NON-CONDUTIVE RADIO FREQUENCY TRANSPARENT METALLIC LOOKING COATINGS

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1. INTRODUCTION

Recently interest in the development of non-conductive thin film coatings that are transparent in the radio frequency range has been increasing together with the expansion of telecommunication systems, especially with the mobile phone market. GSM (Global System for Mobile communications) technology is used for transmitting mobile voice and data services which operates in the lower bandwidths of radio frequency. Further advancements of GSM networks such as Bluetooth, GPRS, EDGE, 3GSM, HSDPA, etc. are operated in the higher rf bandwidths leading to richer and more efficient applications.

In this work, an attempt has been made to optimise the suitable coating(s) that must be rf transparent in one hand as well as decorative (metallic) on the other. Various thin film coatings of Tin (Sn), Silicon (Si) and Aluminium doped Silicon (Si:Al) have been deposited on different substrates using dc magnetron sputtering technique. The films have been characterized by measuring electrical resistance, optical reflectance and transmittance, and RF attenuation in the radio frequency range of 880 MHz to 2.5 GHz. Achieved results are discussed and correlated to the requirements of non-conductivity, metallic appearance and rf performance of the deposited coatings.

2. EXPERIMENT

Thin film coatings of Sn, Si and Si:Al are deposited on glass, metal and various plastic substrates. The coatings have been deposited by DC Magnetron Sputtering technique using Si and Sn targets, and a doped target of Silicon (70%) plus Aluminium (30%) in the case of Si:Al. The deposition parameters maintained for the preparation of Sn, Si and Si:Al films are given in the table.

The thickness of the deposited films have been measured using Quartz Crystal and also by Ball Cratering Calotest method. Sheet resistance of the films has been measured by the standard two-probe and four-probe techniques. Optical transmittance and absolute reflectance spectra of the coatings have been recorded by using a Varian UV-VIS-NIR Spectrophotometer. And the rf attenuation of the coatings have been studied by using an RF Spectrum Analyzer.

Table: Deposition parameters of Sn, Si and Si: Al films

Parameters	**Sn**	**Si**	**Si:Al**
Power Supply	DC	Pulse-DC	DC
Base pressure (mbar)	1E-5	1E-5	1E-5
Sputtering pressure (mbar)	2E-3	3E-3	3E-3
Target current (A)	1 - 5	1 - 2	0.5 – 1.0
Target voltage (V)	370 - 620	230 - 386	500 – 670
Conveyer speed (cm/sec), or rpm	1 – 5 cm/sec	3 rpm	3 rpm
Coating thickness (nm)	6 - 600	~500	200 -500

