# SYNTHESIS OF Al-Si ALLOYS AND STUDY OF THEIR MECHANICAL PROPERTIES

**BY**

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# INTRODUCTION

# Aluminium Alloys:

- High Specific strength
- High strength to weight ratio.
- These have bright lusture.
- Used in automobile and aerospace industries.
- Alloying elements - copper, magnesium, manganese, silicon, and zinc.
- These are designated as from 1xxx to 8xxx.

# Designation Of Aluminum Alloys :

| Alloy | Main alloying element | Applications |
|---|---|---|
| **1xxx** | Mostly pure aluminum; no major alloying additions | Electrical and chemical industries |
| **2xxx** | Copper | Aircraft components |
| **3xxx** | Manganese | Architectural applications |
| **4xxx** | Silicon | Automobile parts, welding rods |
| **5xxx** | Magnesium | Boat hulls, marine industries |
| **6xxx** | Magnesium and silicon | Architectural extrusions |
| **7xxx** | Zinc | Aircraft components |
| **8xxx** | Other elements (e.g., Fe, Ni or Ti) | |
| **9xxx** | Unassigned | |

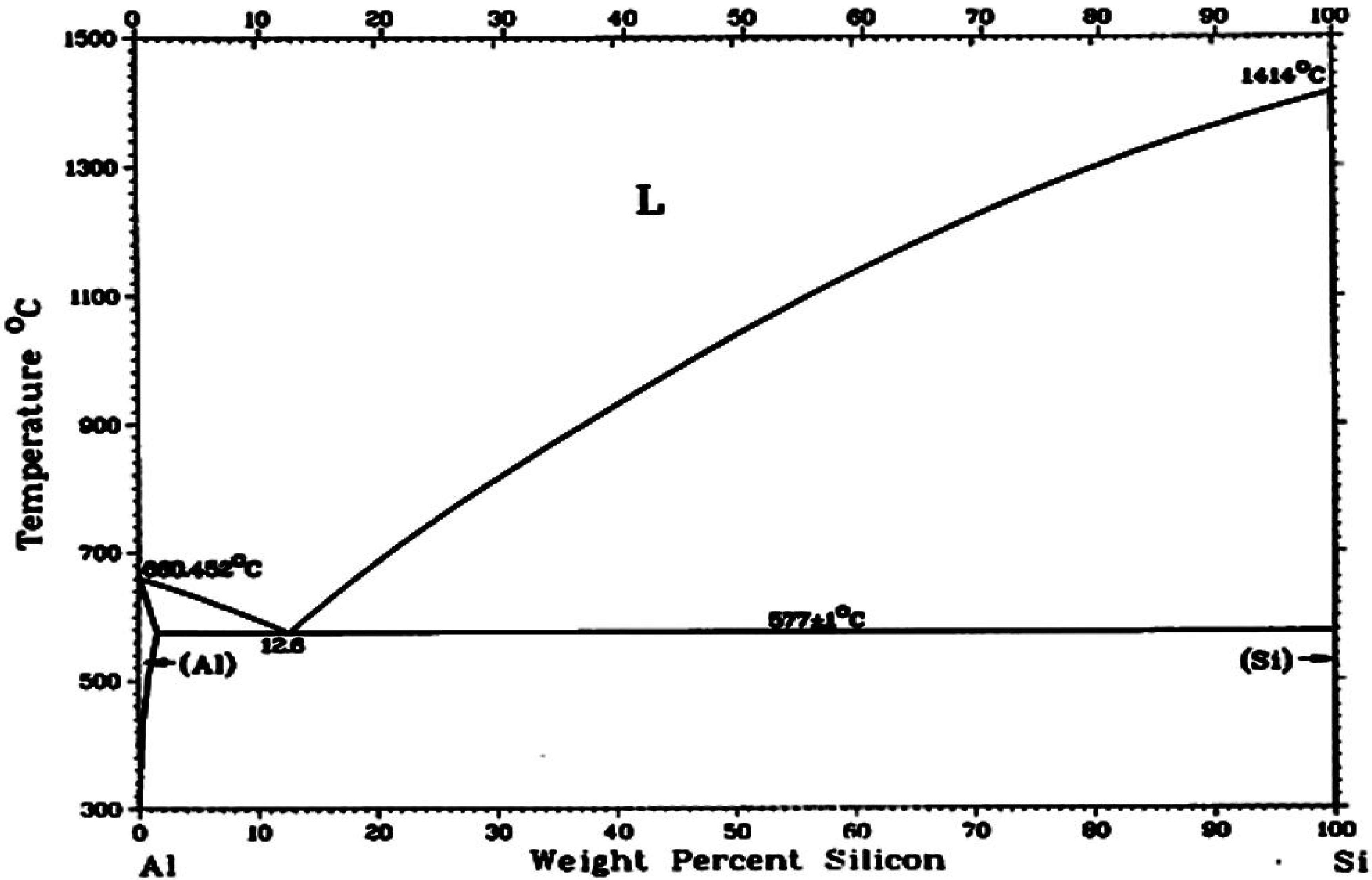
# Aluminium – Silicon Alloys :

- These are designated as 4xxx alloys.
- These form a eutectic mixture at 12.6 wt% silicon, 577 °C.
- These are of significant industrial importance.

# Effects of Silicon :

- Increased fluidity.
- Reduces the melting temperature.
- Decreases the shrinkage during solidification.

# PHASE DIAGRAM:



# PROPERTIES:

- High specific strength.
- High wear resistance.
- Seizure resistance.
- High stiffness.
- Better high temperature strength.
- Controlled thermal expansion coefficient.
- Improved damping capacity.

# USES:

- Increased use in automobile industry.
- Used for forging.
- As a weld filler alloy.

# OBJECTIVE

Due to the advancements in the field of applications of Al-Si alloys, the study of their wear and tensile behaviour is necessary.

Although many investigations exist in literature, it is evident that there is enough scope for further research of Al-Si alloys especially their mechanical properties.

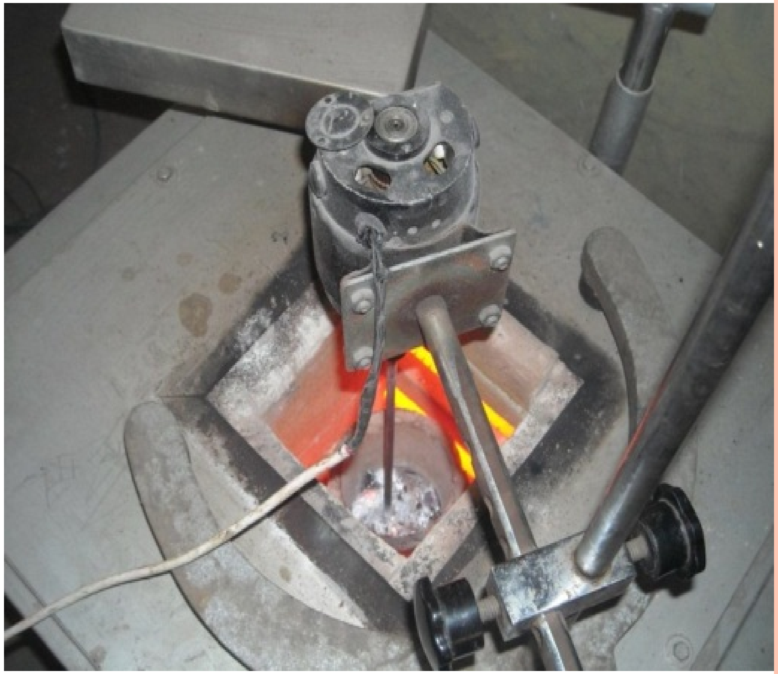
## Therefore the objectives of this study are:

- Preparation of Al-Si alloys of hypo and hyper eutectic compositions.
- To study of their microstructure.
- To study of their mechanical properties.
- To evaluate their wear behaviour.

# EXPERIMENTAL

# Preparation of Alloys:

- Prepared by casting route.
- 99.7% pure Al and 99.5% pure Si were taken.
- The dimensions of the samples were of 100 mm in length, 30 mm in width and 20 mm in height.



| Sl.No. | Material | Al (in gms) | Si (in gms) |
|---|---|---|---|
| **1** | Al - 7% Si | 250 | 18.8 |
| **2** | Al - 12% Si | 250 | 34.1 |
| **3** | Al - 14% Si | 250 | 40.7 |

# Composition Analysis: Optical Emission Spectroscopy

- Analysis of chemical composition
- Model: ARL 3460 Metals Analyser, Thermo Electron Corporation Limited, Massachusetts, United States of America.
- The dimensions of the samples are 20 mm x 20 mm.

