



**DHARAMPETH M. P. DEO MEMORIAL SCIENCE COLLEGE, NAGPUR**

**3.2.2. Number of books and chapters in edited volumes/books published and papers published in national/ international conference proceedings per teacher during the year**

**BOOKS PUBLISHED**

Sr. No.	Name of the teacher	Title of the book/chapters published	Title of the paper	Title of the proceedings of the conference	Year of publication	ISBN/ISSN number of the proceeding	Name of the publisher
1.	P. W. Ambekar, P. Y. Deshmukh, P. A. Tiwari and S. B. Misra;	Cogitations on advances in physical and mathematical sciences	An Effectiveness of AlSr Alloy in the Modification of Eutectic Si Phase in AlSi Alloy,	Cogitations on Advances in Physical and Mathematical Sciences, Vinayak Publishers, Agra.	2022-2023	9789391267452	Shree Vinayak Publication, Agra- 282007
2.	Dr. Mrs. Vaishali Meshram	A Chemistry of Transition Metals	NA	NA	2022-2023	978-93-95021-03-6	Cambridge Book House

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# 23

## An Effectiveness of AlSr All On In the Modification of Eutectic Si Phase in AlSi alloy

P. W. Ambekar, P. Y. Deshmukh, P. A. Tiwari and S. B. Misra

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### ABSTRACT

AlSr alloy was prepared by melting route in an Induction Furnace with Sr5% and 10%. Scanning Electron Microscopy (SEM) along with EDS analysis confirms the uniform distribution of  $Al_4Sr$  phase throughout the master alloy for AlSr5% as well as AlSr10%. The combination of AlSr master alloy with AlTi alloy improves the mechanical properties of AlSi alloy. The 0.03% addition of AlSr10% alloy converts the eutectic Silicon phase morphology of AlSi alloy from coarse plate-like to fine fibrous networks. These fibrous structures in combination with  $\alpha-Al_8Fe_2S$  along the grain boundary makes the strong bonding between two grains. Because of this strong interaction between two grains along with the reduced grain size owing to the formation of  $TiAl_3$  particles imparts better mechanical properties and better surface finish to AlSi alloy.

### Keywords:

Eutectic Si phase, refinement, modification,  $Al_4Sr$  phase, Spinel ( $\alpha-Al_8Fe_2S$ ) phase

### Introduction:

The study was done on A356 alloy with La and Ce were added individually and /or in a combined way to study the modification behaviour. But it was observed that to bring the modification in the eutectic Si phase Sr is also necessary in combination with La and Ce [1]. To achieve the desired degree of structural refining in the cast alloy the quantity of modifier addition is decided. This amount is decided based on the original amount of elements present in the alloy before adding



any master alloy in a particular AlSi alloy. This is based on the cooling rate and the degree of structure refinement desired. Normally 0.015 % to 0.05% (w/w) is added [2]. The aluminum strontium alloy is used as an inoculant for gray and ductile iron. Some of the inventors have worked on the modification of eutectic phase in AlSi alloy or modifying intermetallic phases in wrought aluminum alloys[3]. A large amount of work is done on the morphology and size of the Al<sub>4</sub>Sr phase in modifying the eutectic Si phase. There are two ways for that, one is direct reaction and another is direct reaction-hot extrusion. In direct reaction-hot extrusion, the Al<sub>4</sub>Sr phase exhibited a homogeneous distribution of Al<sub>4</sub>Sr phase in the Al matrix with small size and roundish shapes, which ensured the AlSr master alloy wire has advantageous effect of high recovery, good reproducibility and good workability. However, in the case of the traditional direct reaction process, the Al<sub>4</sub>Sr phase was in large size with shapes of rectangular stripe and plates, which limited the Sr content increasing due to the brittleness of the AlSr alloy. [4]

