

TABLE OF CONTENTS

| | | | | | |
|----------|---|-----------|------------|--|-----------|
| 1 | EXECUTIVE SUMMARY | 10 | 3.3 | ELECTRONIC GOODS MARKET | 32 |
| 1.1 | TARGET BUSINESS – MARKET OVERVIEW | 11 | 3.3.1 | SMARTPHONES | 33 |
| 1.2 | TARGET MARKET TRENDS | 12 | 3.3.2 | AUTOMOTIVE | 34 |
| 1.3 | 2019 IN REVIEW | 13 | 3.3.2.1 | INCREASE IN SEMICONDUCTOR CONTENT FOR AUTOS | 37 |
| 1.4 | TECHNOLOGY TRENDS | 14 | 3.3.2.2 | SEMICONDUCTOR CONTENT BY AUTOMOTIVE ELECTRONIC SYSTEM | 38 |
| 1.5 | TARGET REVENUES 5-YEAR FORECAST | 16 | 3.3.3 | SERVERS / IT | 39 |
| 1.6 | PRECIOUS METAL TARGET MARKET REVENUE FORECAST | 17 | 3.3.4 | PCS / TABLETS | 41 |
| 1.7 | COMPETITIVE LANDSCAPE | 18 | 3.4 | SEMICONDUCTOR INDUSTRY FORECASTS | 42 |
| 1.8 | EHS ISSUES/CONCERNS | 19 | 3.4.1 | SEMICONDUCTOR UNITS GROWTH FORECAST | 43 |
| 2 | SCOPE, PURPOSE AND METHODOLOGY | 20 | 3.4.2 | EQUIPMENT SPENDING AND FAB AND CAPITAL INVESTMENTS | 44 |
| 2.1 | SCOPE | 21 | 3.4.3 | OVERALL CHINA MARKET TRENDS | 45 |
| 2.2 | PURPOSE | 22 | 3.4.4 | WAFER START FORECAST | 46 |
| 2.3 | METHODOLOGY | 23 | 4 | SPUTTERING TARGET MARKET TRENDS | 50 |
| 2.4 | OVERVIEW OF OTHER TECHCET CMR™ REPORTS | 24 | 4.1 | 2020 FIRST HALF | 51 |
| 3 | MARKET OUTLOOK | 25 | 4.1.1 | BEGINNING OF 2020 LOOKED MORE POSITIVE THAN NOW – INITIAL 2020 OUTLOOK BEFORE THE CHANGE | 52 |
| 3.1 | SEMICONDUCTOR INDUSTRY MARKET STATUS OVERVIEW | 26 | 4.1.2 | 1Q2020 STATUS: COVID-19 IMPACT | 53 |
| 3.2 | WORLDWIDE ECONOMY | 28 | 4.1.3 | INITIAL COVID-19 IMPACT ON TARGET MARKET | 54 |
| 3.2.1 | SEMICONDUCTOR INDUSTRIES TIES TO THE GLOBAL ECONOMY | 30 | 4.1.4 | CURRENT CY2020 MARKET ASSESSMENT | 55 |
| 3.2.2 | SEMICONDUCTOR SALE TRENDS | 31 | | | |