# Optical Microscopy:

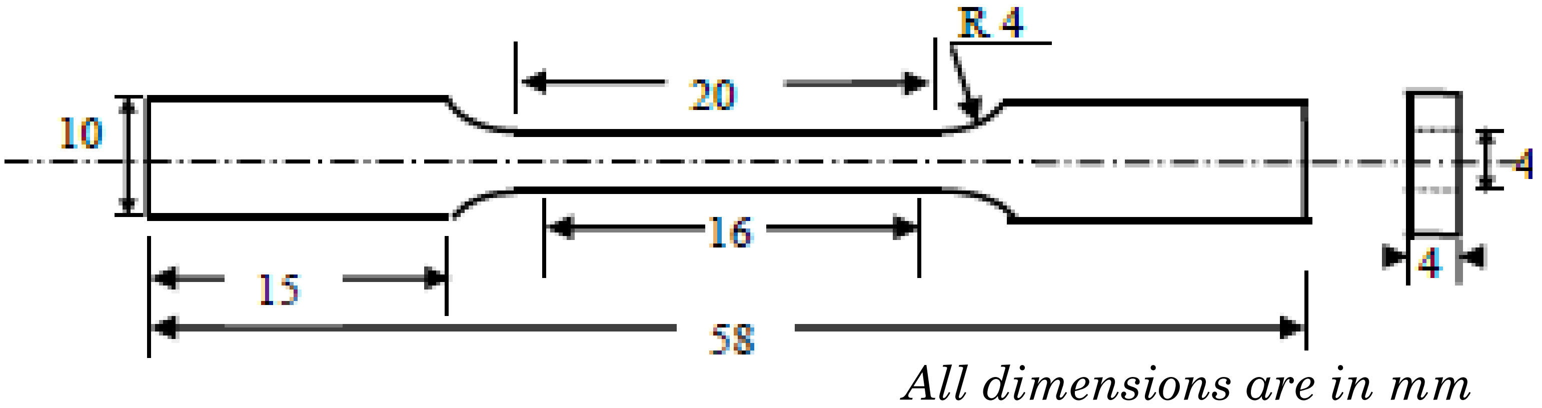
- Microstructures of the polished alloy samples were observed under computerized optical microscope.
- Model: Olympus BX51, Essex, UK
- Etchant used is Keller's reagent.

# Scanning Electron Microscopy

- Model: JEOL6480 LV scanning electron microscope, JEOL Limited, Japan.
- The samples were mechanically polished and the experiment was performed in etched conditions.
- Keller's reagent was used as etchant.

# Tensile test :

- Tensile properties of the alloys were analysed by carrying out tests on the UTM (universal testing machine)
- Model: INSTRON 1195, Instron Industrial Products, Pennsylvania, USA.
- These tests were carried out with a cross head speed of 1mm/min.




Tensile Test Specimen

# Contd..


Universal testing machine (INSTRON 1195)

# Vickers Hardness Test:

- The macro hardness tests of all the samples have been carried out using a Vicker's hardness testing machine.
- It has a square-base diamond pyramid indenter.
- The applied load during the testing was 5 kgf with a dwell time of 15 secs,
- The Vickers hardness number (VHN) is calculated from the following equation:

$$VHN = \frac{2\,P \sin\frac{136°}{2}}{D^2} = \frac{1.854\,P}{D^2}$$

## CONTD..

Vickers Hardness Testing Machine

# WEAR TEST:

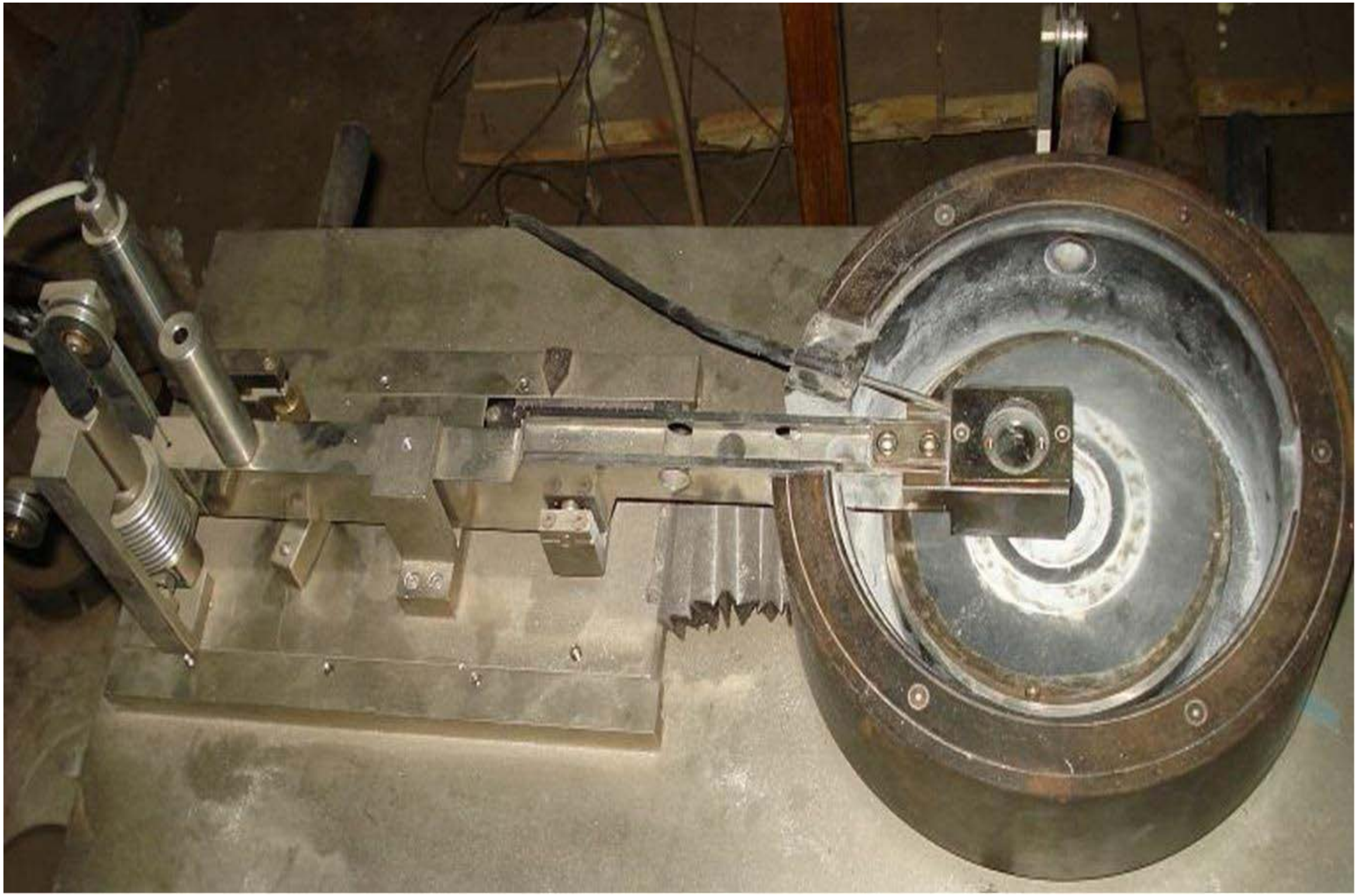
- This test was carried out using Computerized Ducom friction and wear monitor pin on disc wear test machine.
- Model: DUCOM Wear and Friction Monitor, TR-20-M100, Bangalore, India
- The alloy samples were held stationary and a required normal load was applied.
- The tests were carried out by varying one of the following three parameters and keeping other two constants:

  i. applied load ( is 20 N, when constant)

  ii. sliding speed ( is 20 rpm, when constant)

  iii. sliding distance ( is 1256 mm, when constant)
- This test was carried out in dry conditions.