**Materials and Method:**

AlSr alloy with various Strontium % such as 5% and 10% were made in an Induction Furnace of 250 KW power (Inductotherm make) with 99.9% pure Aluminum ingots and 99.9% pure Strontium metal. Aluminium ingot was first melt and then degassing was done with hexachloroethylene tablet for 2 minutes to remove entrapped oxygen and hydrogen. Pure strontium metal was added immediately once the Aluminum melt reaches the temperature of 750°C. The melt is stirred with graphite stirrer for 5 min with 250 rpm to achieve the uniform mixing of Strontium with Aluminum at eutectic combination. The optical metallography of each AlSr master alloy was examined with Carl Zeiss microscope with AXIO VISION Software and based on that AlSr10% was chosen for the eutectic Silicon modification purpose in AlSi alloy, with least porosities. The presence of uniform distribution of Al<sub>4</sub>Sr phase and detail metallography was carried out by SEM-EDS (JEOL make).

AlSr 10% alloy was added in the AlSi alloy with the addition rate of 0.02-0.03%. The chemistry and the change in the metallography, before and after addition of AlSr10% and AlTi10% master alloy was

examined in detail. The experimental findings are mentioned in the following section.

**Results and Discussion:**

AlSr alloy was observed to have lot of porosities owing to gas evolution during making of an alloy due to exothermic reaction. But these porosities does not affect the effectiveness of AlSr alloy in the modification of eutectic Silicon phase morphology from coarse plate-like to fine fibrous networks. Along with AlSr10% alloy AlTi10% was also added in the AlSi alloy to achieve the required mechanical properties with the addition of  $TiAl_3$  particles. These  $TiAl_3$  particles achieve the refinement of grains achieving the AlSi alloy with strength and hardness.

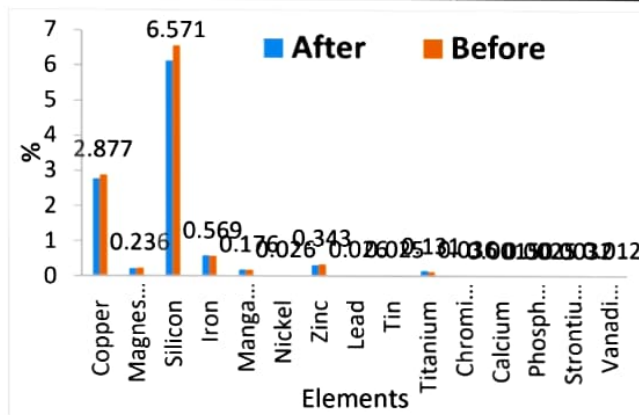
The elemental analysis of AlSi alloy before and after addition of AlSr10% and AlTi10% is as shown in Table 1

From the Table 1 it shows that, with 0.03% addition of AlSr10% alloy and with 0.2% addition of AlTi10% alloy, there is hardly any change in the chemistry but from Figure 1 and Figure 2 it seems that there is substantial change in the morphology of the Silicon eutectic phase as well as grain boundary phase transformation.

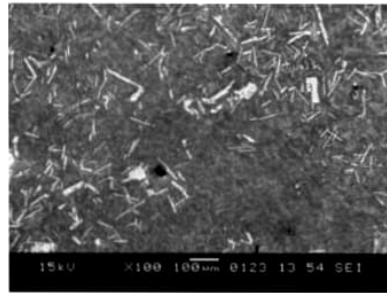
**Table 1:** Elemental composition of AlSi alloy before and after addition of AlSr10% and AlTi10% alloy

Elements	Before addition of master alloys	After addition of master alloys
Copper	2.877	2.768
Magnesium	0.236	0.218
Silicon	6.571	6.139
Iron	0.569	0.6
Manganese	0.176	0.186
Nickel	0.026	0.025
Zinc	0.343	0.323
Lead	0.026	0.019

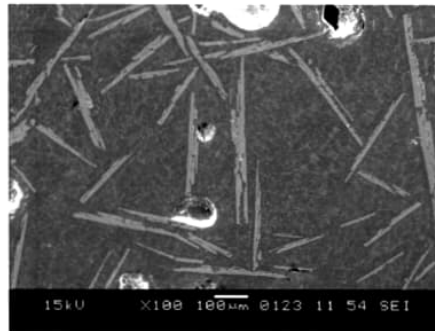
Tin	0.025	0.018
Titanium	0.131	0.163
Chromium	0.036	0.037
Calcium	0.0015	0.0012
Phosphorous	0.0025	0.0029
Strontium	0.0032	0.0067
Vanadium	0.012	0.015
Aluminum	88.931	89.448