3. RESULTS AND DISCUSSION

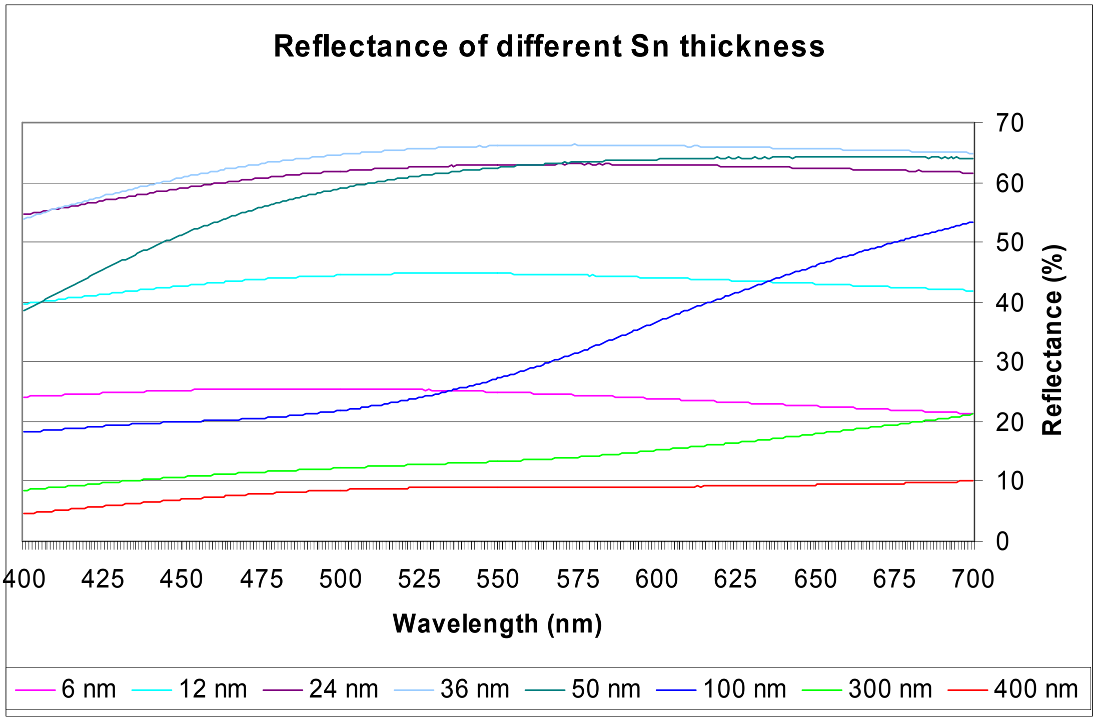

Fig.1: Absolute reflectance spectra of different coating thickness of Sn

Optical transmittance and reflectance spectra of all the films have been measured using glass samples. The thickness of the deposited Tin (Sn) coatings was in the range of 6 - 600 nm. Figure 1 shows the optical reflectance spectra of different Sn thickness in the visible wavelength range and Figure 2 shows the dependence of Sheet resistance and average reflectance (R%) on the coating thickness of Sn.

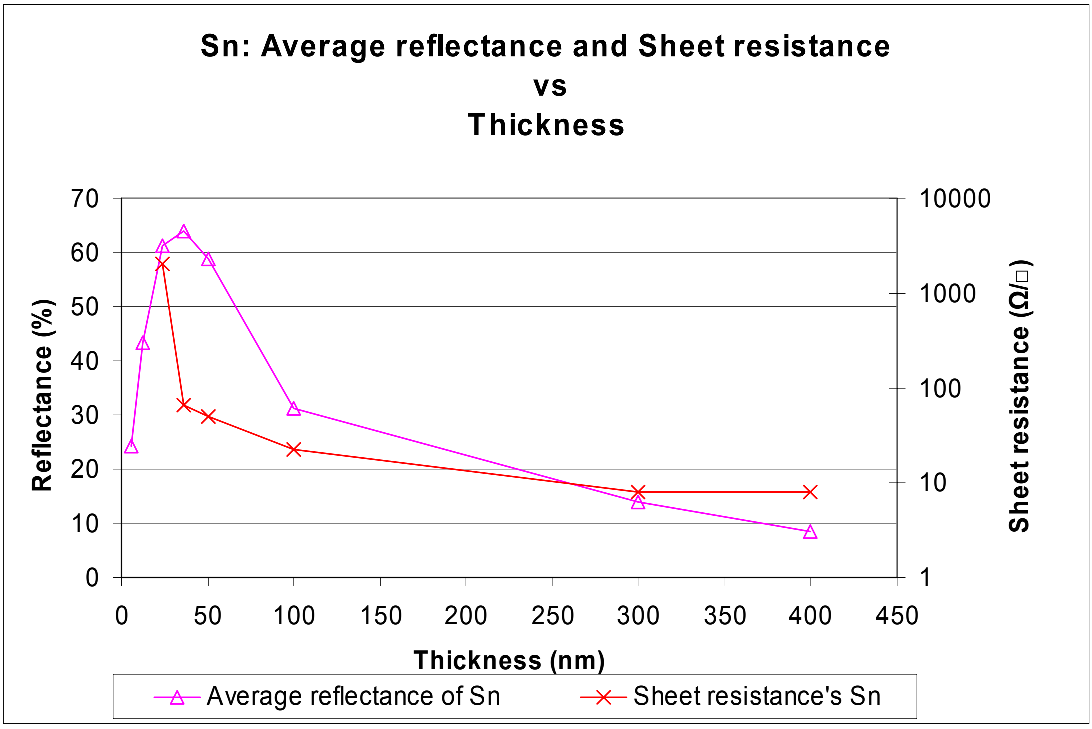

Fig.2: Thickness dependence of Sheet resistance and average R% of Sn

From the figures, the average reflectance was around 24 % for 6 nm coating, which increases up to 63% with increasing coating thickness up to 50 nm and afterwards starts decreasing for higher thicknesses. On the other hand, the measured average transmittance of the 6 nm coating was around 42% that decreases to 5% with increasing thickness of 24 nm, and reaches to zero for 50 nm and above. Since the thinner films are transparent, most of the incident light is transmitted through the substrate while small portion of light gets reflected. When the coating thickness increases, the amount of light transmitted gets decreased which obviously increases the reflectance, and the resulted films look visually more metallic. For higher thickness of 100 nm and above, most of the light gets scattered and partly may be absorbed resulted in white milky films with less reflectance. On the other hand, the sheet resistance decreases obviously with increasing of coating thickness.

Si:Al films were deposited using a doped target of 70% silicon and 30% of aluminium, whose thickness was in the range 17 – 400 nm. Sheet resistance and absolute reflectance spectra were measured and the results are shown in figure 3.