# Contd...



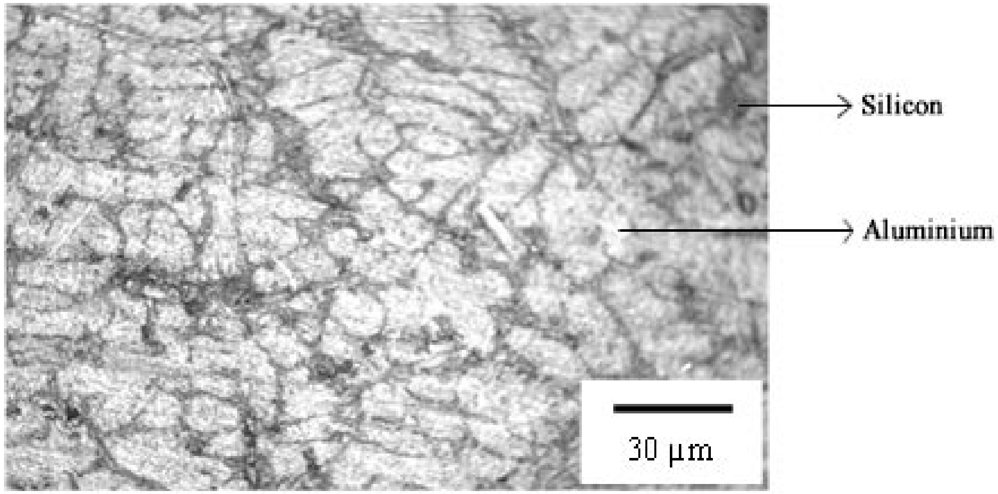
Computerized Ducom friction and wear monitor pin on disc wear test machine

# RESULTS

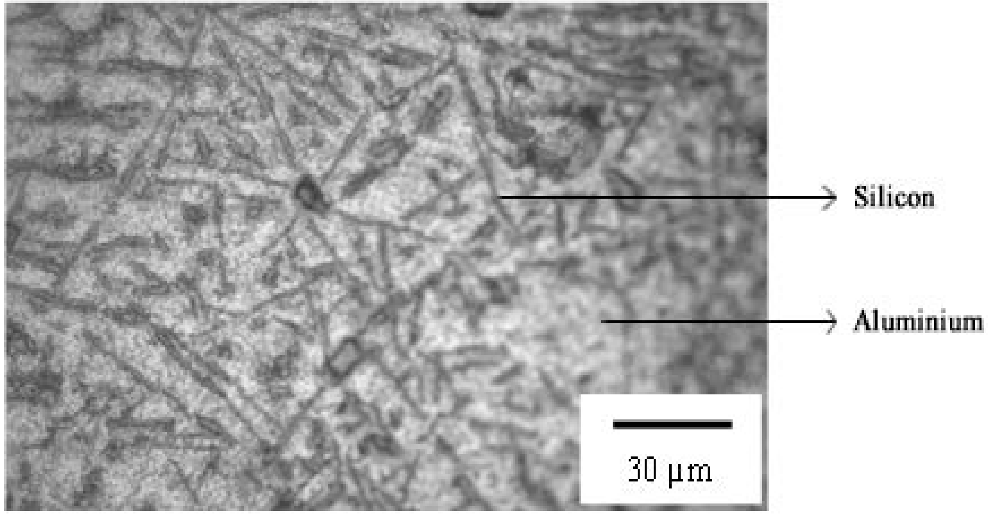
## Compositional Analysis:

| | Al-7% Si (wt%) | Al-12% Si (wt%) | Al-14% Si (wt%) |
|---|---|---|---|
| Si | 7.003 | 12.002 | 13.76 |
| Fe | 0.157 | 0.151 | 0.14 |
| Cu | 0.007 | 0.003 | 0.005 |
| Mn | 0.008 | 0.009 | 0.007 |
| Mg | 0.001 | - | - |
| Zn | 0.038 | 0.022 | 0.019 |
| Ti | 0.016 | 0.011 | 0.018 |
| Ni | 0.002 | - | - |
| Ca | 0.003 | 0.003 | 0.001 |
| B | 0.001 | 0.002 | 0.001 |
| Bi | - | 0.001 | - |
| V | 0.004 | 0.004 | 0.004 |
| Co | 0.001 | 0.001 | 0.001 |
| Sb | 0.001 | 0.001 | 0.001 |
| Ga | 0.015 | 0.015 | 0.015 |
| P | 0.001 | - | - |
| As | 0.002 | 0.002 | 0.002 |
| Al | 92.74 | 87.77 | 86.02 |