**Figure 1:** Graphical representation of the change in the elemental composition of AlSi alloy before and after addition of AlSr105 and AlTi10% master alloy



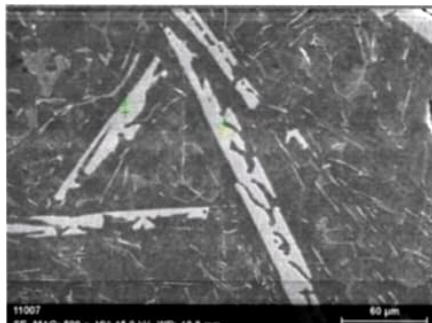
(A)

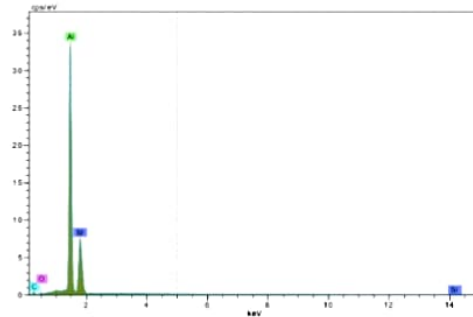


(B)

**Figure 2:** Scanning Electron Microscopy of AlSr alloy with 5% Strontium (A) and 10% Strontium (B) addition displaying the uniform distribution of  $Al_4Sr$  phase

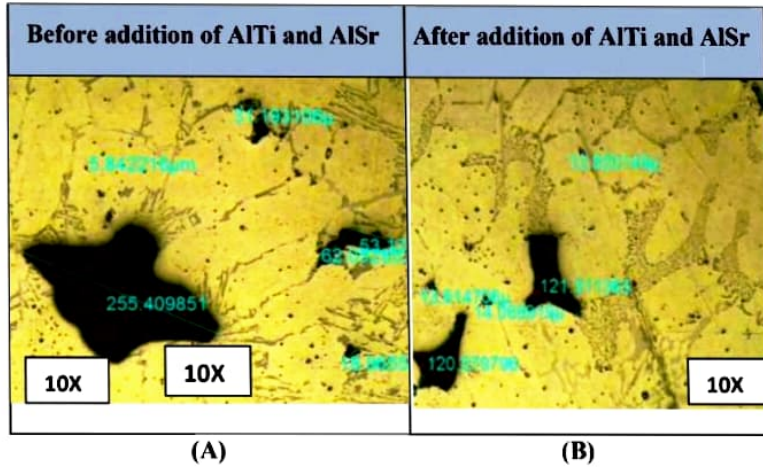
The confirmation of  $Al_4Sr$  phase was done by EDS analysis as shown in Figure 3 as follows:



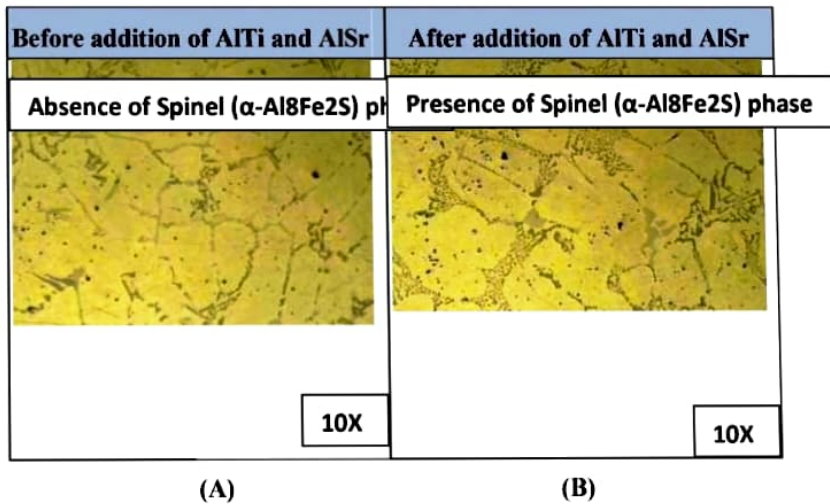


**Figure 3:** Elemental Dispersive Spectroscopy (EDS) of Al<sub>4</sub>Sr phase in the AlSr10% alloy

The Al<sub>4</sub>Sr phase has uniform distribution through out the AlSr alloy in both cases. As shown in the Figure 2, the size of Al<sub>4</sub>Sr phase in AlSr5% is in the range of 50 μm to 140 μm whereas in AlSr10% is in the range of 100 μm to 500 μm. The size of the voids/porosities before the addition of Ti and Sr were of larger size, 255 μm to 392 μm and after the addition of Ti and Sr the voids/porosities were reduced to the size of 120 μm to 162 μm as shown in the following Figure 4. Figure 4 (B) shows the reduction in the size of voids/porosities because of the formation of spinel (α-Al<sub>8</sub>Fe<sub>2</sub>S) phases at the grain boundary after the addition of AlTi and AlSr. The presence of large voids/porosities in the AlSi alloy makes its mechanical properties very week as shown in Figure 4(A).



**Figure 4:** AlSi alloy metallography at 10X before (A) and after (B) addition of AlTi 10% and AlSr 10% alloy displaying the reduction of porosities



**Figure 5:** AlSi alloy metallography at 10X before (A: Absence of Spinel ( $\alpha$ -Al<sub>8</sub>Fe<sub>2</sub>S) phase along the grain boundary, unmodified) and after (B: Presence of Spinel ( $\alpha$ -Al<sub>8</sub>Fe<sub>2</sub>S) phase along the grain boundary)

addition of AlTi10% and AlSr10% alloy displaying the modification and grain size reduction

This presence of  $\alpha$ -Al<sub>8</sub>Fe<sub>2</sub>S along the grain boundary (Figure 5) and reduced porosities gives the required mechanical strength and surface finish properties to AlSi alloy.

**Conclusion:**

The presence of spinel phases along the grain boundary makes the alloy's mechanical properties (hardness, tensile strength, % elongation) very strong. Though there is no major difference in the grain size (71.39  $\mu$ m -71.58  $\mu$ m ) of the alloy, these spinel phases formed due to  $\alpha$ -Al<sub>8</sub>Fe<sub>2</sub>S makes the strong bonding between the two grains. The absence of the  $\alpha$ -Al<sub>8</sub>Fe<sub>2</sub>S in the alloy makes the bonding between the grains weak leading to failure of the engine or automobile parts. The addition of Sr in the form of AlSr alloy modifies the eutectic Si phase (morphology and microstructure) from large platelet like structure to fine fibrous structure, which increases the mechanical and thermal properties of the final casting. The addition of 0.03% strontium makes a modest improvement to the yield strength, ultimate tensile strength and elongation percentage values, and the scatter of these properties. Titanium (Ti) is used to refine primary aluminum grains. Titanium, added in aluminum alloy, forms TiAl<sub>3</sub>, which serves to nucleate primary aluminum dendrites. More frequent nucleation of dendrites means a large number of smaller grains.

**Future scope of reference:**

The next research plan is to carry out the mechanical testing such as hardness, tensile strength, impact strength varying the addition rate of AlSr10% and AlTi10%

**Acknowledgement:**

The authors are very thankful to the support provided by VNIT, Nagpur for carrying out SEM EDS analysis and to the Growth Engine Company for providing the AlSi alloy samples for research purpose.