TABLE OF CONTENTS

| | | | | | |
|---------|--|----|--|--|-----------|
| 4.1.5 | 2020 TARGET MARKET REVENUE ESTIMATE | 56 | 4.5EHS, REGULATIONS, AND LOGISTIC ISSUES | 75 | |
| 4.1.6 | CY2019 IN REVIEW | 57 | 4.5.1 | LOGISTIC ISSUES: COVID-19 | 76 |
| 4.1.6.1 | 2019 TARGET MATERIAL MARKET SHARE | 58 | 4.5.2 | EHS ISSUES | 77 |
| 4.2 | SUB-TIER SUPPLY-CHAIN STATUS & TRENDS FOR 2020 | 59 | 4.5.3 | REGULATIONS: U.S. | 78 |
| 4.3 | TECHNICAL DRIVERS / MATERIAL CHANGES AND TRANSITIONS | 60 | 4.5.4 | REGULATIONS: EU | 79 |
| 4.3.1 | 200 MM TARGET MARKET SEGMENT DRIVERS | 61 | 4.5.5 | U.S. TARIFFS- ALUMINUM | 80 |
| 4.3.2 | 300 MM TARGET MARKET SEGMENT DRIVERS DEVICES | 62 | 4.5.6 | U.S. TARIFFS- TITANIUM | 81 |
| 4.3.3 | METALLIZATION TRENDS | 63 | 5 | SUPPLIER MARKET LANDSCAPE | 82 |
| 4.3.4 | INTERCONNECT TRENDS: RUTHENIUM | 64 | 5.1 | MARKET STATISTICS & FORECASTS | 83 |
| 4.3.5 | MEMORY MATERIALS | 65 | 5.1.1 | TARGET MARKET FORECAST | 84 |
| 4.3.6 | PIEZOELECTRIC MATERIALS – PZT | 66 | 5.1.2 | ESTIMATE FOR PRECIOUS METAL TARGET MARKET | 85 |
| 4.3.7 | PIEZOELECTRIC MATERIALS - AL ALLOYS (ALSC AND ALN) | 67 | 5.1.3 | ESTIMATED 2019 MARKET SHARE | 87 |
| 4.3.8 | PIEZOELECTRIC MATERIALS: ALN AND ALSC PIEZOELECTRICS | 68 | 5.1.4 | TARGET SUPPLIER UPDATES | 88 |
| 4.3.9 | WAFER LEVEL AND PANEL LEVEL PACKAGING | 69 | 5.1.5 | EMERGING MEMORY TARGETS MATERIAL SUPPLIERS | 90 |
| 4.3.10 | PACKAGING PVD TOOL MAKERS | 70 | 5.1.6 | RUTHENIUM TARGET SUPPLIERS | 91 |
| 4.4 | COMMENT ON REGIONAL TRENDS/DRIVERS | 71 | 5.2 | M&A ACTIVITY AND PARTNERSHIPS | 92 |
| 4.4.1 | REGIONAL TRENDS AND ISSUES | 72 | 5.3 | PLANT CLOSURES | 94 |
| 4.4.2 | SPUTTERING TARGET PRODUCTION LOCATIONS– REGIONAL TRENDS | 73 | 5.4 | NEW ENTRANTS | 95 |
| 4.4.3 | REGIONAL MARKET SIZE AND TRENDS | 74 | 5.5 | SUPPLIERS OR PARTS/PRODUCT LINE THAT ARE AT RISK OF DISCONTINUATION | 97 |

TABLE OF CONTENTS

| | | | | | |
|---------|---|-----|---------|--|-----|
| 5.6 | TEHCET ANALYST ASSESSMENT | 99 | 6.1.4.1 | TI METAL-SPONGE SUPPLY | 120 |
| 6 | SUB TIER SUPPLY-CHAIN, METALS | 102 | 6.1.4.2 | TI METAL- SPONGE DEMAND | 121 |
| 6.1 | SUB TIER SUPPLY-CHAIN: SOURCES & MARKETS | 103 | 6.1.4.3 | TI METAL- TI SPONGE FOR SEMICONDUCTOR | 122 |
| 6.1.1 | CU METAL- RAW MATERIAL | 104 | 6.1.4.4 | TI METAL- TI SPONGE PRODUCTION ACTIVITY IN CHINA | 123 |
| 6.1.1.1 | CU METAL- MARKET DEMAND | 105 | 6.1.5 | TUNGSTEN (W) METAL- MINING | 124 |
| 6.1.1.2 | CU METAL- RAW MATERIAL SUPPLY CHAIN | 106 | 6.1.5.1 | W METAL- GLOBAL DEMAND | 125 |
| 6.1.2 | TANTALUM- RAW MATERIAL | 107 | 6.1.5.2 | W METAL- HIGH PURITY W POWDER SUPPLIERS | 126 |
| 6.1.2.1 | TA METAL- MINING SUPPLY CHAIN TRENDS | 108 | 6.1.5.3 | W MINING ACTIVITY | 127 |
| 6.1.2.2 | TA METAL- AUSTRALIAN MINING | 109 | 6.1.5.4 | W SUPPLY CHAIN: CHINA | 128 |
| 6.1.2.3 | TA METAL- GLOBAL DEMAND | 110 | 6.1.5.5 | W METAL- FANYA BOURSE | 129 |
| 6.1.2.4 | TA METAL- GENERAL MARKET TRENDS | 111 | 6.1.6 | COBALT (CO) METAL- MINING | 130 |
| 6.1.2.5 | TA METAL- CAPACITOR MARKETS | 112 | 6.1.6.1 | CO METAL- GLOBAL MINING PROJECTS | 131 |
| 6.1.2.6 | TA METAL SUPPLIER ACTIVITY - GLOBAL ADVANCED METALS | 113 | 6.1.6.2 | CO METAL- POSSIBLE NORTH AMERICA PROJECTS | 132 |
| 6.1.2.7 | TA METAL SUPPLIER ACTIVITY - H.C. STARCK GMBH. | 114 | 6.1.6.3 | CO METAL- DEMAND | 133 |
| 6.1.2.8 | TA METAL- CLOSED MARKET ECONOMICS | 115 | 6.1.7 | PRECIOUS METALS | 134 |
| 6.1.3 | ALUMINUM (AL) METAL- SMELTING | 116 | 6.1.7.1 | PRECIOUS METAL SUPPLY CHINA | 135 |
| 6.1.3.1 | AL METAL- GLOBAL DEMAND | 117 | 6.1.7.2 | PRECIOUS METALS- PLATINUM GROUP METAL TRENDS | 136 |
| 6.1.3.2 | AL METAL- HIGH PURITY REFINERS | 118 | 6.1.8 | RARE EARTHS | 137 |
| 6.1.4 | TITANIUM (TI) METAL- TI MINERAL CONCENTRATE | 119 | | | |