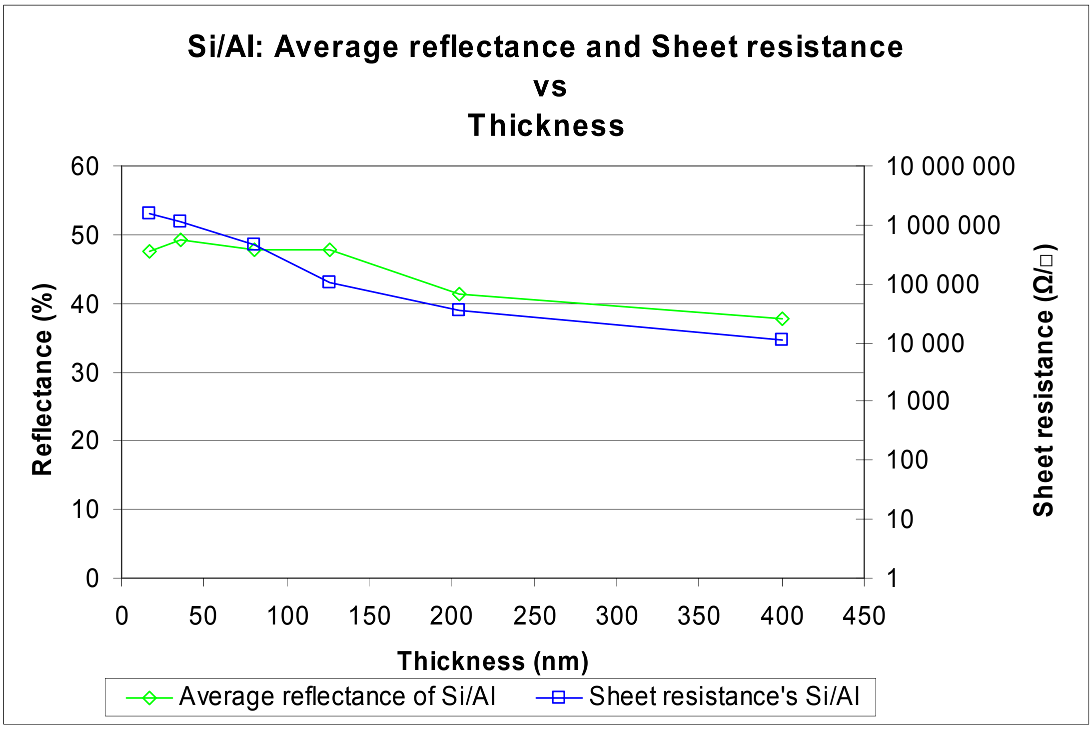

Fig.3: Dependence of Sheet resistance and average reflectance on different thickness of Si:Al

Sheet resistance of the 17 nm Si:Al coating was high as 1.5 MΩ which decreased with increase of coating thickness and reaches to 10 KΩ with the thickness of 400 nm. The reflectance of Si:Al films remain high around 50% and stable for a thickness range of 17 nm to 150 nm, then steadily decreases to 38% for the 400 nm thick coating.

We measured the absolute reflectance of the deposited pure Si coating (of 500 nm) which is around 30% (shown in figure 4). Therefore, the Si:Al films show 17-20% of higher reflectance (than that of the Si) which is due the presence of aluminium content in the films. Moreover, it has been studied that the Si:Al coatings of 150 nm thick is enough to get uniform coverage on three dimensional parts, where as around 500 nm is needed in the case of Si to get uniform coverage. Also, visually the Si:Al films look more metallic than the Si counterpart.

When compared to Sn films, the Si: Al films not only exhibit higher sheet resistance and absolute reflectance, but also remain stable over a larger thickness range.