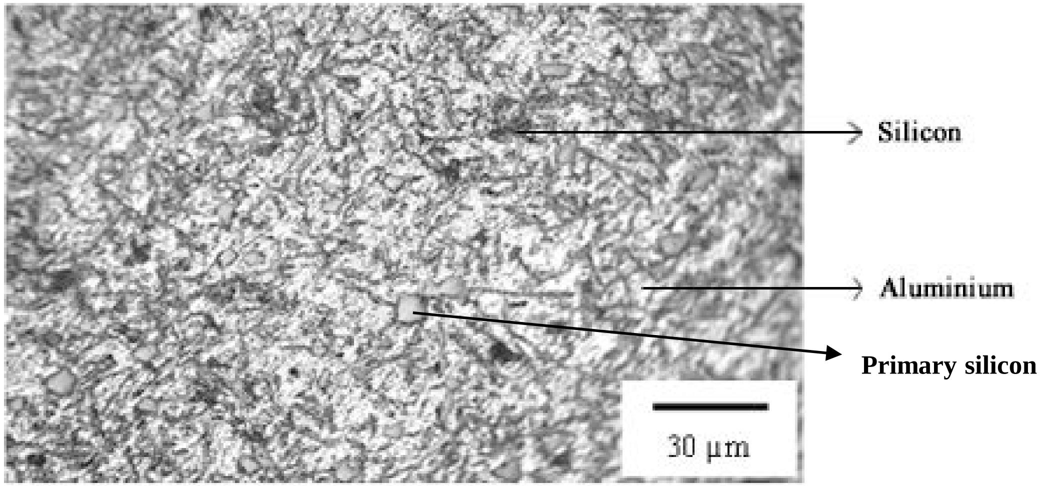
**Microstructure:**




Microstructure of Al-7% Si sample

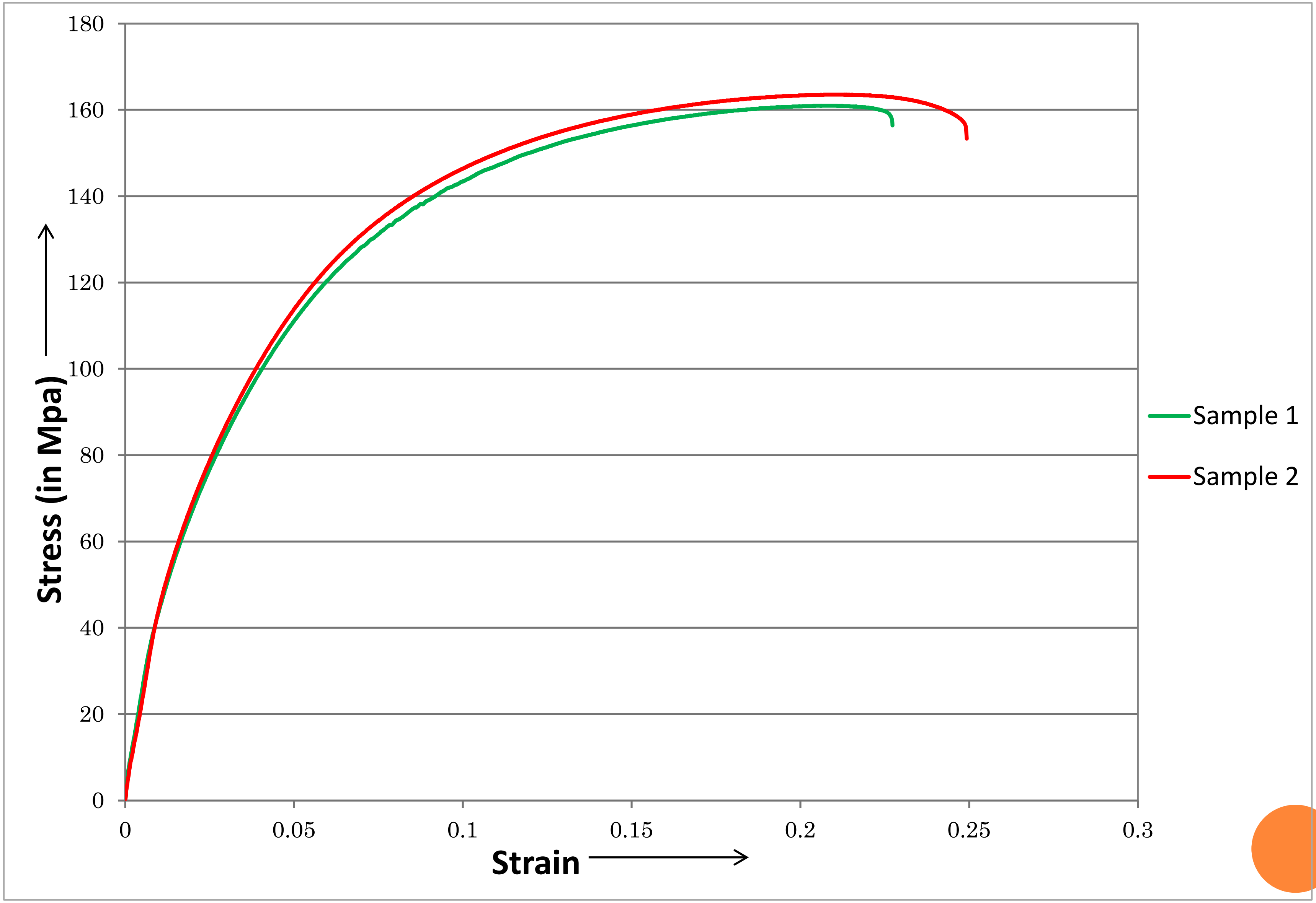



Microstructure of Al-12% Si sample

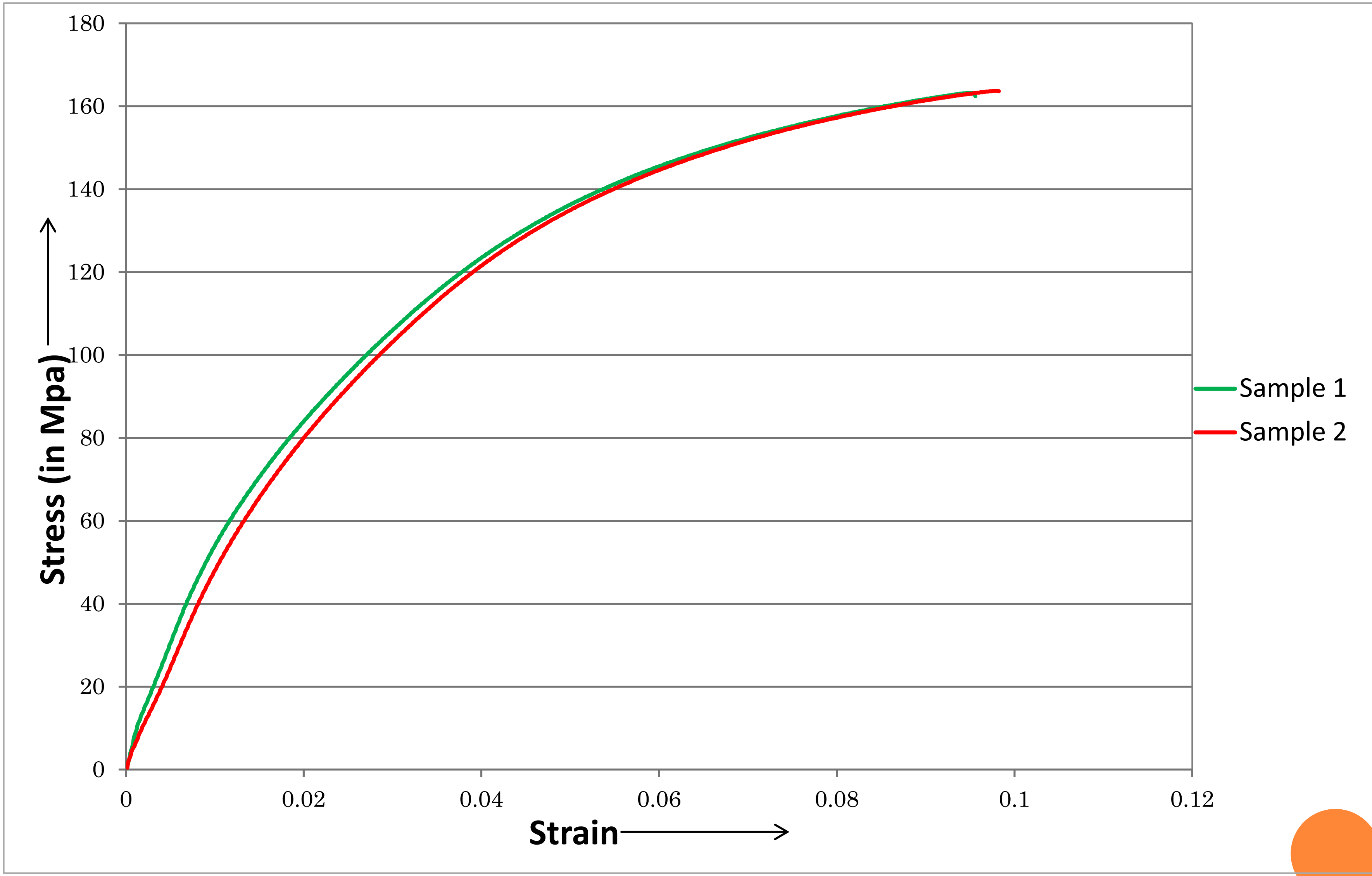



Microstructure of Al-14% Si sample

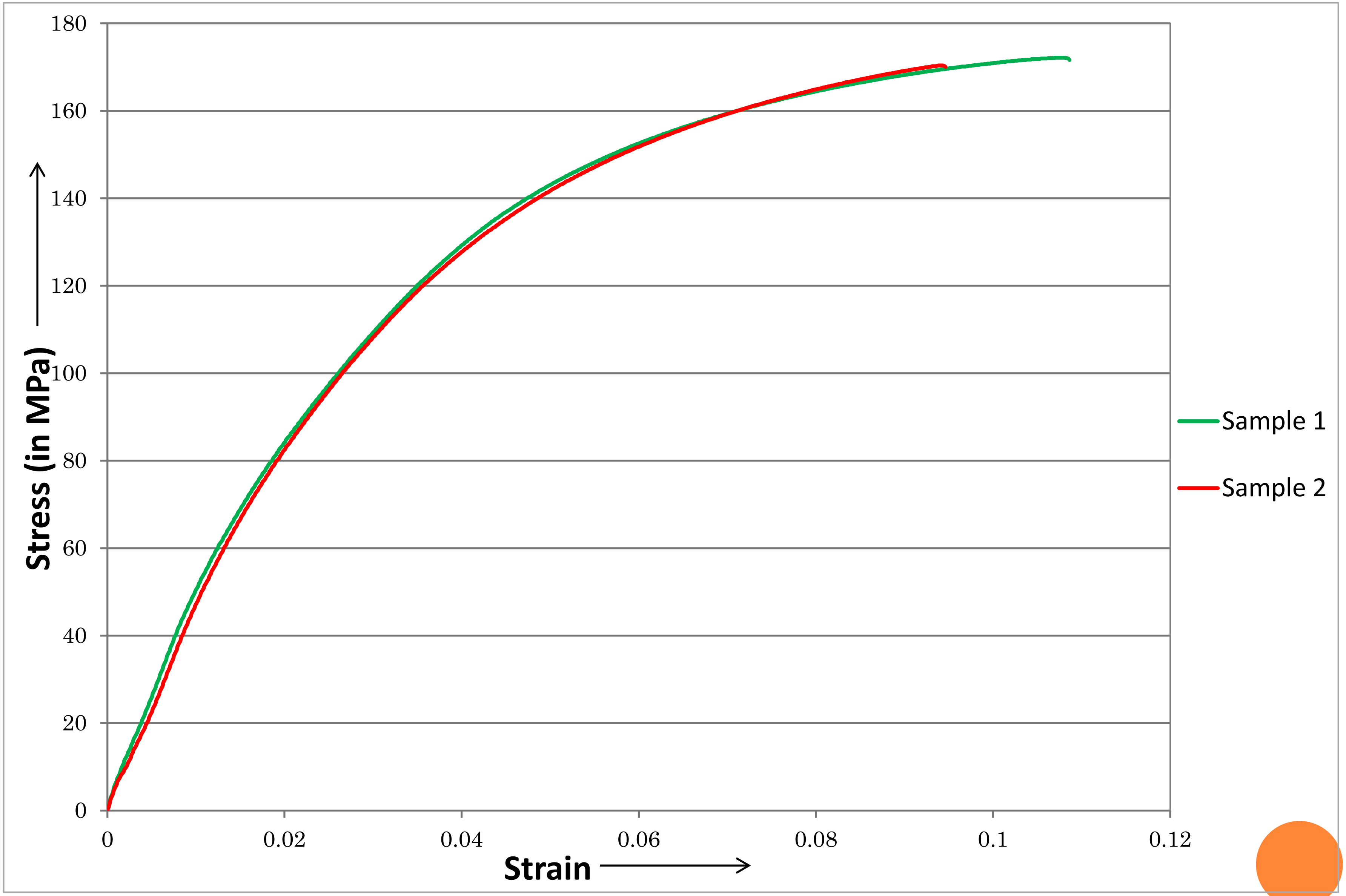
## Tensile Test:




Stress – strain curve for Al-7% Si samples



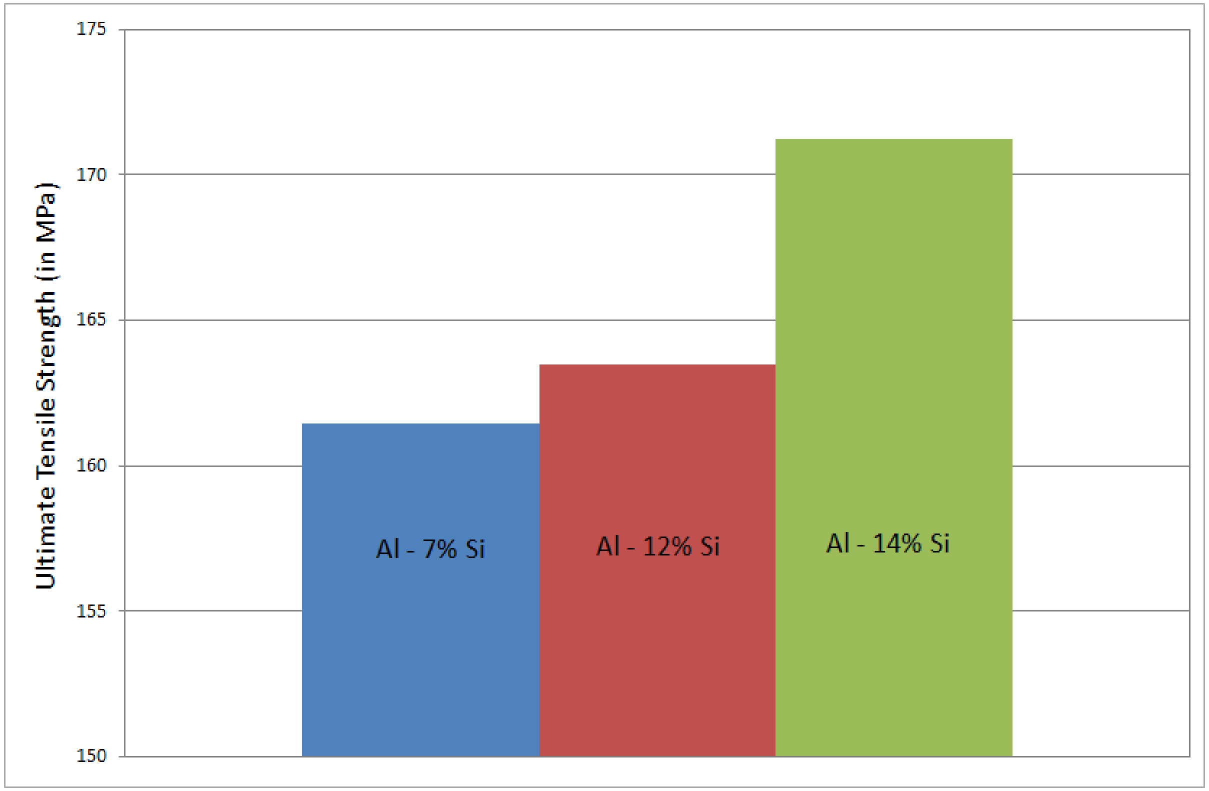

Stress – strain curve for Al-12% Si samples




Stress – strain curve for Al-14% Si samples

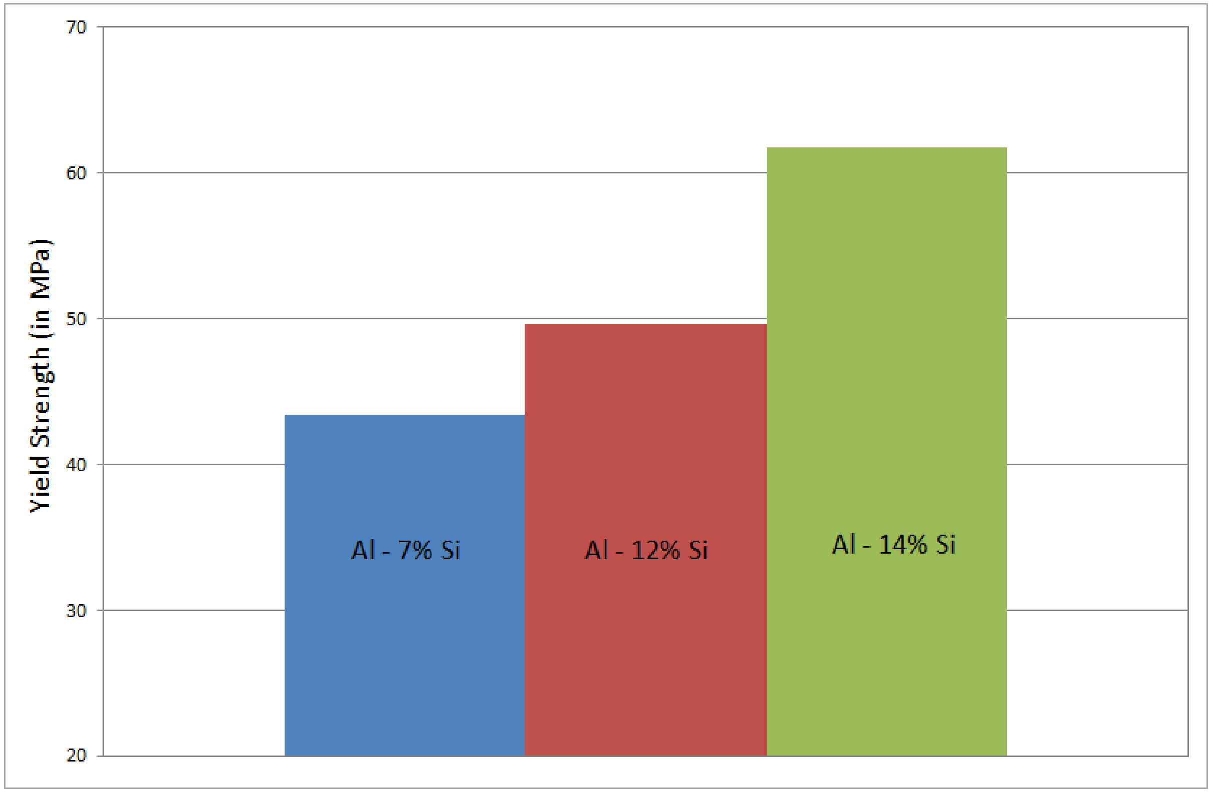
*Comparison of ultimate tensile strength:*

| | UTS of Sample 1 (In MPa) | UTS of Sample 2 (In MPa) | Average UTS (In MPa) |
|---|---|---|---|
| **Al - 7% Si** | 160.97 | 161.87 | 161.42 |
| **Al – 12% Si** | 163.21 | 163.71 | 163.46 |
| **Al – 14% Si** | 172.13 | 170.38 | 171.255 |