TABLE OF CONTENTS

| | | |
|-------|--|-----|
| 6.2 | SUB-TIER SUPPLY-CHAIN: DISRUPTIONS | 138 |
| 6.3 | SUB-TIER SUPPLY-CHAIN M&A ACTIVITY | 139 |
| 6.3.1 | SUB-TIER M&A | 140 |
| 6.4 | SUB-TIER SUPPLY-CHAIN EHS AND LOGISTICS ISSUES | 141 |
| 6.5 | SUB-TIER SUPPLY-CHAIN “NEW” ENTRANTS | 142 |
| 6.6 | SUB-TIER SUPPLY-CHAIN DISRUPTIONS | 143 |
| 6.6.1 | SUB-TIER SUPPLY-CHAIN DISRUPTIONS- COVID-19 | 144 |
| 6.6.2 | SUB-TIER SUPPLY-CHAIN DISRUPTIONS- OTHER | 145 |
| 6.7 | SUB-TIER SUPPLY-CHAIN PRICING TRENDS | 146 |
| 6.7.1 | METAL PRICING TRENDS | 147 |
| 6.7.2 | CU METAL PRICING | 148 |
| 6.7.3 | AL METAL PRICING | 149 |
| 6.7.4 | CO METAL PRICING | 150 |
| 6.7.5 | PRECIOUS METAL PRICING | 151 |
| 6.7.6 | RU PRICING TRENDS | 152 |
| 6.8 | SUB-TIER SUPPLY-CHAIN TECHCET ANALYST ASSESSMENT | 153 |

| | | |
|----------|------------------------------------|------------|
| 7 | SUPPLIER PROFILES | 155 |
| | FURUYA METAL CO. LTD. | |
| | GO ELEMENT CORP | |
| | GRIKIN | |
| | HONEYWELL ELECTRONIC MATERIALS | |
| | JX NIPPON | |
| | KMFI | |
| | MATERION ADVANCED MATERIALS | |
| | PIONEER MATERIALS INC. | |
| | LINDE/PRAXAIR | |
| | SOLAR APPLIED MATERIALS TECHNOLOGY | |
| | SUMITOMO CHEMICAL CO | |
| | TANAKA PRECIOUS METALS | |
| | TOP METAL MATERIAL | |
| | TOSOH SMD | |
| | UMICORE ELECTRO OPTIC MATERIALS | |
| | VACUUM ENGINEERING & MATERIALS | |
| | VITAL MATERIALS CO. LIMITED | |