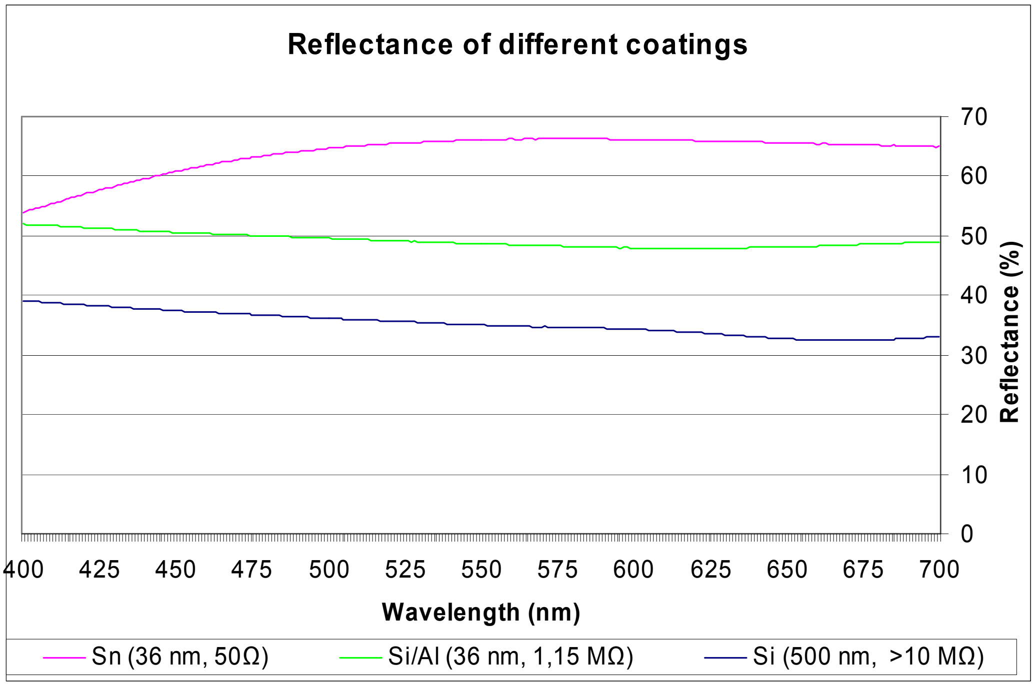

Fig.4: Absolute reflectance spectra of Si, Si:Al and Sn coatings

Figure 4 shows the variation of optical reflectance of one set of Si, Si:Al and Sn films in the visible wavelength range. These films were characterized for RF attenuation in the frequency range of 880 MHz to 2.5 GHz. The preliminary rf results, from figure 5, indicate that the Si and Si:Al films could be more rf transparent than the Sn. The poor rf performance of Sn in the radio frequency range is due to the low sheet resistance.

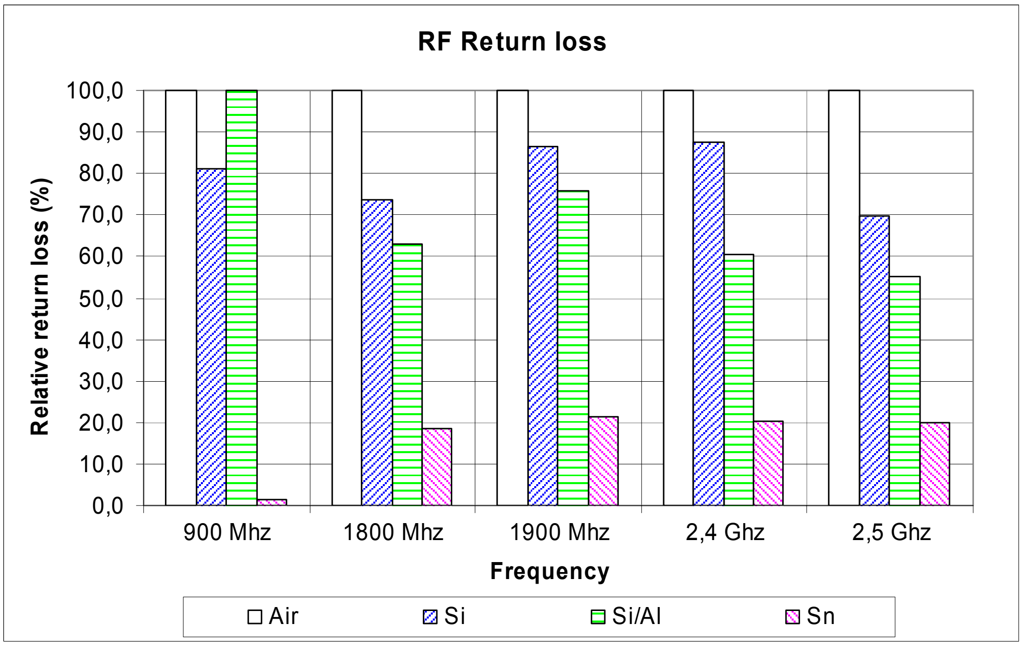

Figure.5: RF Attenuation of Si, Si:Al and Sn coatings

4. CONCLUSIONS

We have presented some results of the Sn, Si:Al and Si coatings deposited by dc magnetron sputtering

Visually Si:Al and Sn coatings appears more metallic than the Si. This could be correlated to their higher optical reflectance of around 50% and 65% respectively (than the Si which is around 30%) in the visible wavelength range.

Electrical resistance of Si is in the order of MΩ. and that of Si:Al is of MΩ- KΩ, whereas Sn coatings with < 50 nm exhibits an electrical resistance of few KΩ.

The RF results show that the film thickness and electrical resistance are very sensitive towards the RF attenuation of the films. The preliminary results indicates that Si and Si:Al coatings could be more suitable than the Sn coatings for this application, but further studies are necessary to investigate the influence of coating thickness, sheet resistance, composition, etc. on the RF transmittance. As the results presented here are preliminary, more number of RF measurements are deserved in order to realize the right coating with better properties.