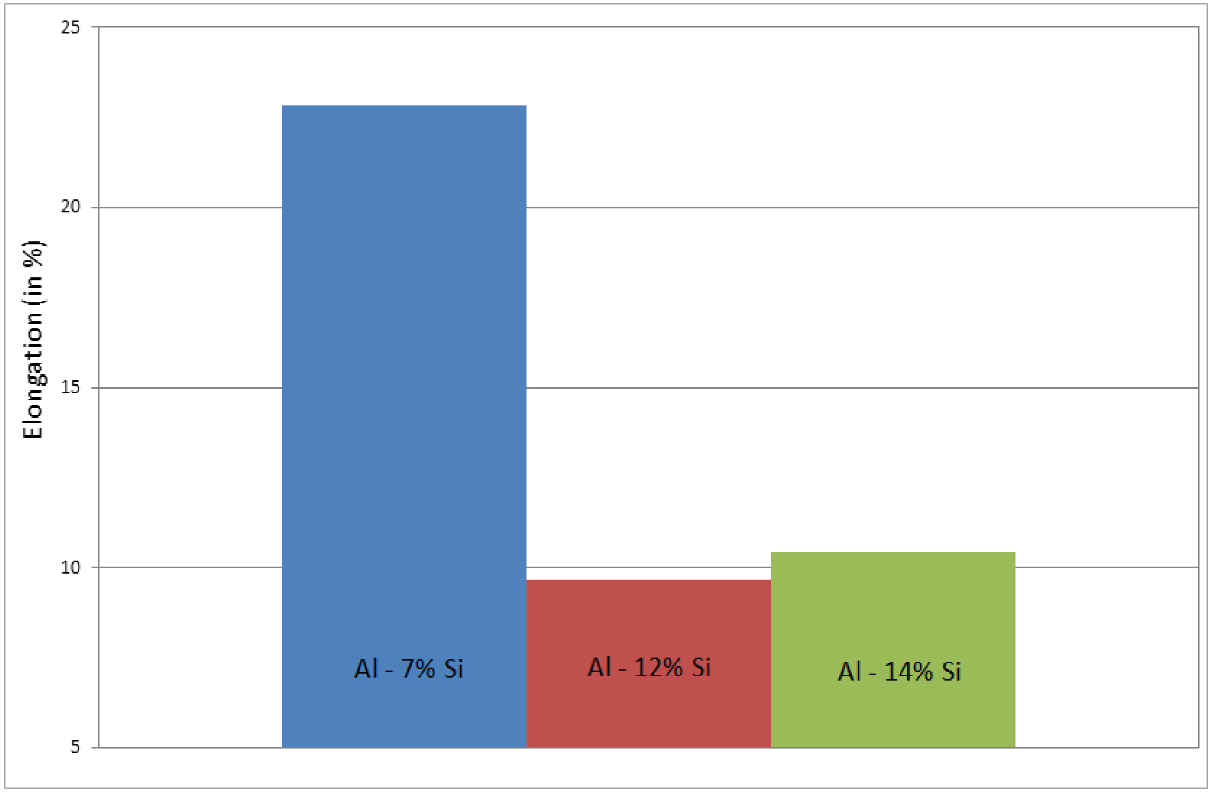
*Comparison of yield strength:*

| | YS of Sample 1 (In MPa) | YS of Sample 2 (In MPa) | Average YS (In MPa) |
|---|---|---|---|
| **Al - 7% Si** | 41.3 | 45.5 | 43.4 |
| **Al – 12% Si** | 48.7 | 50.6 | 49.65 |
| **Al – 14% Si** | 61 | 62.5 | 61.75 |



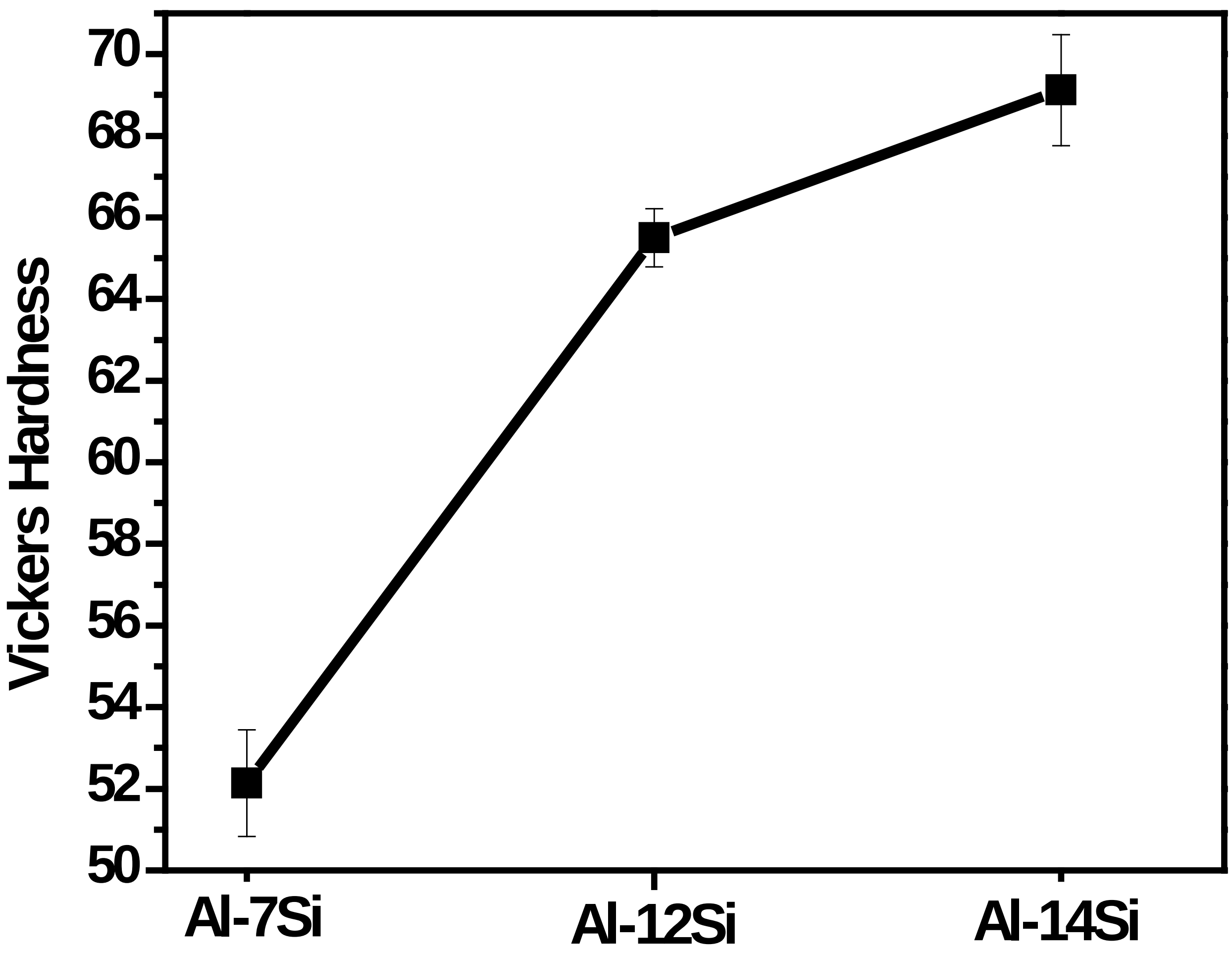
*Comparison of total elongation:*

| | Total Elongation of Sample 1 (In %) | Total Elongation of Sample 2 (In %) | Average Total Elongation (In %) |
|---|---|---|---|
| **Al - 7% Si** | 22.72 | 24.912 | 22.816 |
| **Al – 12% Si** | 9.544 | 9.816 | 9.68 |
| **Al – 14% Si** | 10.848 | 9.448 | 10.418 |



## Vickers Hardness Test:

| Composition | $D_1$ (in µm) | $D_2$ (in µm) | VHN | Avg VHN |
|---|---|---|---|---|
| **Al-7% Si** | 431.6 | 430.5 | 49.9 | **52.14** |
| | 421.5 | 416.6 | 52.8 | |
| | 425.6 | 418.3 | 52.1 | |
| | 418.7 | 415.9 | 53.2 | |
| | 421.3 | 417.6 | 52.7 | |
| **Al-12% Si** | 371.8 | 375.0 | 66.5 | **65.5** |
| | 369.4 | 386.4 | 64.9 | |
| | 376.9 | 378.8 | 64.9 | |
| | 373.6 | 375.8 | 66.0 | |
| | 376.3 | 378.1 | 65.2 | |
| **Al-14% Si** | 367.3 | 370.4 | 68.2 | **69.12** |
| | 359.3 | 362.9 | 71.1 | |
| | 362.4 | 365.3 | 70.0 | |
| | 369.7 | 367.8 | 68.2 | |
| | 368.9 | 369.1 | 68.1 | |

