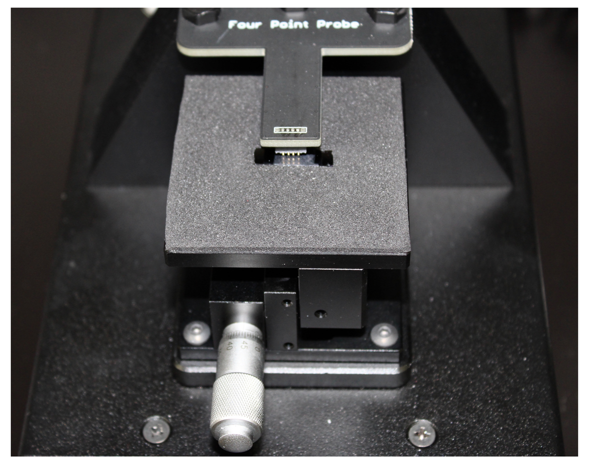


Figure 4: Sample placement in the Ossila Four Point Probe

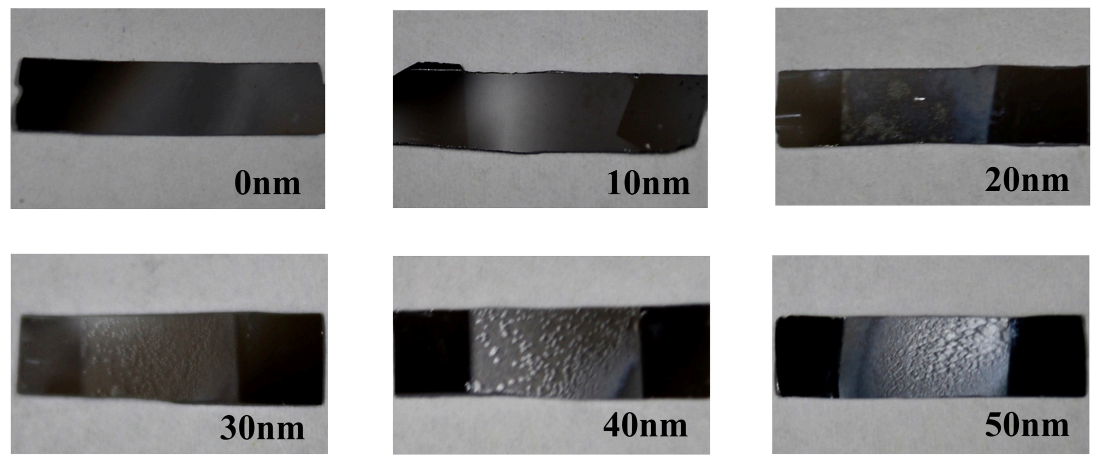


Figure 5 : The above samples are of thicknesses from 0-50nm, note the roughened appearance of the 40 and 50nm samples (bottom right) possibly indicating uneven film deposition.

SUMMARY/CONCLUSIONS

Overall, use of a vapor deposition technique at 900°C, utilizing 0.5mm diameter nickel wire as the vapor source allowed for formation of nickel silicide thin films on a Silicon substrate. Subsequent characterization of films ranging from 25-110nm in thickness via Four-Point Probe resulted in an unexpected trend in resistivity wherein sample below 45nm exhibited a lower resistivity compared to samples above 45nm. Furthermore, the resistivity of samples between 45 and 110nm remained relatively constant, with an average resistivity of 23.35Ω*nm. The behavior of samples at lower thicknesses is most likely the result of incomplete or uneven film formation resulting in a lower resistivity than would be seen in a fully uniform sample. Additional research would most likely involve further sample characterization via TEM to allow for determination of sample uniformity and composition.

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