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# CHEMISTRY OF TRANSITION

# METALS

1 <b>H</b> HYDROGEN 1.0079																	5 <b>B</b> BORON 10.811	6 <b>C</b> CARBON 12.011	7 <b>N</b> NITROGEN 14.007	8 <b>O</b> OXYGEN 15.999	
3 <b>Li</b> LITHIUM 6.941	4 <b>Be</b> BERYLLIUM 9.0122																	11 <b>Al</b> ALUMINIUM 26.981	14 <b>Si</b> SILICON 28.086	15 <b>P</b> PHOSPHORUS 30.974	16 <b>S</b> SULFUR 32.06
19 <b>K</b> POTASSIUM 39.098	20 <b>Ca</b> CALCIUM 40.078	21 <b>Sc</b> SCANDIUM 44.956	22 <b>Ti</b> TITANIUM 47.88	23 <b>V</b> VANADIUM 50.942	24 <b>Cr</b> CHROMIUM 51.996	25 <b>Mn</b> MANGANESE 54.938	26 <b>Fe</b> IRON 55.845	27 <b>Co</b> COBALT 58.933	28 <b>Ni</b> NICKEL 58.693	29 <b>Cu</b> COPPER 63.546	30 <b>Zn</b> ZINC 65.38	31 <b>Ga</b> GALLIUM 69.723	32 <b>Ge</b> GERMANIUM 72.63	33 <b>As</b> ARSENIC 74.922	34 <b>Se</b> SELENIUM 78.96						
37 <b>Rb</b> RUBIDIUM 85.468	38 <b>Sr</b> STRONTIUM 87.62	39 <b>Y</b> YTIPIUM 88.906	40 <b>Zr</b> ZIRCONIUM 91.224	41 <b>Nb</b> NIOSIUM 92.906	42 <b>Mo</b> MOSIUM 95.94	43 <b>Tc</b> TECHNETIUM (98)	44 <b>Ru</b> RUTHENIUM 101.07	45 <b>Rh</b> RHODIUM 102.91	46 <b>Pd</b> PALLADIUM 106.42	47 <b>Ag</b> SILVER 107.868	48 <b>Cd</b> CADMIUM 112.414	49 <b>In</b> INDIUM 114.818	50 <b>Sn</b> TIN 118.710	51 <b>Sb</b> ANTIMONY 121.757	52 <b>Te</b> TELLURIUM 127.6						
55 <b>Cs</b> CAESIUM 132.905	56 <b>Ba</b> BARIUM 137.327	57-71*	72 <b>Hf</b> HAFNIUM 178.49	73 <b>Ta</b> TANTALUM 180.94	74 <b>W</b> TUNGSTEN 183.84	75 <b>Re</b> RHENIUM 186.207	76 <b>Os</b> OSMIUM 190.23	77 <b>Ir</b> IRIDIUM 192.222	78 <b>Pt</b> PLATINUM 195.084	79 <b>Au</b> GOLD 196.967	80 <b>Hg</b> MERCURY 200.59	81 <b>Tl</b> THALLIUM 204.38	82 <b>Pb</b> LEAD 207.2	83 <b>Bi</b> BISMUTH 208.98	84 <b>Po</b> POLONIUM (209)						
87 <b>Fr</b> FRANCIUM	88 <b>Ra</b> RADIUM	89-103**	104 <b>Rf</b> RUFORNIUM (104)	105 <b>Db</b> DUBNIUM (105)	106 <b>Sg</b> SEABORGIUM (106)	107 <b>Bh</b> BOHRIUM (107)	108 <b>Hs</b> HASSIUM (108)	109 <b>Mt</b> MEITNERIUM (109)	110 <b>Ds</b> DARMSTADTIUM (110)	111 <b>Rg</b> ROENTGENIUM (111)	112 <b>Cn</b> COPECNICIUM (112)	113 <b>Uut</b> UNUNTRIUM (113)	114 <b>Fl</b> FLEROVIUM (114)	115 <b>Uup</b> UNUNPENTIUM (115)	116 <b>Lv</b> LIVERTIUM (116)						

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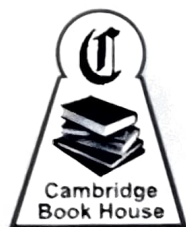
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## About the Book:

**Transition** metal, any of various chemical elements that have valence electrons—i.e., electrons that can participate in the formation of chemical bonds—in two shells instead of only one. While the term transition has no particular chemical significance, it is a convenient name by which to distinguish the similarity of the atomic structures and resulting properties of the elements so designated. They occupy the middle portions of the long periods of the periodic table of elements between the groups on the left- hand side and the groups on the right. Specifically, they form Groups 3 (IIIb) through 12 (IIb).

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