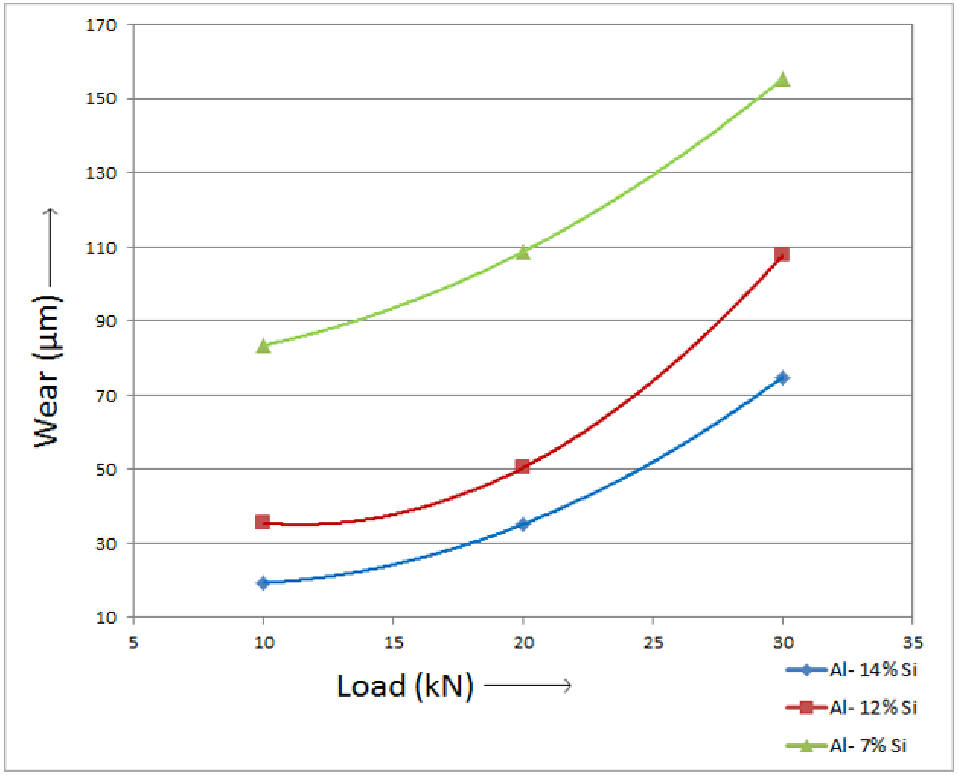



Variation of hardness along with their standard deviation

# Wear Test:

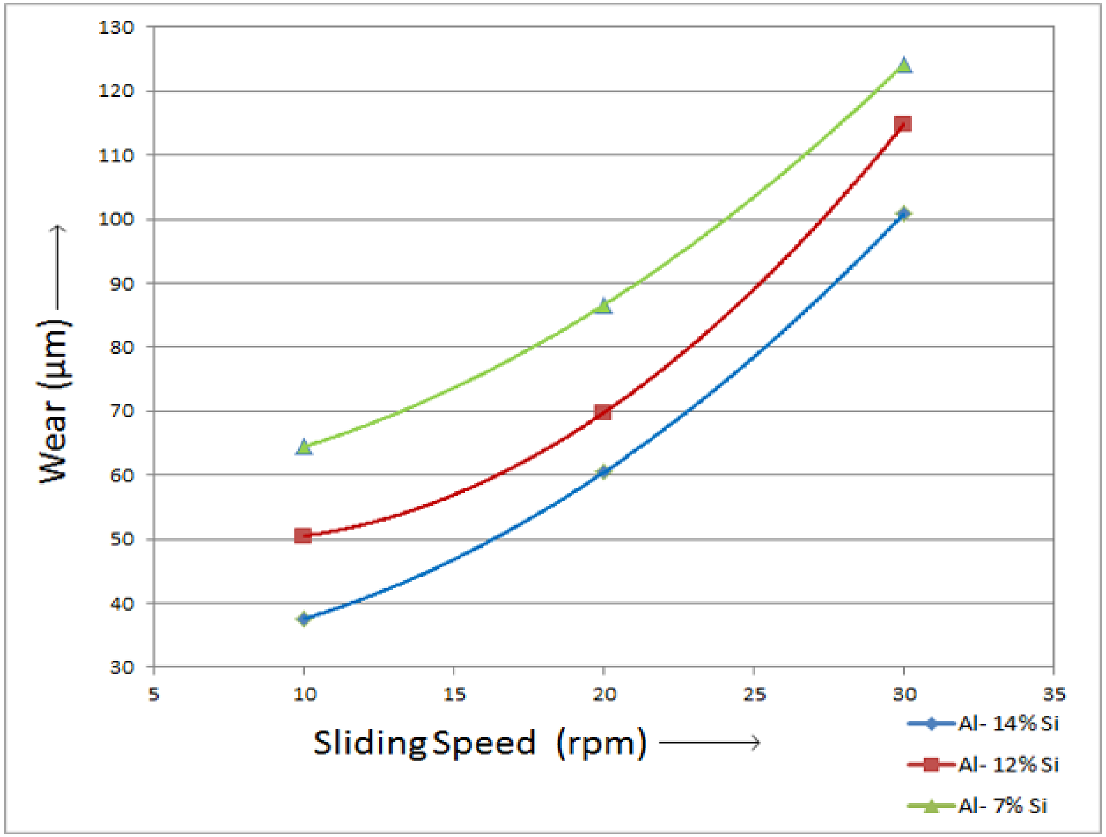
*Load vs. Wear*

| | Load (kN) | Wear (µm) | | |
|---|---|---|---|---|
| | | Al – 7% Si | Al – 12% Si | Al – 14% Si |
| I | 10 | 83.45 | 35.44 | 19.29 |
| II | 20 | 108.79 | 50.5 | 35.13 |
| III | 30 | 155.44 | 107.77 | 74.88 |



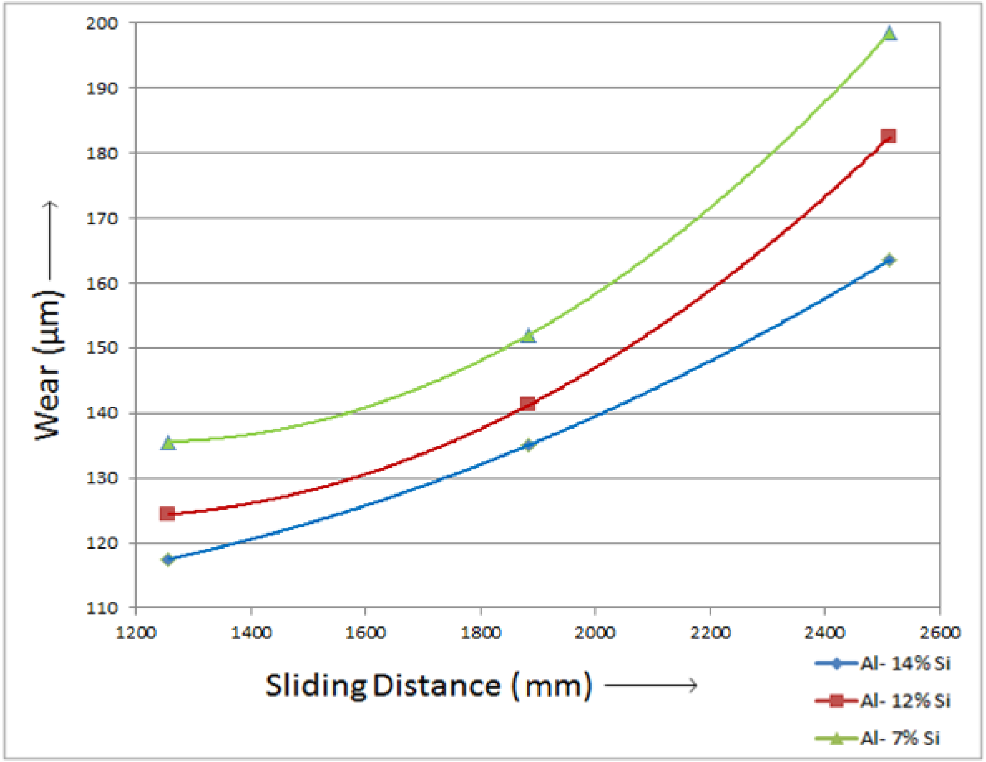
*Sliding speed vs. Wear*

| | Sliding Speed (rpm) | Wear (µm) | | |
|---|---|---|---|---|
| | | Al – 7% Si | Al – 12% Si | Al – 14% Si |
| I | 10 | 64.44 | 50.5 | 37.55 |
| II | 20 | 86.62 | 69.77 | 60.48 |
| III | 30 | 124.11 | 114.74 | 100.79 |