FIGURES & TABLES

TABLE OF FIGURES

| | | | |
|--|----|---|-----|
| FIGURE 1: SPUTTERING TARGET MARKET FORECAST | 16 | FIGURE 16: 2019 SPUTTERING TARGET MARKET BY VOLUME | 58 |
| FIGURE 2: PRECIOUS METAL TARGET FORECAST | 17 | FIGURE 17: AMAT CO METALLIZATION TECHNOLOGY | 63 |
| FIGURE 3: GLOBAL ECONOMY AND THE ELECTRONICS SUPPLY CHAIN (2019) | 30 | FIGURE 18: SC CONTENT IN AL VS. PIEZOELECTRIC RESPONSE | 68 |
| FIGURE 4: WORLDWIDE SEMICONDUCTOR SALES | 31 | FIGURE 19 REGIONAL SHARE (AS A % OF TOTAL TARGET DEMAND BY USD) | 71 |
| FIGURE 5: SEMICONDUCTOR CHIP APPLICATIONS | 32 | FIGURE 20: SPUTTERING TARGET MARKET FORECAST | 84 |
| FIGURE 6: MOBILE PHONE SHIPMENTS WW ESTIMATES | 33 | FIGURE 21: PRECIOUS METAL TARGET FORECAST | 85 |
| FIGURE 7: OIL PRICE PER BARREL US WTI | 35 | FIGURE 22: EST. 2019 SUPPLIER MARKET SHARE | 87 |
| FIGURE 8: SEMICONDUCTOR SPEND PER VEHICLE TYPE | 37 | FIGURE 23: 2019 EST. GLOBAL CU MINE PRODUCTION 20.3 MILLION MT | 104 |
| FIGURE 9: SEMICONDUCTOR CONTENT BY AUTOMOTIVE APPLICATION | 38 | FIGURE 24: 2019 GLOBAL REFINED CU CONSUMPTION 24.5 MILLION MT | 105 |
| FIGURE 10: SEMICONDUCTOR REVENUE GROWTH FORECASTS (JULY 2020) | 42 | FIGURE 25: 2019 EST. TANTALUM MINE PRODUCTION 1840 MT | 107 |
| FIGURE 11: SEMICONDUCTOR UNITS HISTORY AND FORECAST | 43 | FIGURE 26: 2018 TANTALUM PRODUCT DEMAND | 110 |
| FIGURE 12: 200 MM WAFER CAPACITY FORECAST | 46 | FIGURE 27: EST. WORLD ALUMINUM SMELTING PRODUCTION 2019 64 MILLION MT | 116 |
| FIGURE 13: 2020/ 2019 GROWTH ESTIMATES FOR 3DNAN, DRAM AND LOGIC DEVICES (ADVANCED NODES AND LEADING EDGE) | 48 | FIGURE 28: ALUMINUM DEMAND BY END USE APPLICATION 2019 89.8 M METRIC MT | 117 |
| FIGURE 14: SPUTTERING TARGET MARKET FORECAST | 56 | FIGURE 29: EST. GLOBAL TI CONCENTRATE MINING PRODUCTION-2019 7,600 KT | 119 |
| FIGURE 15: 2019 SPUTTERING TARGET MARKET BY REVENUES | 58 | | |

FIGURES & TABLES

TABLE OF FIGURES

| | |
|---|-----|
| FIGURE 30: EST. GLOBAL TI SPONGE CAPACITY-2019 >210,000 MT | 120 |
| FIGURE 31: EST. GLOBAL 2018 TI MILL PRODUCT OUTPUT, ~200,000 MT | 121 |
| FIGURE 32: EST. 2019 W MINE PRODUCTION 84,600 T | 124 |
| FIGURE 33: 2018 GLOBAL W DEMAND 106,00 | 125 |
| FIGURE 34: EST. 2018 CO MINE PRODUCTION 143,000 MT | 130 |
| FIGURE 35: EST. 2018 GLOBAL CO DEMAND 125,000 MT | 133 |
| FIGURE 36: LME CU PRICE CHART | 147 |
| FIGURE 37: LME AL PRICE CHART | 149 |
| FIGURE 38: LME CO METAL PRICE CHART | 150 |
| FIGURE 39: PRECIOUS METAL PRICE CHARTS | 151 |

TABLES

| | |
|---|----|
| TABLE 1: COVID-19 LOCKDOWNS AND RESTRICTIONS BY REGION (APRIL 2020) | 27 |
| TABLE 2: GLOBAL GDP AND SEMICONDUCTOR REVENUES* | 28 |
| TABLE 3: IMF WORLD ECONOMIC OUTLOOK* | 29 |
| TABLE 4: 2020 AUTO INDUSTRY GROWTH IMPACT FACTORS | 36 |
| TABLE 5: DATA CENTER SYSTEMS AND COMMUNICATION SERVICES FORECAST 2020 | 40 |

| | |
|---|-----|
| TABLE 6: WORLDWIDE DEVICE SHIPMENTS BY DEVICE TYPE ,2020-2022 (JAN 2020) | 41 |
| TABLE 7: 2019 INVESTMENT PLANS FOR SELECTED DEVICE COMPANIES (AS OF MARCH 2020) | 44 |
| TABLE 8: CHINA FABRS CAPABILITIES STATUS | 45 |
| TABLE 9: 2020/ 2019 GROWTH ESTIMATES FOR 3DNAND, DRAM AND LOGIC DEVICES | 47 |
| TABLE 10: PVD PACKAGING TOOL MAKERS | 70 |
| TABLE 11: SPUTTERING TARGET SUPPLIER MANUFACTURING LOCATIONS | 73 |
| TABLE 12: REGIONAL SPUTTERING MARKETS | 74 |
| TABLE 13: PHASE CHANGE MATERIAL TARGET SUPPLIERS | 90 |
| TABLE 14: MRAM TARGET SUPPLIERS | 90 |
| TABLE 15: RUTHENIUM TARGET SUPPLIERS | 91 |
| TABLE 16: POSSIBLE CO MINES IN N. AMERICA | 132 |
| TABLE 17: RARE EARTH USAGE BY APPLICATION | 137 |