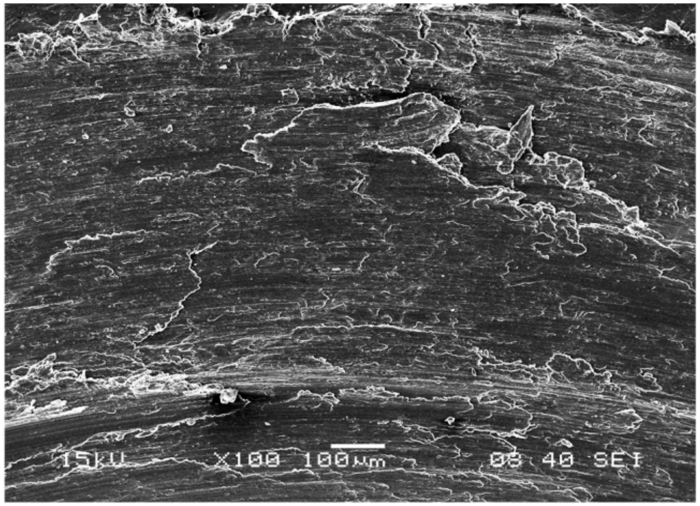


*Sliding distance vs. Wear*

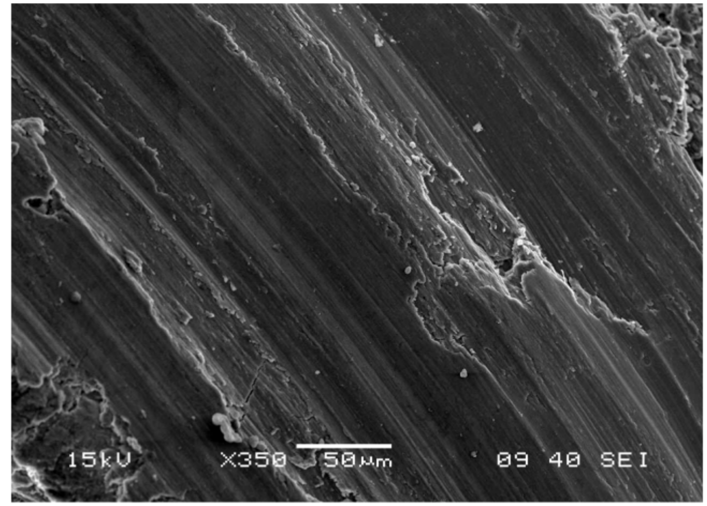
| | Sliding Distance (mm) | Wear (µm) | | |
|---|---|---|---|---|
| | | Al – 7% Si | Al – 12% Si | Al – 14% Si |
| I | 1256 | 135.58 | 124.38 | 117.48 |
| II | 1884 | 152 | 141.21 | 135.06 |
| III | 2512 | 198.42 | 182.43 | 163.51 |



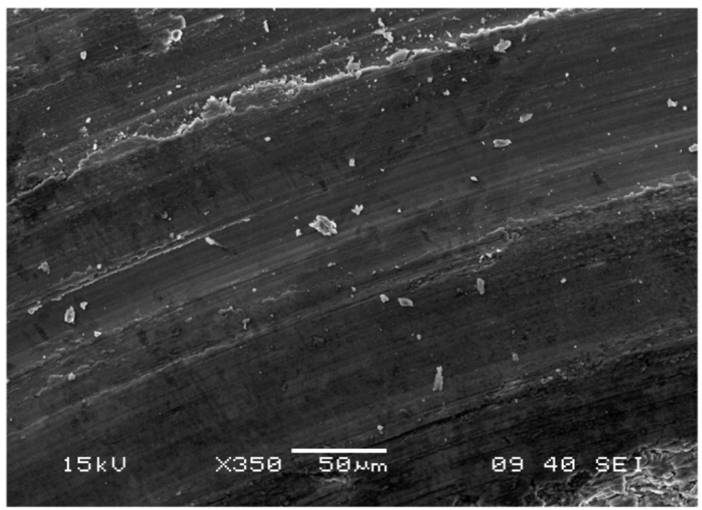
## Microstructure of worn surfaces:




a. Al-7% Si

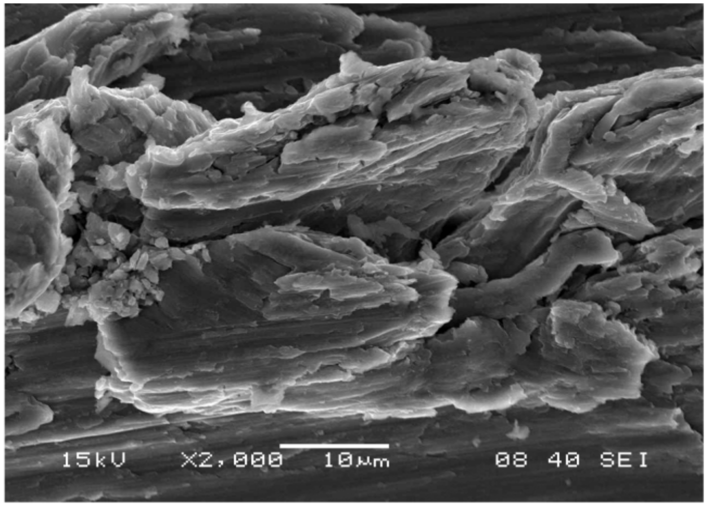



b. Al-12% Si

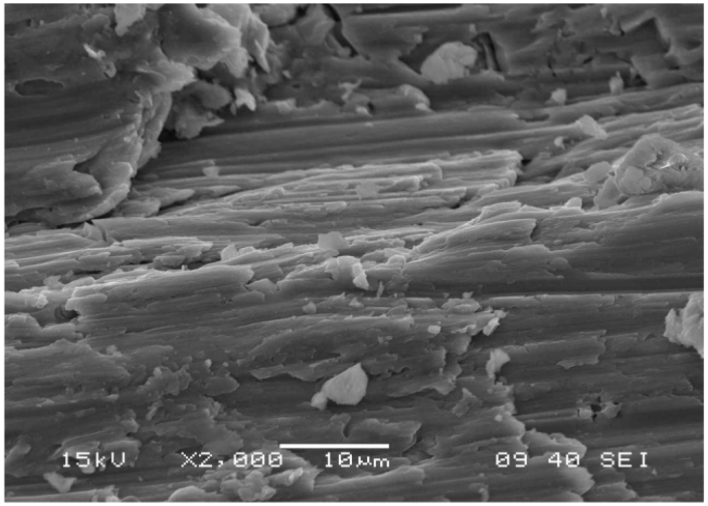



c. Al-14% Si

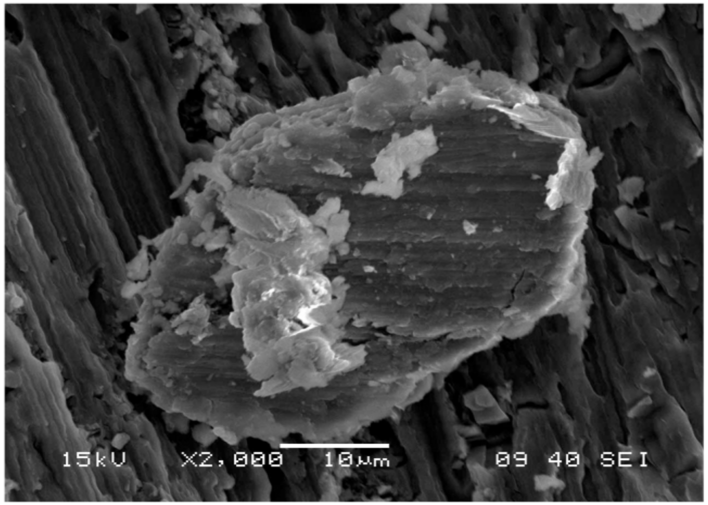
Microstructure of Al-Si samples at low magnification




a. Al-7% Si




b. Al-12% Si




c. Al-14% Si

Microstructure of Al-Si samples at high magnification

# CONCLUSIONS

- The prepared aluminium-silicon alloys have homogenous distribution of silicon throughout the cast.
- The amount of primary silicon increases with the increase in silicon amount in the cast.
- Yield strength and ultimate tensile strength increases with the increase of weight percentage of silicon.
- Total elongation decreases with the increase of weight percentage of silicon.
- Hardness of the Al-Si composite increases with the increase in amount of silicon present.
- The height loss due to wear decreases when the percentage of silicon increases.

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# THANK YOU ☺